TABLE II (continued)

TEST HOLE NUMBER	DEPTH (METRES)	DESCRIPTION
TP19 Elev. 70.36m	0.00 – 0.30	TOPSOIL
	0.30 – 1.20	Grey brown SILTY SAND
	1.20	End of test pit, refusal on large boulder or possible bedrock

No groundwater seepage observed in test pit, December 10, 2012.

TEST HOLE NUMBER	DEPTH (METRES)	DESCRIPTION
TP20 Elev. 70.03m	0.00 – 0.30	TOPSOIL
	0.30 – 0.70	Grey brown SILTY SAND
	0.70 – 2.40	Very stiff to stiff grey brown, becoming grey with depth SILTY CLAY
	2.40	End of test pit, refusal on large boulder or possible bedrock

Depth (m)	Undrained Shear Strength, Cu (kPa)
1.4	>100
1.8	80
2.2	50

No groundwater seepage observed in test pit, December 10, 2012.

TABLE II (continued)

TEST HOLE NUMBER	DEPTH (METRES)	DESCRIPTION
TP21 Elev. 70.09m	0.00 – 0.30	TOPSOIL
	0.30 – 1.10	Grey brown medium SAND
	1.10 – 3.30	Very stiff to firm grey brown, becoming grey with depth SILTY CLAY
	3.30	End of test pit, refusal on large boulder or possible bedrock

Depth (m)	Undrained Shear Strength, Cu (kPa)
1.5	>100
2.6	70
2.8	52
3.1	30

No groundwater seepage observed in test pit, December 10, 2012.

SYMBOLS AND TERMS

SOIL DESCRIPTION

Behavioural properties, such as structure and strength, take precedence over particle gradation in describing soils. Terminology describing soil structure are as follows:

Desiccated	-	having visible signs of weathering by oxidation 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 layers of different soil types, e.g. silt and sand or silt and clay.
Well-Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes (see Grain Size Distribution).
Uniformly-Graded	-	Predominantly of one grain size (see Grain Size Distribution).

The standard terminology to describe the strength of cohesionless soils is the relative density, usually inferred from the results of the Standard Penetration Test (SPT) ‘N’ value. The SPT N value is the number of blows of a 63.5 kg hammer, falling 760 mm, required to drive a 51 mm O.D. split spoon sampler 300 mm into the soil after an initial penetration of 150 mm.

Relative Density	‘N’ Value	Relative Density %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe the strength of cohesive soils is the consistency, which is based on the undisturbed undrained shear strength as measured by the in situ or laboratory vane tests, penetrometer tests, unconfined compression tests, or occasionally by Standard Penetration Tests.

Consistency	Undrained Shear Strength (kPa)	‘N’ Value
Very Soft	<12	<2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

SYMBOLS AND TERMS (continued)

SOIL DESCRIPTION (continued)

Cohesive soils can also be classified according to their “sensitivity”. The sensitivity is the ratio between the undisturbed undrained shear strength and the remoulded undrained shear strength of the soil.

Terminology used for describing soil strata based upon texture, or the proportion of individual particle sizes present is provided on the Textural Soil Classification Chart at the end of this information package.

ROCK DESCRIPTION

The structural description of the bedrock mass is based on the Rock Quality Designation (RQD).

The RQD classification is based on a modified core recovery percentage in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be a result of closely-spaced discontinuities (resulting from shearing, jointing, faulting, or weathering) in the rock mass and are not counted. RQD is ideally determined from NXL size core. However, it can be used on smaller core sizes, such as BX, if the bulk of the fractures caused by drilling stresses (called “mechanical breaks”) are easily distinguishable from the normal in situ fractures.

RQD %	ROCK QUALITY
90-100	Excellent, intact, very sound
75-90	Good, massive, moderately jointed or sound
50-75	Fair, blocky and seamy, fractured
25-50	Poor, shattered and very seamy or blocky, severely fractured
0-25	Very poor, crushed, very severely fractured

SAMPLE TYPES

SS	-	Split spoon sample (obtained in conjunction with the performing of the Standard Penetration Test (SPT))
TW	-	Thin wall tube or Shelby tube
PS	-	Piston sample
AU	-	Auger sample or bulk sample
WS	-	Wash sample
RC	-	Rock core sample (Core bit size AXT, BXL, etc.). Rock core samples are obtained with the use of standard diamond drilling bits.

SYMBOLS AND TERMS (continued)

GRAIN SIZE DISTRIBUTION

MC%	-	Natural moisture content or water content of sample, %
LL	-	Liquid Limit, % (water content above which soil behaves as a liquid)
PL	-	Plastic limit, % (water content above which soil behaves plastically)
PI	-	Plasticity index, % (difference between LL and PL)
Dxx	-	Grain size which xx% of the soil, by weight, is of finer grain sizes These grain size descriptions are not used below 0.075 mm grain size
D10	-	Grain size at which 10% of the soil is finer (effective grain size)
D60	-	Grain size at which 60% of the soil is finer
Cc	-	Concavity coefficient = $(D30)^2$ / (D10 x D60)
Cu	-	Uniformity coefficient = D60 / D10

Cc and Cu are used to assess the grading of sands and gravels:
Well-graded gravels have: $1 < Cc < 3$ and $Cu > 4$
Well-graded sands have: $1 < Cc < 3$ and $Cu > 6$
Sands and gravels not meeting the above requirements are poorly-graded or uniformly-graded.
Cc and Cu are not applicable for the description of soils with more than 10% silt and clay (more than 10% finer than 0.075 mm or the #200 sieve)

CONSOLIDATION TEST

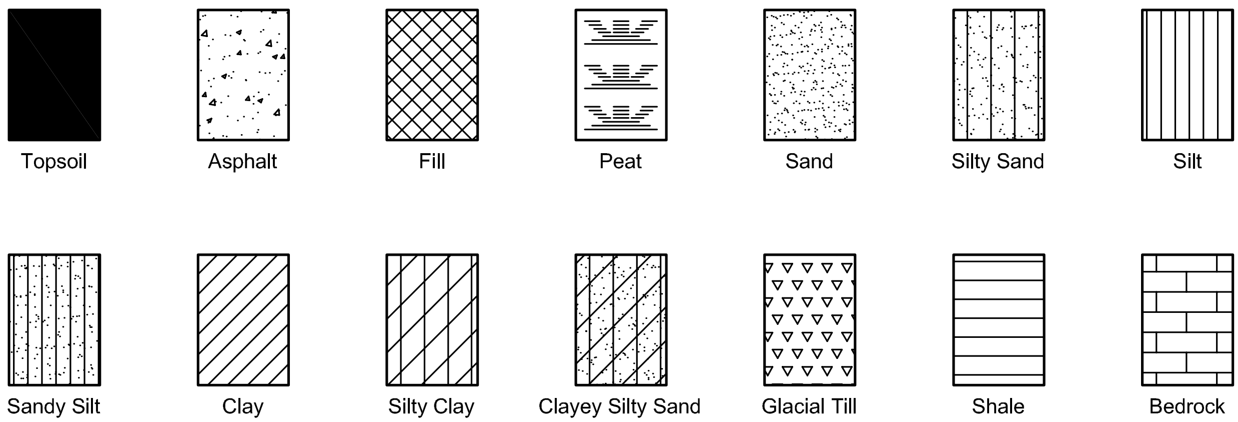
p'_o	-	Present effective overburden pressure at sample depth
p'_c	-	Preconsolidation pressure of (maximum past pressure on) sample
Ccr	-	Recompression index (in effect at pressures below p'_c)
Cc	-	Compression index (in effect at pressures above p'_c)
OC Ratio		Overconsolidaton ratio = p'_c / p'_o
Void Ratio		Initial sample void ratio = volume of voids / volume of solids
Wo	-	Initial water content (at start of consolidation test)

PERMEABILITY TEST

k	-	Coefficient of permeability or hydraulic conductivity is a measure of the ability of water to flow through the sample. The value of k is measured at a specified unit weight for (remoulded) cohesionless soil samples, because its value will vary with the unit weight or density of the sample during the test.

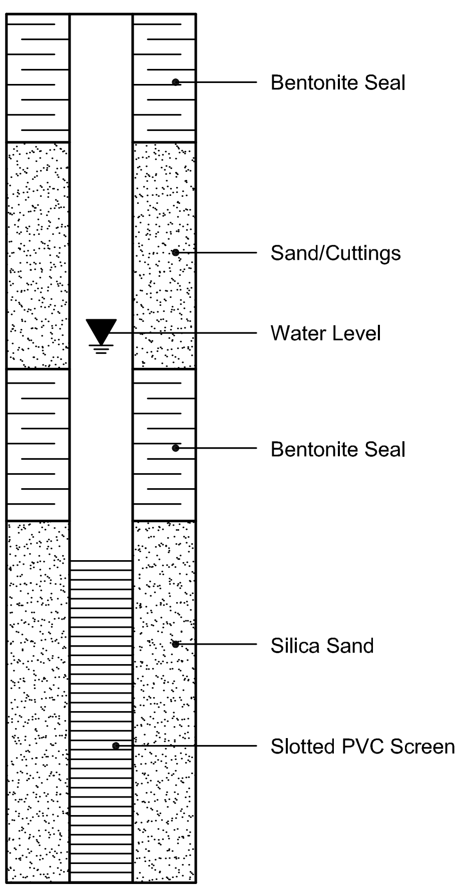
SYMBOLS AND TERMS (continued)

STRATA PLOT

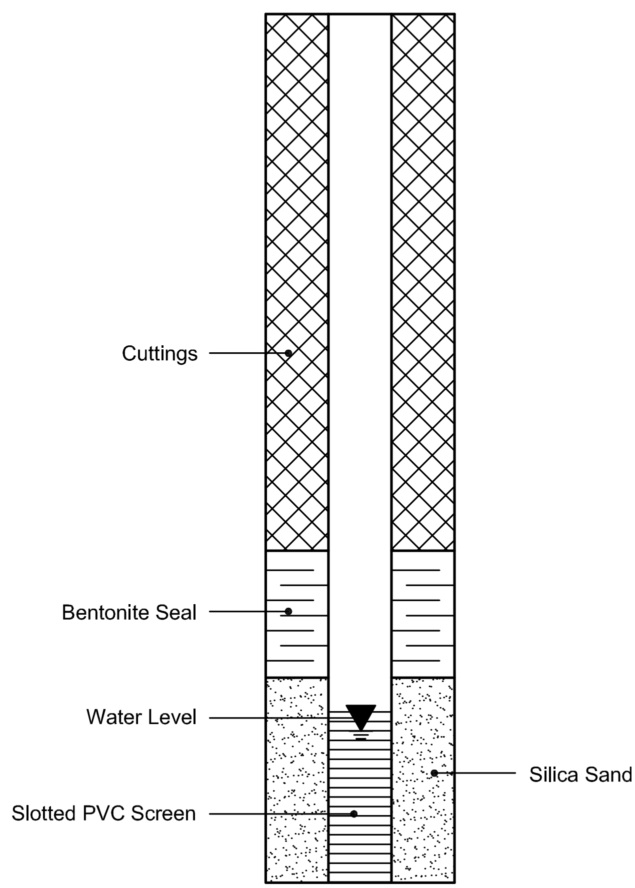


MONITORING WELL AND PIEZOMETER CONSTRUCTION

MONITORING WELL CONSTRUCTION



PIEZOMETER CONSTRUCTION



IES LTD.

PARACEL LABORATORIES LTD.

Order #: 1050073

Certificate of Analysis

Report Date: 13-Dec-2010

Client: **Paterson Group Consulting Engineers**

Order Date:7-Dec-2010

Client PO: 10364

Project Description: PG2256

	Client ID:	TP6 G2	-	-	-
	Sample Date:	04-Nov-10	-	-	-
	Sample ID:	1050073-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	72.1	-	-	-
General Inorganics					
pH	0.05 pH Units	7.23	-	-	-
Resistivity	0.10 Ohm.m	139	-	-	-
Anions					
Chloride	5 ug/g dry	22	-	-	-
Sulphate	5 ug/g dry	26	-	-	-

PARACEL LABORATORIES LTD.

Order #: 1312271

Certificate of Analysis

Report Date: 27-Mar-2013
Order Date:22-Mar-2013

Client: **Paterson Group Consulting Engineers**

Client PO: 13814 Project Description: PG2878

	Client ID:	TP13-G2	TP30-G1	-	-
	Sample Date:	20-Mar-13	21-Mar-13	-	-
	Sample ID:	1312271-01	1312271-02	-	-
	MDL/Units	Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	64.6	62.4	-	-
General Inorganics					
pH	0.05 pH Units	7.41	7.18	-	-
Resistivity	0.10 Ohm.m	72.5	67.2	-	-
Anions					
Chloride	5 ug/g dry	9	<5	-	-
Sulphate	5 ug/g dry	52	75	-	-

APPENDIX 2

FIGURE 1 - KEY PLAN

DRAWING PG2878-1 - TEST HOLE LOCATION PLAN

DRAWING PG2878-2 - PERMISSIBLE GRADE RAISE AREAS - HOUSING

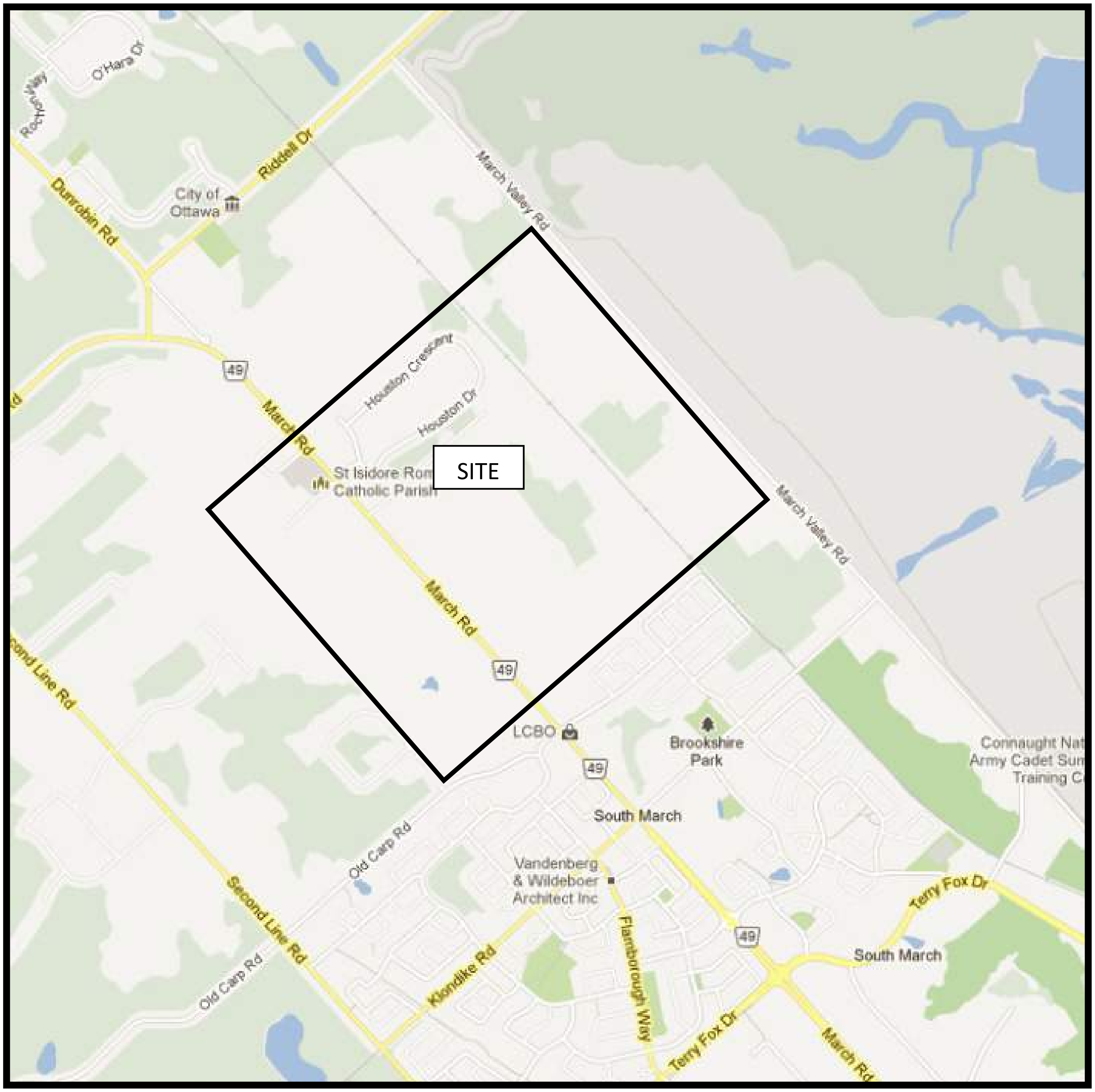


FIGURE 1

KEY PLAN

NO.	REVISIONS	DATE	INITIAL

patersongroup
consulting engineers
154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SCALE: 1:3000
DESIGN: SB
DRAWN: MPG
CHECKED: DG
DATE: 04/2013

CONSOLIDATED PRELIMINARY GEOTECHNICAL INVESTIGATION
KANATA NORTH URBAN EXPANSION AREA
COMMUNITY DEVELOPMENT PLAN - MARCH ROAD
OTTAWA, ONTARIO

DWG. NO. PG2878-1

NOVATECH ENGINEERING CONSULTANTS LTD.

TEST HOLE LOCATION PLAN

NO.	REVISIONS	DATE	INITIAL

patersongroup
consulting engineers
154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SCALE: 1:3000
DESIGN: SB
DRAWN: MPG
CHECKED: DG
DATE: 04/2013

CONSOLIDATED PRELIMINARY GEOTECHNICAL INVESTIGATION
KANATA NORTH URBAN EXPANSION AREA
COMMUNITY DEVELOPMENT PLAN - MARCH ROAD
OTTAWA, ONTARIO

DWG. NO. PG2878-2

NOVATECH ENGINEERING CONSULTANTS LTD.

PERMISSIBLE GRADE RAISE PLAN - HOUSING

Appendix M

Geotechnical Investigation Future Development Lands 936 March Road

REPORT EXCERPT

(Patterson Group – June 13, 2013)

Note: The following sections have been excerpted from the Patterson Group report;

Geotechnical Investigation
Future Development Lands
936 March Road
completed on June 13, 2013.
Patterson report number:
PG2878-4

The purpose of this excerpt is to illustrated the completed slope stability analysis

6.9 Slope Stability Analysis

Slope Conditions

Based on our field observations and available topographic mapping, the subject slopes are stable and sloped at a 8H:1V slope or less. Test pits and boreholes in close proximity to the existing slopes were analyzed to determine the subsurface soil conditions for our analysis.

The soil parameters utilized on our slope stability analysis for the subject slopes are presented in Table 4.

Table 4 - Soil Parameters for Slope Stability Analysis	
Brown Silty Clay	
Unit Weight	17 kN/m^3
Cohesion	5 kPa
Friction Angle	33°
Bedrock	
Strength Type	Infinite Strength
Unit Weight	23 kN/m^3

Slope Stability Analysis

The slope stability analysis was modeled in SLIDE, a computer program which permits a two-dimensional slope stability analysis calculating several methods including the Bishop's method, which is a widely accepted slope analysis method. The program calculates a factor of safety, which represents the ratio of the forces resisting failure to forces favoring failure. Theoretically, a factor of safety of 1.0 represents a condition where the slope is stable. However, due to intrinsic limitations of the calculation methods and the variability of the subsurface soil and groundwater conditions, a factor of safety greater than 1.0 is generally required for the failure risk to be considered acceptable. A minimum factor of safety of 1.5 is generally recommended for conditions where the slope failure would comprise permanent structures. An analysis considering seismic loading was also completed. A horizontal acceleration of 0.21G was considered for the sections for the seismic loading condition. A factor of safety of 1.1 is considered to be satisfactory for stability analyses including seismic loading.

Two (2) slope cross-sections (Sections A and B) were studied as the worst case scenarios. The cross section locations are presented on Drawing PG2878-5 - Test Hole Location Plan in Appendix 2. It should be noted that details of the slope height and slope angle at the cross-section locations are presented in Figures 2 to 5 in Appendix 2 from the topographic data identified on Drawing PG2878-5 - Test Hole Location Plan in Appendix 2.

Static Conditions Analysis

The static conditions analysis for the existing slope conditions at Sections A and B are presented in Figures 2 and 4 in Appendix 2. Sections A and B were found to be stable with slope stability factors of safety of greater than 1.5.

Seismic Loading Analysis

An analysis considering seismic loading was also completed. A horizontal seismic acceleration, K_h, of 0.21G was considered for the analyzed sections. A factor of safety of 1.1 is considered to be satisfactory for stability analyses when considering seismic loading.

The results of the analyses including seismic loading are shown in Figures 3 and 5 for the slope sections. Sections A and B have a factor of safety of greater than 1.1.

Limit of Hazard Lands

The limit of hazard lands for the subject slopes includes a stable slope allowance, where required, based on our slope stability analysis results. A toe erosion allowance and erosion access allowance are not required for the subject slopes. Also, based on our slope stability analysis, a stable slope allowance is not required for the subject slope. Therefore, a limit of hazard lands line is not required for the subject slope from a geotechnical perspective.

If the existing vegetation needs to be removed along the slope face, it is recommended that a 100 to 150 mm of topsoil mixed with a hardy seed or an erosional control blanket be placed across the exposed slope face.

APPENDIX 2

FIGURE 1 - KEY PLAN

FIGURES 2 TO 5 - SLOPE STABILITY SECTIONS

DRAWING PG2878-5 - TEST HOLE LOCATION PLAN

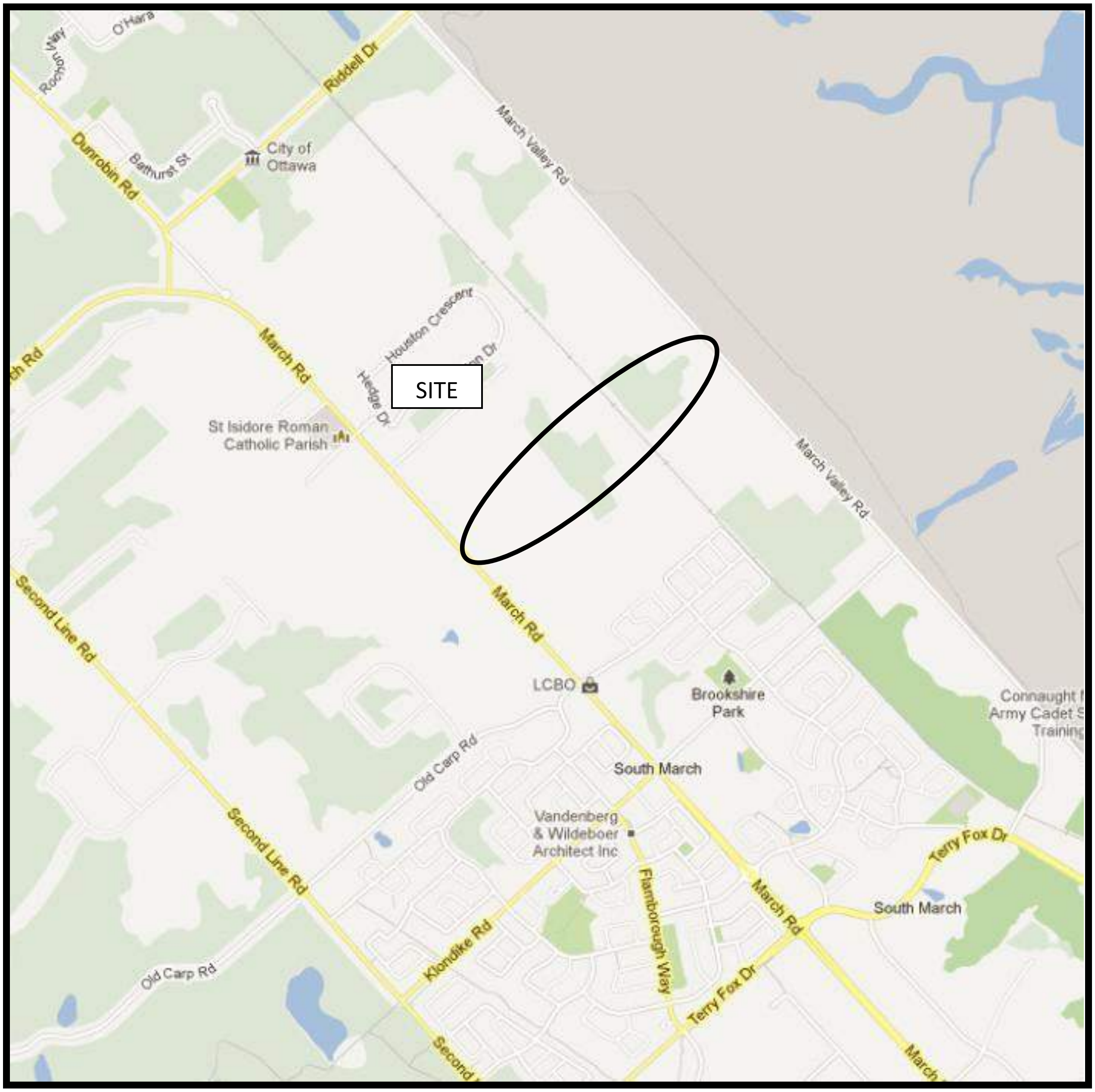


FIGURE 1

KEY PLAN

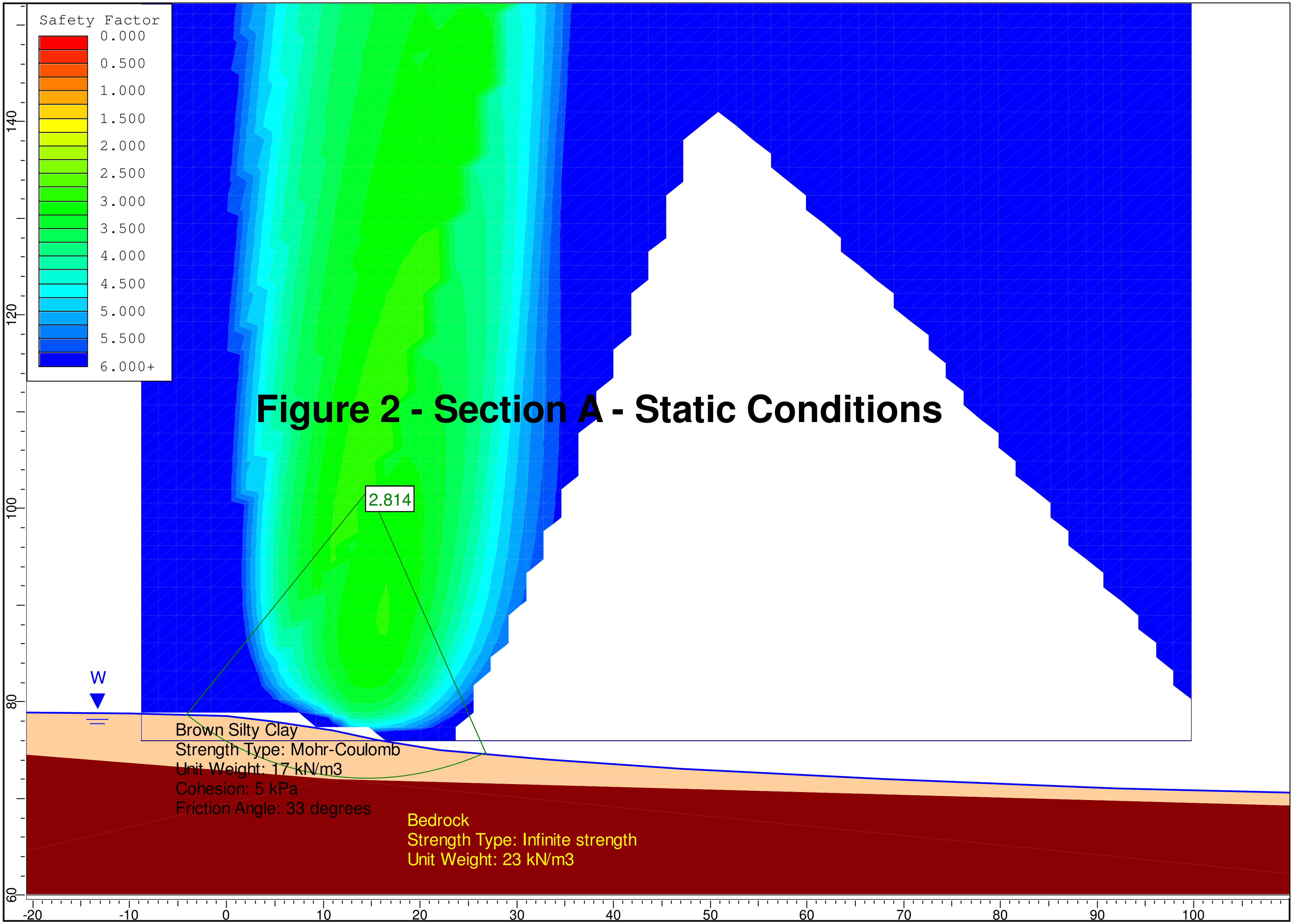
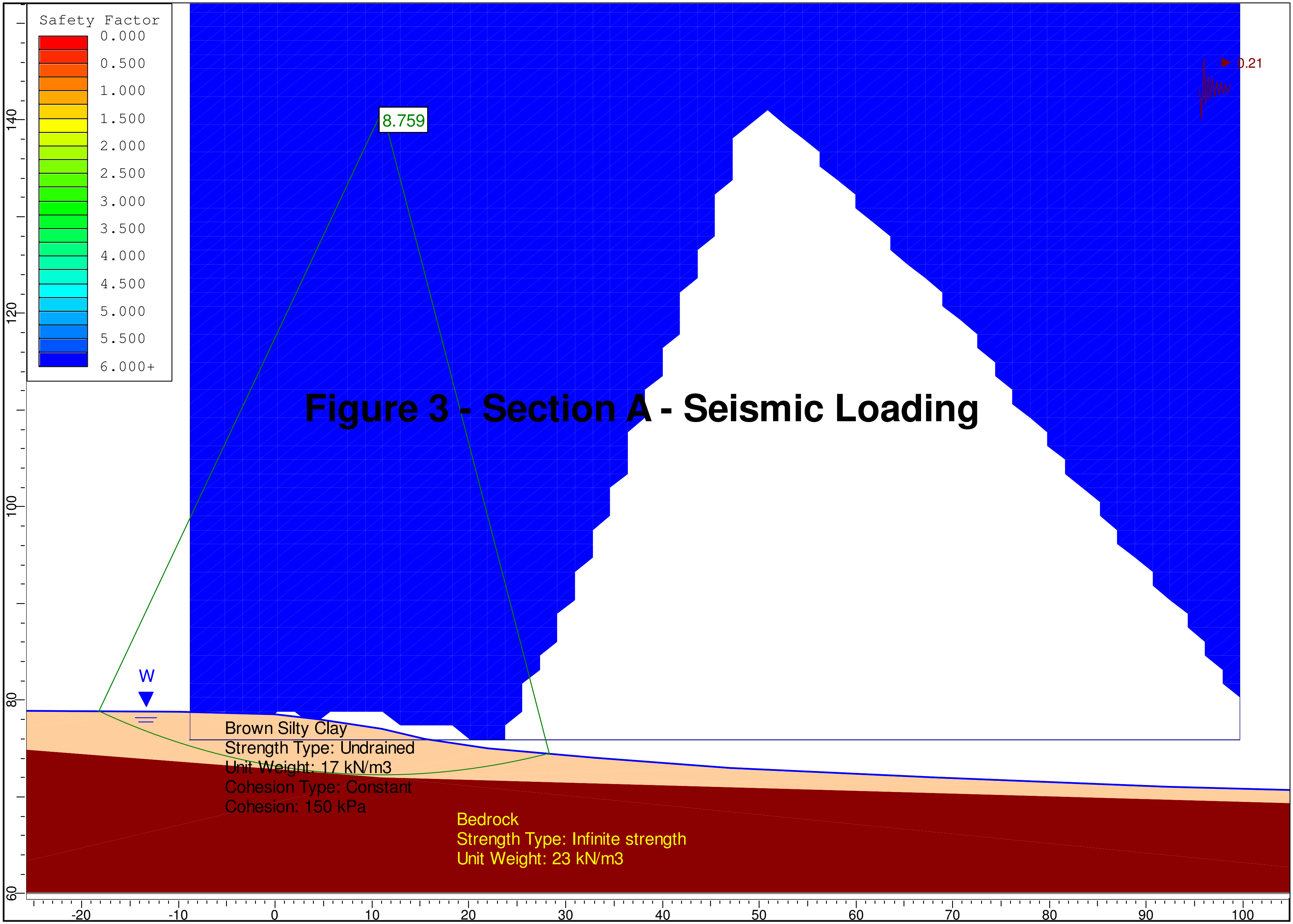
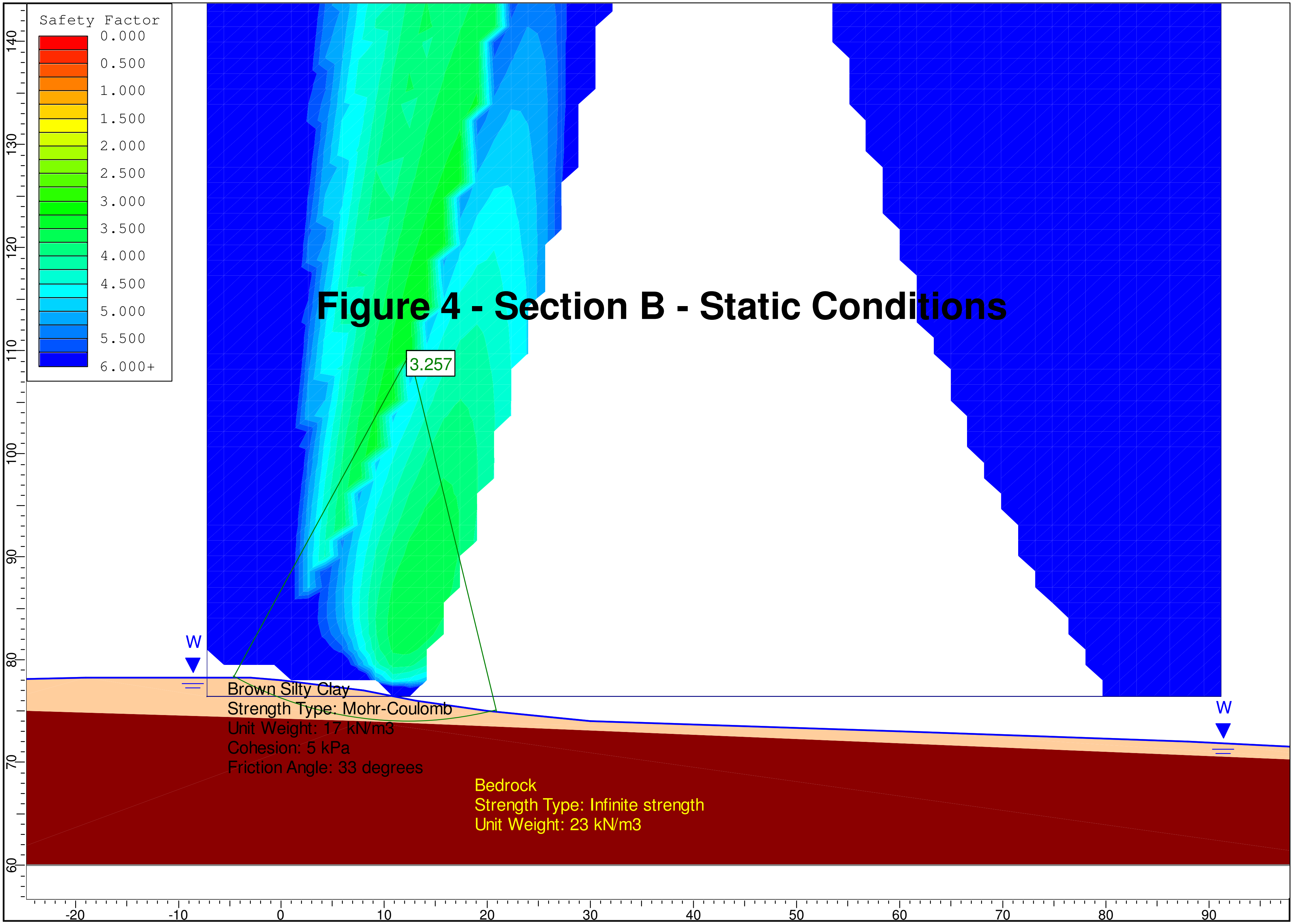

Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
Figure 2 - Section A - Static Conditions
2.814
W
Brown Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 17 kN/m3
Cohesion: 5 kPa
Friction Angle: 33 degrees
Bedrock
Strength Type: Infinite strength
Unit Weight: 23 kN/m3
140
120
100
80
60
-20
-10
0
10
20
30
40
50
60
70
80
90
100

Figure 3 - Section A - Seismic Loading





Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
Figure 4 - Section B - Static Conditions
3.257
W
W
Brown Silty Clay
Strength Type: Mohr-Coulomb
Unit Weight: 17 kN/m3
Cohesion: 5 kPa
Friction Angle: 33 degrees
Bedrock
Strength Type: Infinite strength
Unit Weight: 23 kN/m3
140
130
120
110
100
90
80
70
60
-20
-10
0
10
20
30
40
50
60
70
80
90

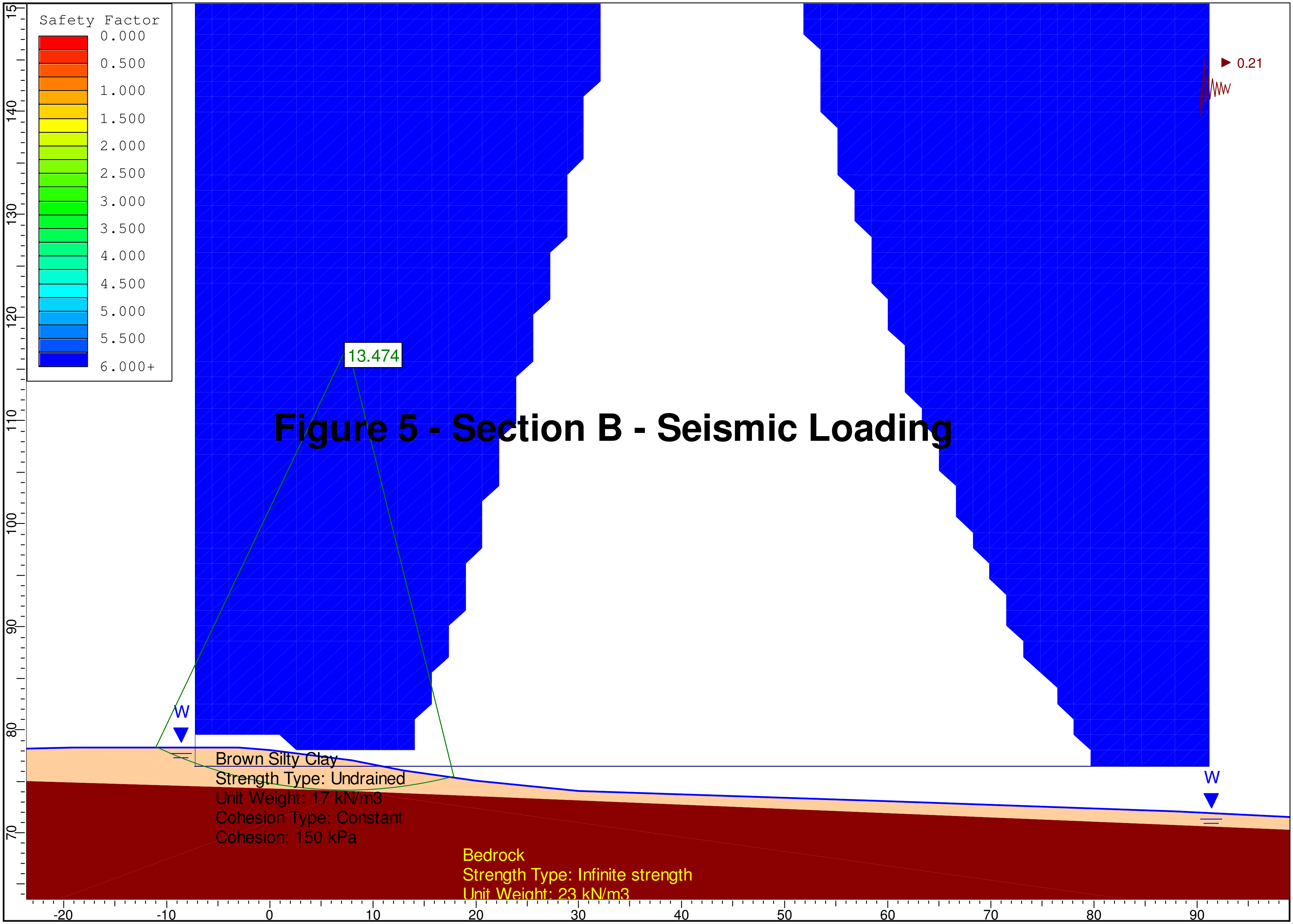
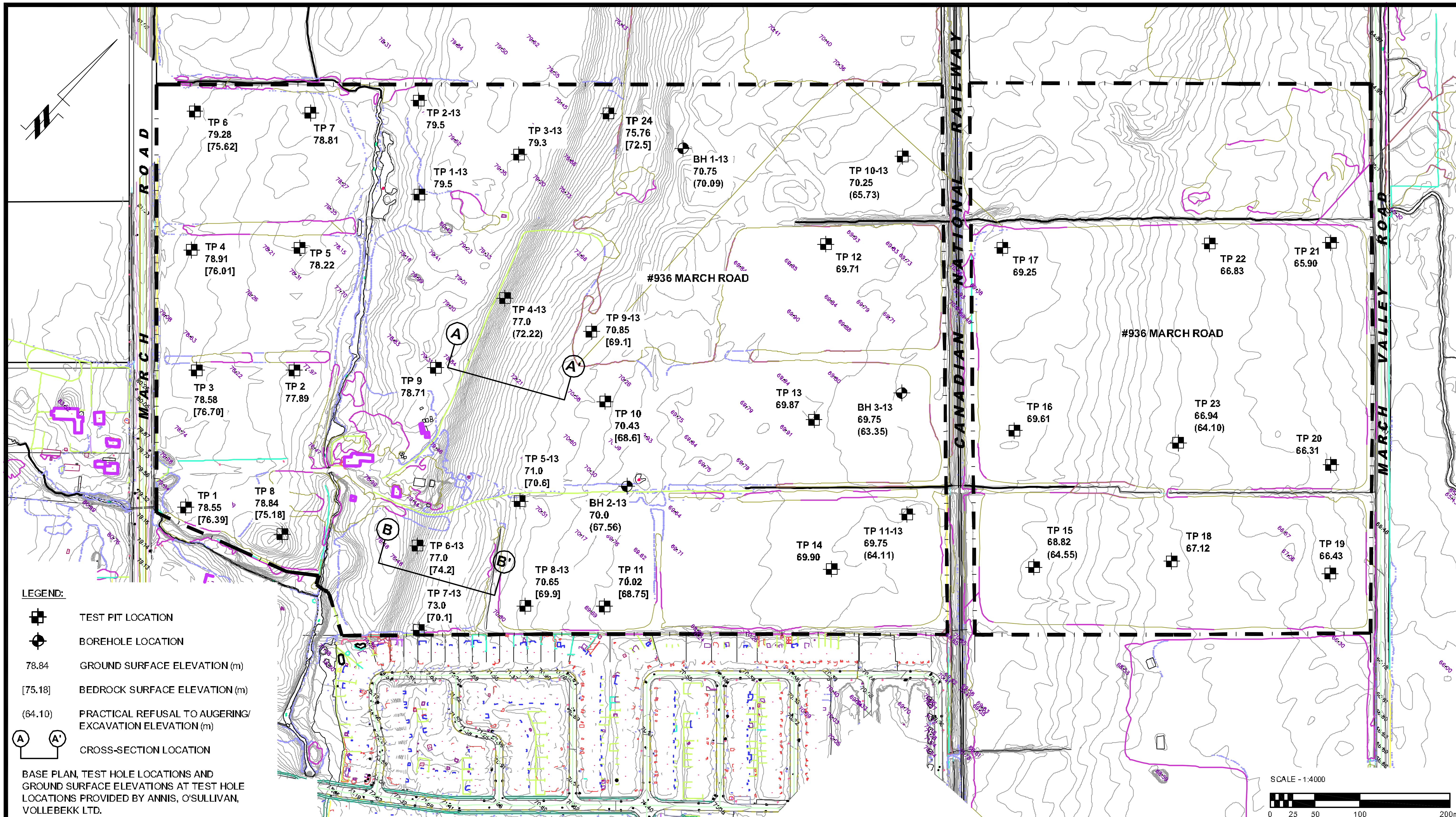


Figure 5 - Section B - Seismic Loading
Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
13.474
0.21
W
W
Brown Silty Clay
Strength Type: Undrained
Unit Weight: 17 kN/m3
Cohesion Type: Constant
Cohesion: 150 kPa
Bedrock
Strength Type: Infinite strength
Unit Weight: 23 kN/m3
150
140
130
120
110
100
90
80
70
-20
-10
0
10
20
30
40
50
60
70
80
90



LEGEND:

(symbol)	TEST PIT LOCATION
(symbol)	BOREHOLE LOCATION
78.84	GROUND SURFACE ELEVATION (m)
[75.18]	BEDROCK SURFACE ELEVATION (m)
(64.10)	PRACTICAL REFUSAL TO AUGERING/ EXCAVATION ELEVATION (m)
A — A'	CROSS-SECTION LOCATION

BASE PLAN, TEST HOLE LOCATIONS AND GROUND SURFACE ELEVATIONS AT TEST HOLE LOCATIONS PROVIDED BY ANNIS, O'SULLIVAN, VOLLEBEKK LTD.

paterson group consulting engineers 154 Colonnade Road South, Ottawa, Ontario K2E 7J5	Scale: 1:4000 / Des.: SB / Dwn: MPG / Chkd: DG	METCALFE REALTY COMPANY GEOTECHNICAL INVESTIGATION KANATA NORTH URBAN EXPANSION AREA 936 MARCH ROAD OTTAWA, ONTARIO	TEST HOLE LOCATION PLAN	Dwg. No. PG2878-5 / Report No.: PG2878-1 / Date: 06/2013

PG2878-5 (936 March Road) NEW.dwg

Appendix N

Hydrogeological Existing Conditions Report
Kanata North Urban Expansion Area

(Patterson Group – May 18, 2016)

Geotechnical Engineering

Environmental Engineering

Hydrogeology

Geological Engineering

Materials Testing

Building Science

Archaeological Services

patersongroup

Hydrogeological Existing Conditions Report

Kanata North Urban Expansion Area
Ottawa, Ontario

Prepared For

Novatech Engineering Consultants Ltd.

Paterson Group Inc.

Consulting Engineers
154 Colonnade Road South
Ottawa (Nepean), Ontario
Canada K2E 7J5

Tel: (613) 226-7381
Fax: (613) 226-6344
www.patersongroup.ca

May 18, 2016

Report: PH2223-3R4

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EXECUTIVE SUMMARY

Assessment

Further to the request and authorization of Novatech, on behalf of the Kanata North Landowners' Group, Paterson Group (Paterson) completed a Hydrogeological Existing Conditons Report for the Kanata North Urban Expansion Area (KNUEA), as per the scope set out by the KNUEA Environmental Management Plan Terms of Reference. The purpose of this report is to characterize the existing geological and hydrogeological conditions at the subject site, including recharge/discharge conditions, and to provide specific recommendations with respect to existing water wells and septic systems, tile drainage systems, and the potential for environmental contamination. This report incorporates the findings of a previous Hydrogeological Existing Conditions Report and Sensitive Groundwater Study by Paterson Group, as well as a borehole drilling, monitoring well installation, groundwater level monitoring, and hydraulic conductivity testing program completed by Paterson of the subject site in 2015.

The subject site is located to the east and west of March Road, between Maxwell Road and Maxwell Bridge Road, in the City of Ottawa, Ontario. The subject site consists primarily of active agricultural land, with minor fallow field/meadow and woodlot areas present throughout the site. Residential and agricultural buildings are present along March Road, with institutional and commercial buildings present to the north, and areas of high-density residential and commercial development to the south. Site topography is flat to gently rolling, with a general downward slope in a southwest-to-northeast direction. Surface water features on the subject site include unnamed tributaries of Shirley's Brook.

Bedrock in the vicinity of the subject site consists of Paleozoic sedimentary rock of the Lower Ordovician age. The interbedded sandstone and dolostone of the Nepean/March Formation is present over the majority of the site, with the Oxford Formation dolostone present in the eastern portion of the site. No karst features were observed in the site bedrock. Overburden soils at the subject site vary between 0 and 10 m in thickness, and are most commonly encountered at thicknesses of 1 to 4 m. Overburden generally consists of silty clay over glacial till, with alluvial silty sand present on the eastern portion of the subject site.

A review of the Ontario water well record database indicated that water supply wells in the vicinity of the subject site are completed in the Nepean/March Formation or Oxford Formation bedrock. The limited thickness and low hydraulic conductivity of the overburden layer at the subject site is considered to limit its use as a water supply aquifer at the subject site. In areas where the Oxford Formation overlies the Nepean/March Formation, the Nepean/March Formation is considered to represent a viable alternative aquifer in the event of potential impacts to shallow wells screened in the Oxford Formation.

In addition to a review of available mapping and the Ontario water well record database, 10 monitoring wells (one shallow and one deeper well at each of 5 locations) were installed in the bedrock at the subject site along a proposed servicing alignment, running in a southwest-to-northeast direction. Hydraulic conductivity testing and groundwater level monitoring was completed at these monitoring wells to assess hydrogeological conditions in the upper fractured bedrock aquifer. This work, in combination with the shallow overburden piezometer installation program previously completed by Paterson as part of the Sensitive Groundwater Assessment, allowed for a characterization of discharge and recharge conditions at the subject site.

Based on hydraulic conductivity testing of the bedrock and the observed characteristics of overburden soils at the subject site, the silty clay and glacial till soils at the subject site are considered to have low hydraulic conductivity relative to the upper fractured bedrock, and as such, function as a confining layer, limiting groundwater discharge and recharge through this layer relative to areas of thinner or more permeable overburden soils. Groundwater is considered to recharge into the bedrock aquifer in areas of exposed bedrock at ground surface upgradient of the subject site. In areas of silty sand soil, groundwater discharge and recharge appear to be occurring on a localized scale, highly influenced by topography.

Based on hydraulic conductivity testing, observed hydraulic gradients, and observed site stratigraphy, groundwater in the bedrock is considered to move laterally, and discharge or recharge between ground surface and the bedrock aquifer unit are considered to be limited over the majority of the site. In areas of upward hydraulic gradients and thin overburden soils, such as the toe of the slope adjacent to Woodlot S20, discharge of groundwater is possible. However, groundwater seepage was not observed in this area by Paterson staff during the 2015 investigation.

Potential impacts to surrounding wells depend on a variety of factors, including site geology and hydrogeology, amount and duration of construction dewatering, separation distance between service trench alignment and surrounding wells, impacts due to blasting such as the mobilization of sediment in existing fractures or the opening of new fractures, site groundwater flow direction, and other factors. Based on the results of this investigation, a baseline groundwater monitoring program is proposed, which will include the monitoring and sampling of surrounding wells and the installation of sentry wells on the subject site.

Recommendations

A brief summary of the recommendations of the hydrogeological existing conditions report is provide as follows:

- It is recommended that existing water wells and private sewage systems be decommissioned by a qualified contractor (in the case of water wells, a licensed contractor as per O.Reg. 903).
- It is recommended that existing agricultural tile drains, if encountered, be removed and/or capped on an as-encountered basis.
- Care should be taken to employ best practices prior to and during site development to minimize the risk of environmental contamination at the subject site.
- It is recommended that existing water wells at country estate lot subdivisions adjacent to the subject site be sampled prior to the commencement of the development of the subject site, as part of a baseline monitoring program. Proposed wells to be included in the baseline monitoring program are shown on Drawing PH2223-4R, appended to this report.
- Sentry wells should be installed on the subject site and monitored for a period of at least one (1) year prior to development in order to establish baseline conditions at the site boundary as a basis for evaluating any potential impacts once construction commences. Proposed sentry well locations are shown on Drawing PH2223-4R, and should be re-evaluated at the detail design phase.

- In the event of impacts to surrounding wells by on-site construction activities, an alternative source of water will immediately be provided to the impacted properties by the proponents of the project. In the event of short-term impacts, tanked or bottled water may be provided, and in the event of long-term impacts which are confirmed to be a result of construction activities at the subject site, consideration will be given to deepening the pumps in affected wells where significant available drawdown is present, or potentially drilling a new well.

- In the event of bedrock removal by blasting, best management practices are to be followed at all times. As a general guideline, peak particle velocities at the property boundary should not exceed 25 mm per second to reduce the risk of damage or impacts to surrounding wells or structures. Blasting operations should be planned and conducted under the supervision of a licensed professional engineer who is also an experienced blasting consultant.

- In areas where service trenches are to pass underneath watercourses, consideration should be given to the construction of clay liners over the service trenches and underneath the culvert crossings.

- Service trenches may act as preferential pathways for groundwater flow, particularly where granular backfill has been used, and may contribute to lowering of groundwater in the surrounding soils or bedrock. It is recommended that packed clay dikes be constructed at regular intervals within service trenches to mitigate long-term dewatering effects.

- In areas where stormwater ponds are to be excavated into bedrock, it is recommended that a liner system, either a packed-in-place clay liner or a manufactured geosynthetic liner, be installed to prevent seepage to or from the ponds.

- This report has been completed as per the agreed-upon scope of work for this project. It is recommended that the sufficiency of these conclusions be re-evaluated at the detail design phase and that any data gaps be addressed accordingly.

1.0 INTRODUCTION

1.1 Background

Paterson Group (Paterson) was retained by Novatech acting on behalf of the Kanata North Landowners' Group to complete a hydrogeological study of the proposed Kanata North Urban Expansion Area (KNUEA), located along March Road between Maxwell Road and Maxwell Bridge Road, in the City of Ottawa, Ontario (hereinafter referred to as the “subject site”). This report incorporates the findings of Paterson’s previous Hydrogeological Existing Conditions Report, dated October 21, 2013 (revised July 22, 2014), and Sensitive Groundwater Assessment of Woodlot S20, dated October 24, 2014, as well as a supplemental field program undertaken by Paterson in the spring and summer of 2015.

The purpose of this report was to characterize the hydrogeological setting of the subject site, with respect to bedrock and surficial geology, aquifers, aquitards, horizontal and vertical flow patterns, existing groundwater use, and aquifer vulnerability, in support of the KNUEA Community Design Plan (CDP).

1.2 Scope of Work

Paterson has completed this report in accordance with Section 4.5 of the finalized KNUEA Environmental Management Plan Terms of Reference (EMP TOR), prepared by Novatech. As per the EMP TOR, the purpose of the hydrogeological study is to assist in the protection of groundwater quality and to identify and protect recharge/discharge functions at the subject site. As per the TOR, the study will provide a summary of existing hydrogeological conditions and identify the following:

- Unused and unmaintained water wells that require proper well abandonment;
- Existing septic systems that will be unused and will require proper decommissioning;
- Tile drainage systems;
- Sites identified by environmental site assessments as potential sources of groundwater contamination;

- Any separation requirements from surrounding wells in estate subdivisions.

In addition to the above, this report addresses groundwater recharge/discharge conditions in the vicinity of the wooded area identified as Woodlot S20, as well as site-specific hydrogeological conditions in the shallow bedrock at the site, along an east-west alignment corresponding to the proposed location of major site services. The findings of this hydrogeological report are intended to provide input to future hydrological/water budget and environmental/ecological studies at the subject site.

2.0 PREVIOUS REPORTS

In addition to a review of the general literature summarized in the following sections and in the 'References' section of this report (MOECC water well database, available geological and physiographic mapping, City of Ottawa Official Plan), Paterson reviewed the following site-specific reports:

- "Kanata North Environmental/Stormwater Management Plan", prepared by CH2M Hill, 2001.
- "Shirley's Brook and Watt's Creek Subwatershed Study", prepared by Dillon Consultants, 1999.
- "Existing Conditions Report: Hydrogeology, Kanata North Urban Expansion Area Community Design Plan, Ottawa (Kanata), Ontario", prepared by Paterson, October 2013 (revised July 2014).
- "Consolidated Preliminary Geotechnical Investigation, Kanata North Urban Expansion Area Community Development Plan, March Road, Ottawa, Ontario", prepared by Paterson, dated April 2013.
- "Sensitive Groundwater Assessment: Woodlot S20, Proposed Kanata North Expansion Area, Kanata, Ontario", prepared by Paterson, 2014

The Dillon and CH2M Hill reports were reviewed by Paterson staff prior to the completion of Paterson's 2013/2014 Existing Conditions report. While the majority of overburden soils on the subject site were reportedly silty clay or glacial till deposits, the Dillon report identified alluvial soils in the eastern portions of the study area. The alluvial deposit was estimated to be up to 2 m thick, where present, and was identified by Dillon as providing an opportunity for infiltration-based stormwater management measures within the study area.

The Dillon report also identified exposed bedrock ridges near the western boundary of the study area as representing a bedrock groundwater recharge area.

A detailed hydrogeological assessment of groundwater discharge to surface water bodies within the study area was beyond the scope of the Dillon report, which stated that, generally speaking, groundwater discharge was considered to be limited due to the low permeability of overburden soils in the study area. Specific conclusions with respect to groundwater discharge and recharge are addressed by Paterson in this report.

The 2013/2014 Existing Conditions report by Paterson consisted primarily of a desktop review of available reports and mapping. A search of the Ontario Ministry of the Environment and Climate Change (MOECC) water well database was completed. The Paterson report confirmed that site soils within the study area consisted primarily of low-permeability silty clay and glacial till deposits over Paleozoic bedrock. Although site-specific infiltration and/or hydraulic conductivity testing was not carried out, opportunities for groundwater infiltration within the study area were considered to be limited.

The Paterson existing conditions report concluded that the majority of the wells in the vicinity of the subject site were associated with estate lots in surrounding residential developments along March Road, Panandrick View Drive, Marchbrook Circle, Houston Crescent, and March Valley Road. Several properties within the subject site were identified as having water wells and/or private sewage systems that would require decommissioning upon redevelopment. No agricultural tile drains were encountered, and the Paterson report recommended removing and/or capping tile drains on an as-encountered basis.

The Paterson consolidated geotechnical report provided a variety of site-specific soils data which was incorporated into the findings of the existing conditions report.

Following review comments and discussions with the City of Ottawa and the Mississippi Valley Conservation Authority, Paterson revised the existing conditions report and completed a shallow piezometer installation and groundwater monitoring program to determine the potential for groundwater discharge in the overburden soils in the location of the test sites in Woodlot S20. Soil samples were obtained by hand augering in various locations, and shallow piezometers were installed to measure vertical hydraulic gradients in overburden soils.

Site soils consisted of topsoil and sandy silt overlying a silty clay layer of lower permeability. Neutral to slightly downward vertical hydraulic gradients were measured in upland areas. Neutral to slightly downward hydraulic gradients were measured in low-lying areas. The report concluded that localized recharge and discharge within the topsoil and silty sand layers was occurring, with the silty clay layer largely preventing significant recharge to the bedrock within Woodlot S20.

The findings of Paterson's previous reports have been incorporated into this assessment. Paterson's sensitive groundwater assessment report has been appended to this report for reference. Specific details of the hydraulic gradients observed during the 2015 investigation, as they relate to discharge and recharge at the subject site, are provided in following sections.

3.0 METHOD OF INVESTIGATION

3.1 Records Review

A review of available physiographic, geological, and hydrogeological data was completed as a part of this assessment. As discussed above, the literature review and previous reports did not provide site-specific data regarding the shallow bedrock aquifer at the subject site, or recharge and discharge conditions in this aquifer. However, site-specific data regarding hydraulic gradients within Woodlot S20 was summarized in Paterson's previous 2014 sensitive groundwater assessment report. Further detail is provided in following sections.

3.2 Borehole Drilling Program

A borehole drilling program was developed to assess geology, groundwater conditions, and hydraulic gradients in the shallow bedrock at the subject site. These boreholes were drilled into the shallow bedrock at the subject site to assess hydrogeological conditions at the approximate depth of the proposed services for the site, which are understood to extend up to 8 m at their deepest, along March Road.

A total of ten boreholes (a shallow and a deep borehole at each of five locations) were drilled along the approximate alignment of a proposed servicing corridor running in an east-to-west direction across the subject site. The location of the boreholes is shown on Drawing PH2223-5 - Test Hole Location Plan (2015), appended to this report. All boreholes were instrumented with groundwater monitoring wells.

The borehole drilling program was completed on June 2, 3, and 4, 2015. The boreholes were advanced using a track-mounted CME 55 power auger drill rig. The drilling contractor was George Downing Estate Drilling of Hawkesbury, Ontario. Drilling occurred under full-time supervision of Paterson personnel.

A total of 16 soil samples were obtained from the boreholes by means of split spoon sampling and the sampling of shallow soils directly from auger flights. Split spoon samples were taken at approximate 0.76 m intervals. The depths at which split spoon and auger flight samples were obtained from the boreholes are shown as "**SS**" and "**AU**" respectively on the Soil Profile and Test Data Sheets, appended to this report.

Shallow and deep boreholes at each location were drilled consecutively, with a horizontal separation distance of approximately 2 to 3 m. At each location, the deep borehole was drilled first, with soil samples and rock core samples retained and reviewed. Shallow boreholes were subsequently drilled. Overburden samples were not retained from the shallow boreholes. Overburden stratigraphy was not anticipated to vary significantly in the distance between the shallow and deep boreholes at each location, and soil conditions at shallow boreholes were interpreted based on deep boreholes. Some variation in overburden thickness was noted. Rock core samples from all boreholes were retained for review.

Site soils generally consist of a layer of topsoil, overlying native silty clay underlain by a glacial till deposit. The glacial till material consisted of a silty clay to clayey silt matrix with sand and gravel. The glacial till was not observed at BH1/BH1A or BH2/BH2A. The silty clay was not observed at BH1/BH1A, and instead a layer of silty sand was observed, extending to bedrock. Specific details are provided on the Soil Profile and Test Data Sheets, appended to this report.

Stratigraphy within Woodlot S20, as per the hand auger holes advanced by Paterson during the 2014 sensitive groundwater assessment, consisted of a transitional soil (topsoil to silty sand), overlying silty clay. Soil profile and test data sheets are contained within the sensitive groundwater assessment report, appended to this report. On the whole, overburden soils at the subject site consist of silty clay over glacial till, with isolated areas of more conductive transitional topsoil to silty sand, particularly in the vicinity of Woodlot S20 and the eastern portion of the subject site.

3.3 Laboratory Testing

All soil and rock core samples were retained for laboratory review following the field portion of the subsurface investigation. Rock Quality Designation (RQD) was calculated for all rock samples, and is summarized on the Soil Profile and Test Data Sheets appended to this report.

Grain size analysis was performed on two (2) representative samples of the silty sand material (TP13-G1 and TP16-G1 from the geotechnical investigation PG2878), one (1) representative of the silty clay material (BH3-15-SS3) and one (1) representative sample of the glacial till (BH4-15-SS4). Grain size analysis results are appended to this report. Based on the soil descriptions encountered across the subject site during the various geotechnical and hydrogeological investigations, and based on the spatial distribution of the above-noted samples, these samples are considered to be sufficiently representative of the subject site.

3.4 Monitoring Well Installation

A total of ten groundwater monitoring wells were installed by George Downing Estate Drilling of Hawkesbury, Ontario under the full-time supervision of Paterson personnel. The monitoring wells consisted of 51 mm diameter Schedule 40 threaded PVC risers and screens. A sand pack consisting of silica sand was placed around the screen, and a bentonite seal was placed above the screen and extended to ground surface to minimize cross-contamination. All groundwater monitoring wells were equipped with steel stick-up protective casings.

Monitoring well construction details are provided on the Soil Profile and Test Data Sheets appended to this report. A summary of monitoring well construction details is provided on Table A1 in the appendix of this report.

At each nested location, the deep borehole was advanced to a depth of approximately 5 m below the bedrock/overburden interface. Monitoring wells with 1.5 m screens were installed in all deep holes. Shallow holes at each location were drilled to depths of approximately 1.8 m into the upper bedrock, to allow the installation of a 1.5 m screen and an appropriate bentonite seal above the screen to prevent hydraulic communication between bedrock and overburden units, as per O.Reg. 903 (Wells). The purpose of screening the wells in the above-noted interval at each location was to assess groundwater conditions and determine upward or downward hydraulic gradients (discharge or recharge conditions) between the uppermost fractured bedrock layer (shallow wells) and the deeper bedrock layer (deep wells).

Following installation, monitoring wells were developed by removing 3 to 10 volumes of standing water. The purpose of well development was to remove any water introduced by the bedrock coring process and to remove fines from the sand pack.

3.5 Piezometer Installation

During the 2014 sensitive groundwater assessment, piezometers were installed in select locations along the drainage channels and in low lying areas where a minimum of 100 mm of standing water was present. This depth of water allowed for sufficient submersion of the surface water side of the piezometer in order to ensure consistent reproduction of the testing, as needed.

The mini piezometer installation and testing followed the protocol specified by United States Institute of Food and Agricultural Sciences (IFAS). Specifically, document No. AE454, one in a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, IFAS, was used. This document is appended to this report as a component of the sensitive groundwater assessment appendix.

At each of the piezometer locations, a 12.5 mm I.D. metal pipe was used to seat a wooden dowel constructed as a disposable drive point, approximately 150 mm below the surface of the ground in the underlying shallow soil/sediment. Next, a 6 mm diameter polyethylene tube, wrapped in a nylon stocking and tied off with a plastic cable tie was inserted in to the pipe and lowered to the bottom of the hole. The metal pipe was carefully removed leaving the polyethylene pipe in place. The polyethlyene pipe was attached using a plastic tee connector and cable clamps were used to secure and prevent air leakage. Another piece of tubing was attached to the other side of the tee and lowered into the water. Finally , a long piece of tubing was connected and clamped to the tee and connected to an automotive hand vacuum pump when the piezometer testing was performed.

3.6 Groundwater Level Measurement

Following the 2015 monitoring well installation program, groundwater levels were measured at the monitoring wells using an electronic water level meter. Groundwater levels were generally measured relative to the top of pipe (TOP) elevation at each monitoring well location. Groundwater levels at all locations are summarized in Table A1, appended to this report.

Four groundwater level measurement events were completed as part of this assessment, including groundwater levels measured during the hydraulic conductivity testing program outlined below. It is noted that different wells were slug-tested on different days, which is reflected in Table A1.

Groundwater levels measured in the piezometers installed as part of the sensitive groundwater study in 2014 varied between 0 and 0.52 m below ground surface. Groundwater levels in the shallow monitoring wells varied between 1.20 m below existing grade and 0.25 m above existing grade. Groundwater levels in the deep monitoring wells varied between 1.23 m below existing grade and 0.22 m above existing grade. Water levels above existing grade in areas with no standing water observed at ground surface suggest that overburden soils of lower hydraulic conductivity, such as the silty clay and glacial till soils, act as a confining layer to the underlying bedrock aquifer. Further discussion is provided in subsequent sections.

3.7 Hydraulic Conductivity Testing

Hydraulic conductivity testing was completed at all monitoring wells installed during the 2015 subsurface investigation. Falling head and rising head tests (“slug tests”) were completed in accordance with ASTM Standard Test Method D 4404 - Field Procedure for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers.

Slug testing was completed on June 24, 25, and 26, 2015 by Paterson personnel. The general test method consisted of the measurement of the static water level in the well, followed by inducing a near-instantaneous change of head in the monitoring well and subsequent monitoring of water level recovery with an electronic water level tape. The change in head was induced by the introduction of an aluminum slug, 2.0 m in length and 40 mm in diameter. The slug was initially introduced to raise the groundwater level in the monitoring well, following which the decrease in water level over time was monitored (falling head test). Once the water level had stabilized or nearly stabilized, the slug was then removed to lower the groundwater level, following which the increase in water level over time was monitored (rising head test).

Following the completion of the slug tests, the test data was analyzed as per the method set out by Hvorslev (1951). Assumptions inherent in the Hvorslev method include a homogeneous and isotropic aquifer of infinite extent, negliglble aquifer storage through compressibility (“zero-storage assumption”), and a screen length significantly greater than monitoring well diameter. The assumption regarding aquifer storage is considered to be appropriate for groundwater flow through preferential fracture flowpaths in relatively incompressible bedrock. The assumption regarding screen length and well diameter is considered to be met, as per the monitoring well construction details appended to this report.

While the idealized assumptions regarding aquifer extent, homogeneity, and isotropy are not strictly met in this case (or indeed in any real-world situation), it has been our experience that the Hvorslev method produces effective point estimates of hydraulic conductivity in conditions similar to those encountered at the subject site.

Hvorslev analysis is based on the line of best fit through the field data (hydraulic head recovery vs. time), plotted on a semi-logarithmic scale. In cases where the initial hydraulic head displacement is known with relative certainty, such as in this case where a physical slug has been introduced, the line of best fit is considered to pass through the origin. In cases where the initial hydraulic head displacement is known with less certainty (e.g. a bail test, where water is pumped rapidly from the well), the best-fit line is drawn regardless of the origin.

Based on the above testing, hydraulic conductivity values in the shallow wells ranged from 2.4×10^{-7} m/s to 2.9×10^{-5} m/s, with a geometric mean of 9.2×10^{-7} m/s. Hydraulic conductivity values in the deep wells ranged from 2.0×10^{-7} m/s to 7.4×10^{-5} m/s, with a geometric mean of 4.3×10^{-6} m/s. It is noted that higher hydraulic conductivity values were observed at BH3 (3.7×10^{-5} to 7.4×10^{-5} m/s), BH5 (7.8×10^{-6} to 1.1×10^{-5}), and BH5A (2.1×10^{-5} to 2.9×10^{-5}), while hydraulic conductivity values at the remaining wells generally ranged from 2.0×10^{-7} to 1.4×10^{-6} m/s.

3.8 Surveying

The locations of all monitoring wells, as well as geodetic elevations of the top of pipe and ground surface elevation at all monitoring well locations, were surveyed in the field by Annis, O'Sullivan, Vollebekk Limited Ontario Land Surveyors. Monitoring well elevations are shown on the Soil Profile and Test Data Sheets and on Drawing PH2223-5 - Test Hole Location Plan (2015), appended to this report.

4.0 REVIEW AND EVALUATION

4.1 Physical Setting

The subject site is located on the east and west sides of March Road, between Maxwell Road and Maxwell Bridge Road, in the City of Ottawa, Ontario. The location of the subject site is shown on Drawing PH2223-1 - Site Location Plan.

The subject site consists primarily of active agricultural land, with minor fallow field/meadow and woodlot areas present throughout the site. Surrounding land use to the north, west, and southwest of the site consists of wooded areas and residential development (privately-serviced estate lots around Panandrick View Drive and Marchbrook Circle). Commercial and institutional land uses are also present to the north, including St. Isidore Parish and school, and commercial businesses along March Road. To the south of the site, municipally-serviced residential and commercial developments are present. To the north and northeast of the subject site, lands associated with the Canadian Department of National Defence (DND) are present, northeast of March Valley Road. A rail line is present running in a northwest-southeast direction across the northeastern portion of the subject site.

Site topography is flat to gently rolling, with the subject site gradually decreasing in elevation in a northwest-to-southeast direction. Steeper slopes are present in localized areas, particularly in the vicinity of Woodlot S20/BH1/BH1A/BH2/BH2A. An elevated wooded area is present at the northwest corner of the site, adjacent to Panandrick View Drive.

Surface water bodies at the subject site include unnamed tributaries of Shirley's Brook, flowing in an approximate east-to-west direction across the subject site. Areas of standing water are observed in local topographical low areas, agricultural fields and within Woodlot S20 in the spring and in times of high precipitation.

According to available mapping, the subject site is located in the Ottawa valley Clay Plains physiographic region (Chapman and Putnam, 1984). The region is characterized by relatively flat clay plains interrupted by rock ridges, which is generally consistent with field observations at the subject site. According to Chapman and Putnam, the Connaught Rifle Range (DND lands to the east of the subject site) are within a former channel, which is consistent with the alluvial sediments identified on the eastern portion of the subject site.

4.2 Geology

4.2.1 Surficial Geology

Overburden mapping provided by the Ontario Geological Survey online mapping tool was reviewed as a part of this assessment. Available mapping indicates that overburden soils at the subject site consist primarily of marine deposits (silt and clay) associated with the Champlain Sea, with exposed Precambrian bedrock to the west, isolated areas of exposed Paleozoic bedrock on the eastern portion of the site, glacial till deposits to the north, and an area of alluvial sediment associated with a former channel of the Ottawa River on the eastern portion of the site. Overburden soils mapping is shown on Drawing PH2223-2 - Surficial Soils Mapping and on Drawing PH2223-8 - Cross-Section A-A'.

Overburden soils identified by the previous geotechnical investigation by Paterson and the current subsurface investigation were generally consistent with the available mapping. Bedrock outcropping was generally not observed by Paterson at the subject site, with the exception of within the creek channel on the western portion of the site. Overburden thickness varied from 0 to approximately 4.6 m across the subject site, with between 1 and 4 m of soil generally present. Soils generally consisted of topsoil over silty clay, underlain by glacial till. The glacial till layer was not observed in all test holes.

Additionally, a silty sand layer was observed on the eastern portions of the subject site and intermittently throughout the site. This layer was generally less than 1 m thick, where encountered. In the central portions of the site, the silty sand layer was underlain by silty clay or glacial till. In a localized area in the vicinity of BH1/BH1A and TP19, the silty clay and glacial till layers are absent and silty sand layer was observed to extend to bedrock. Silty clay was observed at all remaining test pit and borehole locations at the subject site. The silty sand layer was underlain by silty clay within Woodlot S20, as per the findings of the sensitive groundwater assessment by Paterson (2014).

Specific details are provided on the Soil Profile and Test Data Sheets appended to this report.

4.2.2 Bedrock Geology

Bedrock mapping, provided by the Ontario Geological Survey online mapping tool, was reviewed as a part of this assessment. Available mapping indicates that bedrock in the western and central portions of the subject site consists of interbedded quartz sandstone and dolostone of the March Formation (Lower Ordovician). A fault line is shown running in a northwest-to-southeast direction through the east-central portion of the subject site. East of the fault line, the bedrock consists of dolostone of the Oxford Formation (Lower Ordovician). The Oxford and March Formations are collectively known as the Beekmantown Group. The March Formation is underlain by Lower Ordovician sandstone of the Nepean Formation.

Bedrock encountered during the field portion of the investigation consisted of grey sublithographic interbedded limestone and dolostone consistent with the description of the March and Oxford Formations. Rock core samples retained during the investigation reacted moderately to vigorously with hydrochloric acid during laboratory review, indicating carbonate composition.

Rock core recovered from the subject site was moderately fractured, with horizontal and vertical fractures observed. Rock quality designation (RQD) of the rock core samples ranged from 0 (very poor) to 100 (excellent), with most RQD values in the fair to good range. Rock quality tended to improve with depth, although exceptions were noted. Details are provided on the Soil Profile and Test Data Sheets, appended to this report.

The term ‘karst’ refers to a geologic formation characterized by the dissolution of carbonate bedrock, such as limestone or dolostone. Based on a desktop review of available literature, and on visual inspection of the rock core samples from the subject site, karst features are not considered to be present at the subject site.

4.3 Hydrogeological Setting

4.3.1 Existing Aquifer Systems

Aquifer systems may be defined as geological media, either overburden soils or fractured bedrock, which permit the movement of groundwater under hydraulic gradients. In general, aquifer systems may be present in overburden soils or bedrock. Although groundwater has been observed within overburden soils at the subject site, the relatively thin overburden does not allow for the development of significant water supply wells. Water supply wells in the vicinity are instead found in bedrock aquifers.

Based on a review of the MOECC water well record database, Paterson has previously identified two water supply aquifer systems in the vicinity of the study area. It is noted that the majority of water well logs in the MOECC database are completed by well drilling contractors from a water supply perspective. Intervals where water is encountered are recorded on the well logs. In the case of wells completed in rock, these depths represent fractured intervals where significant amounts of water are encountered, although fractures containing water may also be present at other depths.

The March Formation/Nepean Formation aquifer system is located to the east, south, and west of the study area, as well as the majority of the study area itself. The water well records do not differentiate between March Formation and Nepean Formation sandstone, and as such, the two units are considered as one for the purposes of this assessment. Wells utilizing this aquifer system generally report encountering water-bearing intervals at depths between 12 and 20 m below existing grade.

The Oxford Formation aquifer system is generally encountered to the north and east of the fault line discussed in the previous section. Water wells completed in this formation report encountering water-bearing fractures at depths of over 30 m below existing grade. Based on the limited stratigraphic information provided on the water well records, wells advanced through the Oxford Formation to depths exceeding 30 m may have fully penetrated the formation and are likely intercepting water within the underlying March/Nepean Formation. It is noted that in areas where the March/Nepean formation is overlain by the Oxford Formation, the March/Nepean Formation represents an alternative water supply aquifer in the events of potential impacts to wells completed in the Oxford Formation.

This assessment primarily addresses groundwater conditions in overburden soils and the shallow fractured bedrock aquifer (within approximately 5 m of the overburden interface). While the majority of water wells are completed at greater depths within the bedrock unit, understanding hydraulic gradients and recharge/discharge conditions in the shallow bedrock unit at the subject site will provide useful information with respect to environmental, ecological, and stormwater management as the site is developed.

4.3.2 Groundwater Levels

Groundwater was observed in the monitoring wells screened in the shallow and deeper (approximately 5.9 to 8.1 m) bedrock units. Based on a review of water well records, groundwater is also present in the bedrock at greater depths; water wells were generally completed at depths ranging from 14 to 75 m below existing grade.

Groundwater levels in the shallow bedrock unit were observed to vary between 1.20 m below existing grade and 0.25 m above existing grade. Groundwater levels in the deeper bedrock unit were observed to vary between 1.23 m below existing grade and 0.22 m above existing grade. Groundwater levels were observed to vary slightly between monitoring events. Groundwater levels are summarized on Table A1, appended to this report.

At several locations, groundwater elevations were within the elevation of the overburden layers, or above ground surface. This suggests that the upper fractured bedrock layer is fully saturated, and that overburden soils are acting as a confining layer. In the vicinity of BH1/BH1A, where overburden soil consists of silty sand, soils at ground surface were wet to saturated, although no standing water was observed. At the remaining locations, the ground surface was dry.

During the subsurface investigation, overburden soils were generally observed to be moist, becoming wet with depth, with saturated conditions observed in the silty sand layer at BH1/BH1A and in the lower glacial till at BH4 and BH5. Monitoring wells were not screened in overburden soils as a component of the 2015 borehole drilling program, given the available data from the 2014 sensitive groundwater study by Paterson. It is noted that site services will generally be extended into the bedrock at the site. Surrounding water supply wells are also completed within the bedrock. As such, and given the available data from the 2014 sensitive groundwater study, additional investigation of water levels within the overburden at the subject site was not completed.

Based on the results of the 2014 sensitive groundwater assessment, groundwater levels in the overburden soils within Woodlot S20 varied between 0 and 0.52 m below ground surface. Groundwater levels in overburden soils are expected to vary seasonally, and if the glacial till and silty sand units are hydraulically connected to the upper fractured bedrock, water levels may drop below the overburden level into the bedrock in dry periods, although perched groundwater conditions may exist in topsoil/overburden soils during periods of high precipitation. It is our interpretation that saturated conditions in the more permeable overburden soils (till, silty sand) and the upper fractured bedrock unit together represent the long-term water table at the subject site.

During site visits completed in support of the 2014 field program, saturated soils and isolated areas of standing water were observed at ground surface within Woodlot S20. Piezometers were installed in areas of standing water as a component of the 2014 sensitive groundwater assessment by Paterson. Based on the negative to neutral hydraulic gradients observed in areas of standing water during the 2014 field program, it is Paterson's interpretation that these areas of standing water are predominantly the result of poor surface grading as opposed to significant groundwater discharge. Standing water was not observed during the 2015 field program.

4.3.3 Horizontal Hydraulic Gradients

Due to the relatively linear alignment of the monitoring wells, the absolute direction of horizontal hydraulic gradients in the vicinity of the subject site was not determined. However, along the alignment of the monitoring wells, a horizontal hydraulic gradient in the upper fractured bedrock was observed with a northwest-to-southeast orientation and a magnitude of approximately 0.009 to 0.03 m/m.

Shallow groundwater flow in the vicinity of the subject site is considered to reflect local topography. Regional groundwater flow is considered to be in an easterly or northeasterly direction, towards the Ottawa River.

4.3.4 Vertical Hydraulic Gradients

Vertical hydraulic gradients were measured at each monitoring well location. The vertical hydraulic gradient is defined as the difference in groundwater surface elevation between the shallow and deep well, divided by the vertical distance between the centre of the screens of the shallow and deep well. Hydraulic gradients are summarized below:

- Vertical hydraulic gradients between BH1 and BH1A were consistently downward, with magnitudes of 0.04 to 0.12 m/m.
- Vertical hydraulic gradients between BH2 and BH2A were consistently upward, with magnitudes of 0.03 to 0.11 m/m.
- Vertical hydraulic gradients between BH3 and BH3A were consistently upward, with magnitudes of 0.09 to 0.26 m/m.
- Vertical hydraulic gradients between BH4 and BH4A were consistently downward, with magnitudes of 0.01 m/m.
- Vertical hydraulic gradients between BH5 and BH5A were consistently upward, with magnitudes of 0.01 m/m.

Ground surface elevation along the alignment of the above-noted boreholes slopes gently downward from southwest to northeast, with a somewhat steeper slope present between BH2/BH2A and BH1/BH1A. These gradients observed within the bedrock unit are generally not considered to be indicative of significant groundwater discharge or recharge, given the confining nature of the overburden soils.

Although upward hydraulic gradients may be expected at BH4/BH4A based on topography, it is noted that downward hydraulic gradients were consistently observed at this location. Localized variations in hydraulic gradients are expected due to the inherent variability of site geology and hydrogeology.

Vertical hydraulic gradients between areas of standing water and underlying strata were also measured as a component of Paterson’s 2014 sensitive groundwater assessment. It is noted that standing water was not observed during the 2015 investigation. Hydraulic gradients were either neutral or slightly upward from the underlying strata into the areas of standing water, and were neutral to slightly downward in upgradient areas. These gradients indicate the potential for localized groundwater recharge into the upper silty sand soil in upland areas, and the potential for localized discharge in low-lying or poorly drained areas.

Given the site geology, particularly the thin overburden soils in the vicinity of Woodlot S20 as shown on Drawing PH2223-8, and the observed hydraulic gradients in the area, it is possible that discharge may be occurring on a localized basis in the vicinity of Woodlot S20. However, evidence of discharge to surface, such as seeps or localized standing water, were not observed during the 2015 investigation, and standing water observed during the 2014 investigation was interpreted to be the result of poor grading and drainage as opposed to direct evidence of groundwater discharge.

4.3.5 Hydraulic Conductivity

Based on the field hydraulic conductivity testing undertaken as part of this assessment, the hydraulic conductivity of the fractured bedrock unit is generally on the order of 2.0×10^{-7} to 1.4×10^{-6} m/s, with higher hydraulic conductivities observed at BH3, BH5, and BH5A, on the order of 2.1×10^{-5} to 7.4×10^{-5} m/s. These values are consistent with tabulated values from Freeze and Cherry (1979) and field values encountered at similar sites. Hydraulic conductivity values are summarized in Table A2, and individual hydraulic conductivity test results are appended to this report.

Monitoring wells were not screened in overburden soils. However, based on the observed overburden soil types and our experience with similar sites, the hydraulic conductivity of the silty clay and glacial till material are expected to be on the order of 10^{-8} to 10^{-11} m/s. The hydraulic conductivity of the silty sand material observed within Woodlot S20 is expected to be on the order of 10^{-4} to 10^{-7} m/s.

The hydraulic conductivity testing results suggest that the glacial till and silty clay act as a confining layer with respect to the fractured bedrock layer below and limit the potential for groundwater discharge/recharge between ground surface and the fractured bedrock layer. Based on the inferred higher hydraulic conductivity of the localized silty sand overlying the silty clay and glacial till, it is our opinion that localized groundwater discharge and recharge may be occurring on a localized basis within the silty sand layer.

4.3.6 Groundwater Recharge and Discharge

In general, groundwater will follow the path of least resistance from areas of higher hydraulic head to areas of lower hydraulic head. While upward and downward hydraulic gradients may be indicative of areas of discharge and recharge respectively, other factors must be considered.

Based on hydraulic conductivity testing undertaken in the bedrock unit, and hydraulic conductivity estimates based on grain size analysis of overburden soils, the bedrock unit is considered to have a higher hydraulic conductivity than the silty clay and glacial till overburden soils, which are generally considered to act as a confining layer. it is our interpretation that groundwater will generally flow laterally through the fractured bedrock aquifer units or through localized shallow silty sand deposits, as opposed to vertically upwards or downwards through the overburden soils of lower hydraulic conductivity.

Generally speaking, in areas where downward hydraulic gradients were observed (BH1/BH1A, BH4/ BH4A), the presence of overburden soils of lower hydraulic conductivity overlying the bedrock aquifer units are considered to limit the potential for significant groundwater recharge in these areas. In areas where upward hydraulic gradients were observed (BH2/BH2A, BH3/BH3A, BH5/BH4A), the presence of overburden soils of lower hydraulic conductivity overlying the bedrock aquifer units are considered to limit the potential for significant groundwater discharge in these areas.

Although discharge and recharge between overburden and bedrock units may be present, particularly in areas of thin overburden soil and upward gradients (i.e. vicinity of Woodlot S20), such areas are considered to be highly localized, due to the prevalence of the low-conductivity silty clay and glacial till layers throughout the subject site.

Furthermore, the presence of groundwater levels in the vicinity of BH1/BH1A and BH5/BH5A at elevations above ground surface supports the conclusion that overburden soils are acting as a confining layer above the bedrock aquifer units in these specific locations.

In general, ponded water at ground surface may be indicative of groundwater discharge. Water at ground surface has historically been observed within Woodlot S20. As per the conclusions of Paterson's previous sensitive groundwater assessment, no natural drainage outlets are present within Woodlot S20. Drainage channels are negatively graded in areas, allowing water to pond. It is noted that ponded water was not noted during the 2015 investigation.

Hydraulic gradients were neutral to upward in the vicinity of areas of ponded water, indicating the potential for groundwater discharge, and neutral to downward in upgradient areas, indicating the potential for groundwater recharge. In our opinion, groundwater recharge and discharge is occurring on a localized scale within the shallow silty sand soils.

In general, underlying silty clay soils and the limited extent of silty sand soils minimize any significant discharge or recharge from the underlying bedrock aquifer. However, in areas of thin overburden soil and upward hydraulic gradients, such as in the vicinity of Woodlot S20, localized discharge from the bedrock layer to overburden or surface is possible on a localized scale.

It is noted that the area in the vicinity of BH1/BH1A/TP19 where the silty sand layer extends to bedrock is highly localized and limited in lateral extent. As such, any groundwater discharge or recharge in this area is considered to be limited in scope and is not considered to be occurring on a significant scale.

Based on the foregoing, it is our conclusion that groundwater discharge from the bedrock aquifer units to ground surface, or groundwater recharge from ground surface to the bedrock aquifer units, are considered to be generally limited in the presence of overburden soil layers of lower hydraulic conductivity.

4.3.7 Preferential Flow Paths

The potential for large-scale preferential flow pathways was assessed as a part of this investigation. Although groundwater within the bedrock aquifer unit will flow through small-scale preferential fracture flowpaths within the bedrock matrix, water well records, and site-specific geological data and hydraulic conductivity testing did not identify any significant site-scale preferential flowpaths, such as karst features or formations of significantly higher permeability, within the bedrock in the vicinity of the subject site.

Based on hydraulic conductivity testing at the subject site and on the nature of the overburden soils, groundwater will generally preferentially flow through the more conductive upper fractured bedrock layer, as opposed to the silty clay and glacial till overburden, which are interpreted to act locally as a confining layer. The alluvial silty sand overburden soils observed on the eastern portion of the subject site are more permeable than the underlying silty clay and glacial till and may act as a preferential flowpath on a localized scale.

Based on the limited thickness of the silty sand layer, groundwater flow in this layer is considered to be predominantly lateral and largely influenced by topography. Infiltration of groundwater from the silty sand layer to the underlying bedrock is considered to be limited by evapotranspiration, localized discharge, and the presence of the underlying silty clay and glacial till layers, where present.

In general, agricultural tile drains are installed to provide lateral subdrainage of agricultural fields. The presence of tile drains was not confirmed on the subject site, although a potential tile drain outlet was observed in the vicinity of the Shirley's Brook tributary to the west of March Road, near BH4/BH4A.

Given that the subject site is to be developed with a high-density urban development, the site will no longer require subdrainage. It is recommended that tile drains be dewatered and capped on an as-encountered basis.

4.3.8 Impact of Proposed Development on Surrounding Wells

As a component of this investigation, a review of water well records in the vicinity of the subject site was conducted, using the Ministry of the Environment and Climate Change's online water well record search tool. Water well records in the vicinity of the site are appended to this report, and the locations of the water wells provided by MOECC's mapping tool are shown on Drawing PH2223-4R.

The Master Servicing Study has been completed for the subject site. Although specific details of site servicing are to be confirmed at the time of subdivision and detail design, the following servicing details are currently available:

- Servicing depths of approximately 2 to 8 m are estimated along March Road, generally shallower to the north and deeper to the south.
- Two (2) stormwater ponds are proposed for the site, both located to the west of March Road. It is expected that these stormwater pods will be excavated into rock, with the exact amount of rock excavation to be confirmed in the detail design phase.
- Services within the development lands are expected to be excavated to depths of up to 6 m into rock. Given the topography of the subject site, servicing depths will be deeper in the northwestern portion of the development lands. Depending on overburden thickness, services may not be required to be excavated into bedrock. Based on preliminary information, service trenches are expected to be located a minimum of 30 m from adjacent properties.

A preliminary estimate of the radius of influence of the dewatering of service trench excavations can be estimated by the following formula, provided by Bear (1979):

$$R(t) = 1.5\left[\frac{Tt}{S}\right]^{\frac{1}{2}}$$

Where *R* is the radius of influence at time *t*, and *T* and *S* are the transmissivity and storativity, respectively, of the aquifer unit being considered. Transmissivity is calculated by multiplying hydraulic conductivity (*K*) by saturated aquifer thickness (*b*). The Bear formula assumes predominantly horizontal flow in a confined aquifer. The Bear formula assumes porous media, such as unconsolidated soil, but is used here to approximate conditions in fractured rock, which may be modelled as equivalent porous media assuming a sufficiently large scale.

Typical storativity values for fractured rock of 5×10^{-4} to 5×10^{-5}, hydraulic conductivity values of 2.0×10^{-7} m/s to 7.4×10^{-5} m/s (based on site-specific testing), and pumping times between 5 and 30 days were used to estimate radius of influence. As a conservative measure, the bedrock unit was assumed to be completely saturated, and an overburden thickness of 0.3 m was assumed, corresponding to the shallowest overburden thickness observed on the subject site. Resulting aquifer thickness parameter *b* was therefore assumed to vary between 3.0 and 7.7 m. Based on the above assumptions, radius of influence values ranging from 35 to 8,000 m from the dewatering locations were estimated.

The above estimated values, taken alone, are not considered a reliable predictor of actual radius of influence of pumping activities at the subject site. For instance, while the equivalent porous media assumption may be valid on a larger or regional scale, it may not be valid for particular preferential fracture flowpaths on a site-specific scale. Also, the Bear formula predicts the distance at which zero drawdown will be observed. Minimal drawdowns may be experienced at much shorter distances from the dewatering point without having a significant effect on water quantity at surrounding wells. It is our assumption that neither best-case nor worst-case conditions are completely representative of the subject site.

Potential effects of the proposed development on surrounding wells are not limited to drawdown/water quantity effects, but may include water quality effects as well. Additional factors to be considered include the potential for the loosening of sediment within existing fractures or well casings, the opening of new fractures, the removal of overburden soils, and the expectations of the public. These factors cannot be readily quantified, and as such, conservative assumptions must be made in developing a proposed monitoring program to mitigate any potential adverse effects on surrounding wells.

Water well records in the vicinity of the study area were reviewed as a part of this assessment. It is noted that the majority of water well records in the area reported that water-bearing fractures were encountered at depths of 15 m or more, significantly below the deepest anticipated servicing depth of 8 m. As per Section 4.3.7 of this report, groundwater within the bedrock is interpreted to flow within preferential fracture flowpaths. In sedimentary rock, these fractures are interpreted to exist primarily along horizontal bedding planes. This is consistent with our review of rock core recovered during the 2015 investigation, although it is noted that vertical fractures may be present as well. Sediment infilling is considered to limit the potential for groundwater flow through vertical fractures in the upper bedrock layer. Wells completed at greater depths are therefore considered to be at less risk of impacts by construction dewatering activities due to the greater vertical separation between the dewatering zone and the zone(s) at which water was encountered in these wells. However, the proposed monitoring program described below is intended to address any potential impacts to these wells.

Bulk advective groundwater flow in the study area is considered to be primarily horizontal, based on the nature and orientation of fractures in the bedrock layer. As per Section 4.3.3 of this report, hydraulic gradients in the study area are interpreted to reflect site and regional topography, and groundwater flow is interpreted to be in an easterly to northeasterly direction towards the Ottawa River. Given the conservative assumptions stated above in the ROI calculations, and the vertical separation between proposed depth of services and water-bearing intervals utilized by surrounding water wells, the effect of bulk advective flow on potential impacts to surrounding wells are considered to be minimal.

In order to develop a baseline monitoring program, the above-noted factors were considered, along with considerations related to public perception and input from City of Ottawa staff. The baseline monitoring program will consist of the following:

- Wells within an area of approximately 250 m from the subject site boundary will be included in the baseline monitoring program. This area is shown on Drawing PH2223-4R, and will include the majority of lots within adjacent country estate lot subdivisions. This area may be expanded based on the results of the baseline monitoring program and/or sentry well monitoring.

- A visual inspection of the well will be completed. The details of the well (location, casing type, address, well tag number) will be verified with the published well record, if possible. Any discrepancies will be noted.

- Wells will be surveyed to a geodetic benchmark.

- The water level at the well will be recorded, using an electronic water level meter that has been properly cleaned and disinfected in accordance with industry best practices.

- A water sample will be obtained either directly from the well or from a suitable tap prior to any treatment process (disinfection, softening, etc.). The water sample will be submitted for analytical testing for the City of Ottawa "subdivision package" suite of parameters.

- Based on the results of the above-noted methodology, specific wells may be selected for installation of automatic water level logging devices. Level loggers will be installed in accordance with industry best practices. Wells selected for level logger installation will be determined in consultation with landowners and the City of Ottawa.

In addition to the monitoring program proposed above, it is proposed that baseline monitoring of on-site wells continue, for the purpose of observing seasonal fluctuations in water levels prior to construction. As an additional measure, and in consultation with City of Ottawa staff, it is recommended that sentry wells be installed near the boundaries of the subject site for the purpose of early detection of drawdown effects related to service trench dewatering on the subject site. Several locations for these proposed wells are shown on Drawing PH2223-4, and may be revised as the servicing plan for subdivisions within the development lands are finalized, with input from City staff and the public.

The installation of these sentry wells will be considered mandatory to the development, although their locations may be altered as necessary to provide optimal coverage. It is recommended that baseline water level monitoring data be obtained at these wells for a period of at least one (1) event prior to site development. It is recommended that sentry wells be completed at depths of 6-8 m as well as 10-15 m, to observe potential effects at the proposed maximum depth of services as well as at the depth at which the shallowest surrounding wells are completed.

In the event of impacts to surrounding wells by on-site construction activities, an alternative source of water will immediately be provided to the impacted properties by the proponents of the project. In the event of short-term impacts, tanked or bottled water may be provided, and in the event of long-term impacts which are confirmed to be a result of construction activities at the subject site, consideration will be given to deepening the pumps in affected wells where significant available drawdown is present, or potentially drilling a new well. In areas where affected wells are completed in the Oxford Formation, the underlying March-Nepean Formation represents a suitable aquifer in which to complete these wells.

4.3.9 Environmental Concerns

A review of the MOECC’s Brownfield Environmental Site Registry did not identify any environmental concerns in the immediate vicinity of the subject site. Based on observations of Paterson staff during field work, no potential environmental concerns were identified with respect to the subject site. No visual or olfactory evidence of contamination was observed in the soil, groundwater, or bedrock at the subject site.

Agricultural activities in the vicinity of the subject site were observed to consist primarily of cash crops (corn, soybeans, and grains). Given the nature of agricultural activities, the low to moderate intrinsic susceptibility of the aquifers in the vicinity of the subject site, and the silty clay/glacial till confining layer present over much of the site, agricultural practices are considered to have a low potential to impact groundwater quality at the subject site.

5.0 ASSESSMENT AND RECOMMENDATIONS

Existing Wells

Existing water supply wells in the vicinity of the subject site are completed at significant depths within the March/Nepean and Oxford Formation bedrock aquifers. The majority of these wells were reported as encountering water-bearing zones significantly below the proposed servicing depths at the subject site. As such, these wells are considered to have a relatively low potential to be impacted by construction dewatering activities at the subject site. No environmental concerns were identified with respect to the existing water supply wells.

It is our understanding that the proposed development of the subject site will be serviced by municipally supplied water. The assessment of the suitability of groundwater resources for the proposed development of the subject site was not considered.

If the proposed development necessitates the redevelopment of existing residential properties, decommissioning of existing on-site water wells may be required. These wells should be decommissioned by licensed water well contractors as per Ontario Regulation 903 (Wells) under the Ontario Water Resources Act. Without proper decommissioning, wells may act as downward conduits for the migration of contaminants. Additionally, the potential for artesian conditions (elevation of piezometric surface above upper confining layer elevation) has been identified at the subject site, and well decommissioning by a licensed contractor will ensure any artesian conditions are properly addressed, if encountered.

At the time of detailed engineering design of the proposed development of the subject site, specific hydrogeological studies may be required to address any specific engineering challenges associated with selected designs. However, as a due diligence measure, prior to the earlier of subdivision registration or the commencement of site excavation works, it is recommended that a baseline monitoring program be completed at selected existing water wells in the vicinity of the subject site. The baseline monitoring program, outlined in preceding sections, will be completed at all wells within 250 m of the subject site, and may be expanded on an as-required basis. The following program is proposed:

- Wells within an area of approximately 250 m from the subject site boundary will be included in the baseline monitoring program. This area is shown on Drawing PH2223-4R, and will include the majority of lots within adjacent country estate lot subdivisions. This area may be expanded based on the results of the baseline monitoring program and/or sentry well monitoring.
- A visual inspection of the well will be completed. The details of the well (location, casing type, address, well tag number) will be verified with the published well record, if possible. Any discrepancies will be noted.
- Wells will be surveyed to a geodetic benchmark.
- The water level at the well will be recorded, using an electronic water level meter that has been properly cleaned and disinfected in accordance with industry best practices.
- A water sample will be obtained either directly from the well or from a suitable tap prior to any treatment process (disinfection, softening, etc.). The water sample will be submitted for analytical testing for the City of Ottawa "subdivision package" suite of parameters.
- Based on the results of the above-noted methodology, specific wells may be selected for installation of automatic water level logging devices. Level loggers will be installed in accordance with industry best practices. Wells selected for level logger installation will be determined in consultation with landowners and the City of Ottawa.

In addition to the monitoring program proposed above, it is proposed that baseline monitoring of on-site wells continue, for the purpose of observing seasonal fluctuations in water levels prior to construction. As an additional measure, and in consultation with City of Ottawa staff, it is recommended that sentry wells be installed near the boundaries of the subject site for the purpose of early detection of drawdown effects related to service trench dewatering on the subject site. Several locations for these proposed wells are shown on Drawing PH2223-4, and may be revised as the servicing plan for subdivisions within the development lands are finalized, with input from City staff and the public.

The installation of these sentry wells will be considered mandatory to the development, although their locations may be altered as necessary to provide optimal coverage. It is recommended that baseline water level monitoring data be obtained at these wells for a period of at least one (1) event prior to site development. It is recommended that sentry wells be completed at depths of 6-8 m as well as 10-15 m, in order to observe potential effects at the proposed maximum depth of services as well as at the depth at which the shallowest surrounding wells are completed.

In the event of impacts to surrounding wells by on-site construction activities, an alternative source of water will immediately be provided to the impacted properties by the proponents of the project. In the event of short-term impacts, tanked or bottled water may be provided, and in the event of long-term impacts which are confirmed to be a result of construction activities at the subject site, consideration will be given to deepening the pumps in affected wells where significant available drawdown is present, or potentially drilling a new well. In areas where affected wells are completed in the Oxford Formation, the underlying March-Nepean Formation represents a suitable aquifer in which to complete these wells.

Existing Private Sewage Systems

It is recommended that existing private sewage systems within the subject site be properly decommissioned by a qualified contractor prior to the redevelopment of the subject site. Based on our field observations, the locations of existing sewage systems to be decommissioned are shown on Drawing PH2223-4, appended to this report. Any additional private sewage systems encountered will also be properly decommissioned.

Existing Tile Drains

The presence of tile drains was not confirmed on the subject site, although a potential tile drain outlet was observed in the vicinity of the Shirley's Brook tributary to the west of March Road, near BH4/BH4A.

Given that the subject site is to be developed with a high-density urban development, the site will no longer require subdrainage. It is recommended that tile drains be removed and/or capped on an as-encountered basis.

Sources of Contamination

No concerns were identified with respect to actual or potential sources of contamination at the time of the completion of this study.

Prior to and during site development, it is recommended that construction best practices with respect to fuels and chemical handling, spill prevention, and erosion and sediment control be followed, to minimize the potential for the introduction of contaminants to the soil, surface water, or groundwater at the subject site.

Blasting

In general, bedrock removal by means of blasting within the shallow bedrock at a site has limited potential to impact the water quantity and quality in neighbouring water wells, which are generally completed at depths significantly below underground service trenches. In the event that neighbouring wells are adversely impacted by blasting, an alternative source of water is required to be provided, as per the Ontario Water Resources Act. Best management practices for blasting are to be followed at all times.

It is understood that the baseline monitoring program proposed in above sections will be completed prior to any blasting activities at the subject site, and will provide water quantity and quality data which may be compared to conditions observed during blasting if problems are reported.

As a general guideline, peak particle velocities (measured at the property boundary) should not exceed 25 mm per second at frequencies above 40 hertz during the blasting program to reduce the risk of damage or impacts to surrounding wells or structures. The blasting operations should be planned and conducted under the supervision of a licensed professional engineer who is also an experienced blasting consultant.

Services

It is our understanding that the subject site is to be developed with municipal sewer and water services. Although specific details of site servicing are to be confirmed at the time of subdivision and detail design, the following servicing details are currently available:

- Servicing depths of approximately 2 to 8 m are estimated along March Road, generally shallower to the north and deeper to the south.

- Two (2) stormwater ponds are proposed for the site, both located to the west of March Road. It is expected that these stormwater pods will be excavated into rock, with the exact amount of rock excavation to be confirmed in the detail design phase.

- Services within the development lands are expected to be excavated to depths of up to 6 m into rock. Given the topography of the subject site, servicing depths will be deeper in the northwestern portion of the development lands. Depending on overburden thickness, services may not be required to be excavated into bedrock. Based on preliminary information, service trenches are expected to be located a minimum of 30 m from adjacent properties.

Servicing details will be confirmed at the detail design phase. However, consideration will be given to minimizing the amount of rock excavation required. Further information on proposed servicing alignments and depths can be found in the Master Servicing Study, provided under separate cover.

Service trenches may act as preferential pathways for groundwater flow, particularly where granular backfill has been used, and may contribute to lowering of groundwater in the surrounding soils or bedrock. It is recommended that packed clay dikes be constructed at regular intervals within service trenches to mitigate long-term dewatering effects.

Stormwater Pond Construction

As a component of the development of the subject site, two (2) stormwater management ponds are to be constructed. Based on preliminary information reviewed as a part of this assessment, the stormwater management ponds will be excavated into bedrock. Although further details on stormwater management pond construction will be provided at the detail design phase, it is recommended that the stormwater management ponds be constructed with a constructed/ packed clay liner or a manufactured geosynthetic clay liner.

Further information on proposed servicing alignments and depths can be found in the Master Servicing Study, completed by Novatech.

Groundwater Control in Excavations

For any water taking of greater than 50,000 L/day, a Permit To Take Water (PTTW) or registration of the water taking activity on the Environmental Activity and Sector Registry (EASR) is required from the MOECC. In general, EASR registration is required for construction dewatering where less than 400,000 L per day are to be pumped under normal conditions. Additional takings require PTTW registration. Passive diversion of a water course, active diversion of a water course with discharge control measures in place, or wetlands rehabilitation are exempted from PTTW or EASR registration.

The requirement for a PTTW or EASR at the subject site will be determined during the detail design phase. The information contained in this report may be used as supporting documentation for a PTTW or EASR application for the subject site. Depending on the nature of the proposed water taking, additional hydrogeological investigation may be required.

Construction best practices should be employed when dewatering excavations at the subject site, including erosion and sedimentation control measures and discharge quality control.

Areas of Recharge Potential

Based on geological and hydrogeological conditions at the subject site, as discussed in previous sections, the potential for significant groundwater recharge through overburden soils to the underlying bedrock aquifer is considered to be limited over much of the subject site. The majority of recharge to bedrock aquifers is interpreted to occur in areas upgradient of the subject site where bedrock is present at ground surface. In areas with alluvial silty sand soil, recharge and discharge are interpreted to occur on a localized scale, influenced by topography. Given observed hydraulic gradients, groundwater discharge and recharge between the silty sand soil and the bedrock aquifer are expected to be limited.

Surface Water Crossings

At several locations at the subject site, the preliminary servicing information indicates that service trench alignments are to cross underneath existing watercourses. It is our understanding that these watercourses are ephemeral, and consideration will be given to constructing these crossings when the watercourses are dry. Additionally, consideration should be given to the construction of clay liners over the service trenches and underneath the culvert crossings associated with the surface water bodies.

6.0 CLOSURE

The client should be aware that any information pertaining to soils and all test hole logs are furnished as a matter of general information only, and test hole descriptions or logs are not to be interpreted as descriptive of conditions at locations other than those of the test holes.

This report has been prepared for Novatech on behalf of the Kanata North Landowners' Group and in support of the Kanata North Community Design Plan. It is hereby acknowledged that Metcalfe Realty Company Ltd., J.G. Rivard Ltd., 8409706 Canada Inc. (Valecraft Homes), 3223701 Canada Inc., and 7089121 Canada Inc. (Junic/Multivesco) may rely upon and utilize this report for the purpose of obtaining approval of the community design plan and for their own use to seek development approval.

It is further acknowledged that future confirmed participating landowners within the Kanata North Landowners' Group may rely upon and utilize this report for the purpose of obtaining approval of the Community Design Plan and for their own use to seek development approval.

Paterson Group Inc.

Daniel J. Arnott, P.Eng.

Carlos P. Da Silva. P.Eng.

Report Distribution:

- Novatech
- Paterson Group Inc.

7.0 REFERENCES

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Paterson Sensitive Groundwater Study, 2014

Appendix O

Kanata North Urban Expansion Area
Fluvial Geomorphic Assessment

(Parish Aquatic Services – March 2016)

PARISH
aquatic services
A Division of Matrix Solutions Inc.

KANATA NORTH URBAN EXPANSION AREA
FLUVIAL GEOMORPHIC ASSESSMENT

Report Prepared for:
NOVATECH ENGINEERING CONSULTANTS LTD.

Prepared by:
PARISH AQUATIC SERVICES
a Division of Matrix Solutions Inc.

March 2016
Perth, Ontario

15A Foster St.
Perth, ON, Canada K7H 1R5
P 613.686.5492
www.parishgeomorphic.com

KANATA NORTH URBAN EXPANSION AREA

FLUVIAL GEOMORPHIC ASSESSMENT

Report prepared for Novatech Engineering Consultants Ltd., March 2016

Matthew McCombs, M.A.Sc., E.I.T.
Water Resources EIT

reviewed by
John Parish, P.Geo.
Principal Geomorphologist

Mark Wojda, M.ScE., E.I.T.
Water Resources EIT

DISCLAIMER

We certify that his report is accurate and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but not guaranteed. We have exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

RELIANCE CLAUSE

This report has been prepared for Novatech Engineering Consultants Ltd., on behalf of the Kanata North Landowner's Group and in support of the Kanata North Community Design Plan. It is hereby acknowledged that Metcalfe Realty Company Limited, J.G. Richards Ltd., and 8409706 Canada Inc. (Valecraft Homes), 3223701 Canada Inc. (Junic/Multivesco) can rely upon this report for the purposes of obtaining approval of the community design plan and for their own use to seek development approval.

Any use of this report by other parties, or any reliance on decisions made based on it, are the responsibility of that party. We are not responsible for damages or injuries incurred by any other party, as a result of decisions made or actions taken based on this report.

EXECUTIVE SUMMARY

A community design plan is being undertaken for the Kanata North Urban Expansion Area in eastern Ontario. PARISH Aquatic Services, a Division of Matrix Solutions Inc., was retained to provide geomorphic expertise throughout the study site. The assessment provided includes a review of historical findings, field observations of channel process, meander belt widths, erosion thresholds, and crossing assessments at reaches through the development area and surrounding lands. Recommendations are provided for use during various stages of planning and design.

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1.1 Study Outline

A community design plan is being undertaken for the Kanata North Urban Expansion Area (KNUEA) in eastern Ontario. In support of this study, PARISH Aquatic Services, A Division of Matrix Solutions Inc. (PARISH; formerly PARISH Geomorphic Ltd.) has been retained to provide a geomorphic assessment involving the complete characterization of watercourses within the study area. To achieve this objective, the following work plan was undertaken:

- collecting and reviewing pertinent background information, including reports, mapping, and aerial photography
- using available mapping to confirm channel reach boundaries
- completing, where possible, channel migration analysis to determine 100-year erosion rates
- delineating the meander belt width on a reach basis based on mapping and aerial photographs
- completing field reconnaissance to confirm existing geomorphic conditions, documenting any evidence of active erosion, and confirming appropriateness of the desktop results
- determining erosion threshold values of sensitive reaches and reaches downstream of proposed stormwater management ponds (SWMP)
- providing observations and geomorphic recommendations for crossing structures of concern

1.2 Study Area

The development boundary is located in the community of Kanata in Ottawa, Ontario (**Figure 1**). The watercourses investigated in the current study area include a portion of the main branch of Shirley's Brook and three of its tributaries. The tributaries are numbered Tributary 1, furthest north, to Tributary 3, furthest south, from Project North. For the purposes of this report, March Valley Road, March Road, and the Canadian National Railway run north-south. Tributaries 2 and 3 flow east, through the study area to the confluence with the main branch of Shirley's Brook between March Road and Maxwell Bridge Road. Tributary 1 is north of the study area and flows east toward its confluence with the main branch of Shirley's Brook at March Valley Road. Shirley's Brook flows to its outlet at Shirley's Bay on the Ottawa River. The surrounding area contains a mixture of developed area that includes residential subdivisions and farmland/open fields. The development area itself is mostly composed of agricultural lands and open fields. The study area extends to reaches downstream of those contained within in the development area. These reaches were also analyzed to gain a complete understanding of geomorphic processes occurring through Shirley's Brook and its tributaries.

FIGURE 1 Location of Development Area

2 BACKGROUND REVIEW

2.1 Previous Reports

A number of reports relevant to the current study have been completed to-date. These reports include:

- "Shirley's Brook and Watts Creek Subwatershed Study" (Dillon 1999): PARISH Geomorphic Ltd. completed the fluvial geomorphology analysis component of this report. Watercourses within the Shirley's Brook subwatershed were adjusting to changes in hydrologic regime and sediment load as a result of modifications within the subwatershed, such as changes in land use. Various human activities modified the channel planform, and interfered with water balance and sediment transport processes. Overall, in the Shirley's Brook drainage network, the bed morphology of various reaches was nonexistent, poorly defined, or dominated by pools and glides. The substrate material was dominated by silts and clays. However, in undeveloped areas along Shirley's Brook, the bed morphology had a balanced pool-glide-riffle complex coincident with coarser bed materials. Many reaches within Shirley's Brook were entrenched. A lack of riparian vegetation in parkland and developed areas and agricultural activity close to the channel boundaries contributed to the destabilization of channel banks. Most of the sediment load originated within the river corridor, while a smaller portion was derived from the surrounding floodplain during precipitation events. The report included meander belt widths for watercourses within the Shirley's Brook watershed, and these results will be compared to those developed in the current study.

- “Greater Shirley’s Brook - Constance Creek Environmental Management Study” (Aquafor Beech and Brunton 2006): The purpose of the study was to develop an environmental management plan for the area, including recommendations to ensure the protection of the stream and valley corridors. As part of the study, detailed reach level data were collected on Shirley’s Brook and its tributaries. Each of the watercourse reaches (Dillon 1999) was revisited, and observations were consistent with the 1999 data. Stream corridor (belt) widths ranging from 25 to 55 m were recommended, and are compared to the recent PARISH results in the current report.

- “Shelley’s Brook and Kizell Drain/Watts Creek, Fluvial Geomorphology Draft Existing Conditions Report” (JTBES 2013): The area investigated contained a segment of the main branch of Shirley’s Brook, which was also assessed for the current report. JTB Environmental Systems Inc. (JTBES) completed creek walks and measured channel parameters in areas of concern, assessed channel stability, and determined preliminary erosion thresholds. Shirley’s Brook was responding to changes in the flow and sediment regimes resulting from land use change and development. The results of this investigation are compared to the findings of the most recent field work completed by PARISH in the current report.

2.1.1 Geology

A review of surficial geology mapping within the study area revealed primarily older alluvial deposits (clay, silt, sand, gravel) and fine-textured glacio-marine deposits (silt and clay, minor sand and gravel), with some stone: poor, sandy silt to silty-sand textured till and Paleozoic bedrock (OGS 2010).

Paterson Group Inc. completed a hydrogeological assessment of the study site, which identified the presence of bedrock just beneath the topsoil and glacio-fluvial soil veneer in the southwest quadrant of the subject area and within Tributary 1 and the North Branch of Shirley’s Brook. The bedrock was generally flat-lying and primarily consisted of interbedded sandstone and limestone (Paterson 2015).

In much of the Shirley’s Brook drainage network, the bed morphology is poorly defined, and the substrate material is dominated by silt and clay. In locations throughout the site, exposed bedrock was observed on channel bottoms. In undeveloped areas along Shirley’s Brook, the bed morphology tends to have a balanced pool-glide-riffle complex coincident with coarser bed materials. Many of the channels that constitute the Shirley’s Brook drainage network have been altered.

The cohesive sediments (silt and clay) that constitute the bed material in much of Shirley’s Brook respond differently than alluvial deposits when subjected to the same erosive forces, and typically do not erode as readily as small-diameter, non-cohesive materials. For this reason, some of the energy available to erode the channel bed will be diverted against the channel banks, enhancing the erosion potential. Bank materials tend to be fine-grained silt and sand mixed with clay, and are susceptible to erosion (Dillon 1999). Much of the sediment that is transported by Shirley’s Brook originates from within the river corridor.

2.1.2 Historical Assessment

A review of past conditions is typically carried out to document changes in land use and channel form over time. Digital ortho-imagery from 1971 was compared to more recent images from 1991 and 2008. Land use in the study area and surrounding land was agricultural and open fields in 1971, and included some remnant forest. The 1991 and 2008 photographs reveal that land use within the study area has not changed substantially; however, residential development in the surrounding land has increased in the more recent photographs. The three photos are provided on **Figure 2** for comparison.

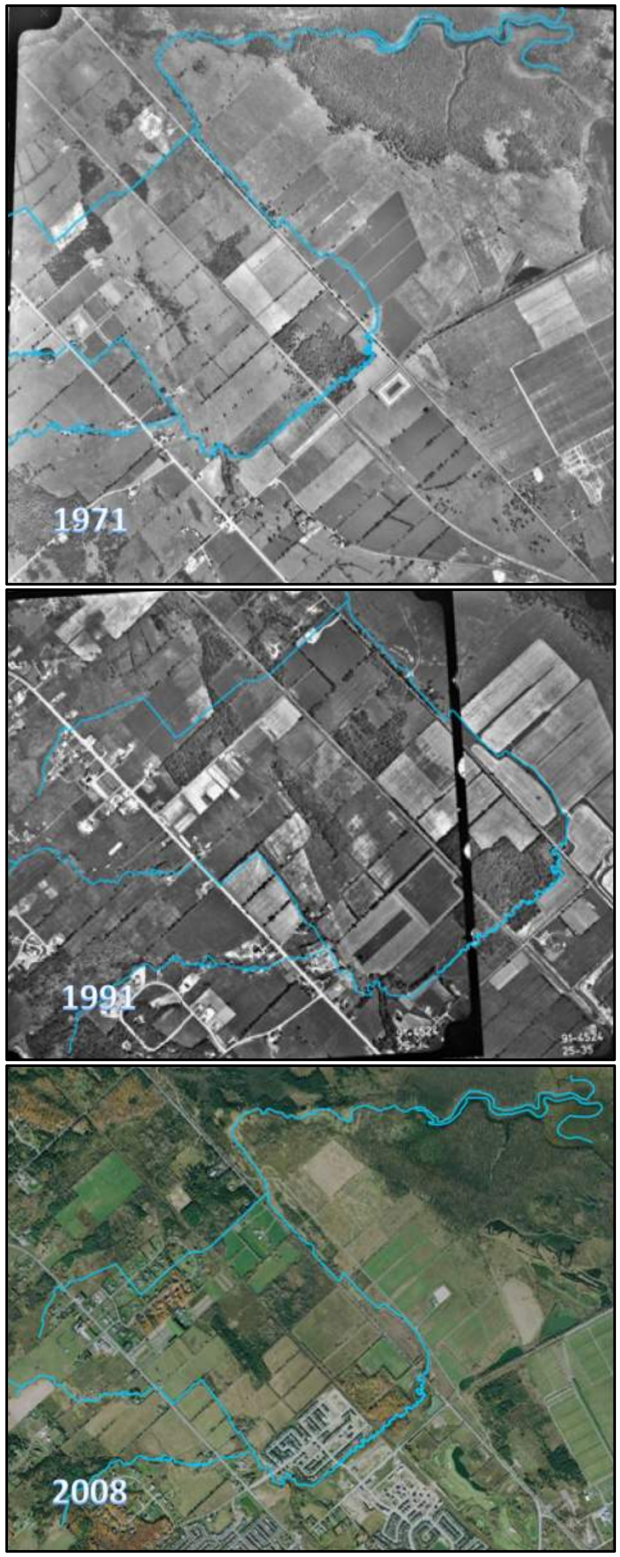

FIGURE 2 Historical Land Use

3 REACH DELINEATION

Reaches are lengths of channel that display similar valley setting, channel planform, floodplain materials, and land use/cover. Reach length will vary with channel scale since the morphology of low-order watercourses will vary over a smaller distance than those of higher order. At the reach scale, characteristics of the stream corridor exert a direct influence on channel form, function, and process. To characterize the geomorphological form and function of watercourses in the KNUEA, the channels are first partitioned into reaches.

3.1 Shirley's Brook and Tributaries

Study reaches were identified using available aerial photography and watercourse planform. Final reach delineations were adjusted during the field investigation. **Table 1** summarizes the length and sinuosity of each of the reaches, while **Figure 3** displays the location of reach breaks. Those labelled SBT (SBT-1 to SBT-7B) correspond to tributary reaches of Shirley's Brook, while the reaches along the main branch of Shirley's Brook, downstream of the confluence of Tributary 3, are labelled SB (SB-1A to SB-5). The main branch of Shirley's Brook extends further upstream to the south; however, this portion of the watercourse will not be investigated as part of this study.

TABLE 1 Reach Summary

Reach	Length (m)	Sinuosity
Shirley's Brook		
SB-1A	485	1.21
SB-1B	396	1.14
SB-2A	290	1.97
SB-2B	513	1.32
SB-3	1,883	1.10
SB-4	1,949	1.18
SB-5	1,674	1.28
Tributaries		
SBT-1A	841	1.00
SBT-1B	771	1.02
SBT-2	522	1.01
SBT-3	1,125	1.13
SBT-4	1,026	1.02
SBT-5	1,457	1.1
SBT-6	247	1.1
SBT-7A	295	1.39
SBT-7B	241	1.11

The planform of Shirley's Brook and its tributaries on **Figure 3** indicates that certain segments have been straightened. While these alterations must be considered, the straightened segments are part of an overall natural stream course. This characteristic differentiates them from the drainage features highlighted in **Section 3.2**. Tributary 1 (consisting of reaches SBT-1A, SBT-1B, and SBT-2) is almost entirely channelized; however, due to the scale of the channel, it is considered here as a watercourse.

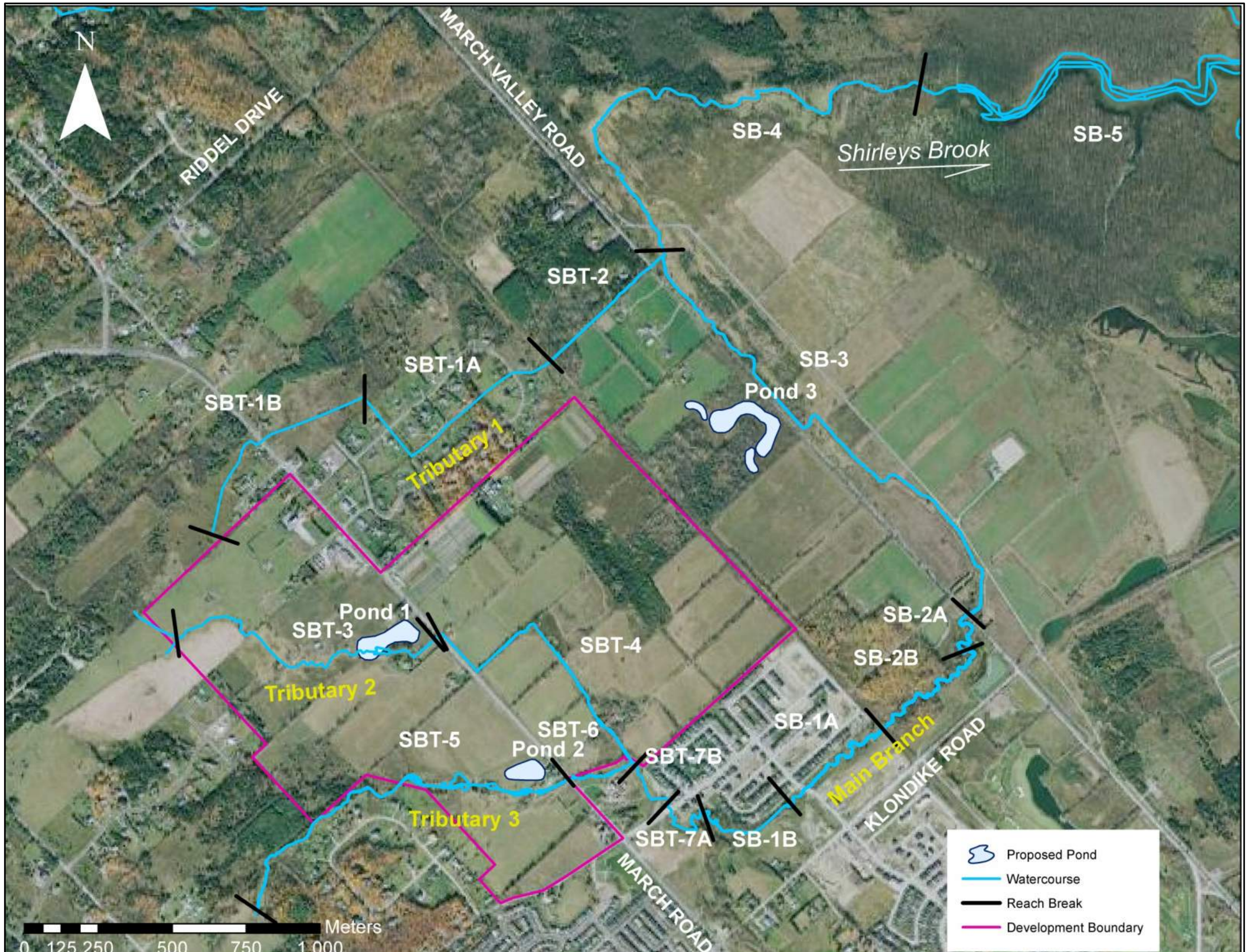

FIGURE 3 Delineated Reaches of Watercourses within the Greater Study Area

4 FIELD RECONNAISSANCE - EXISTING CONDITIONS

To provide insight into existing geomorphic conditions and to document any evidence of active erosion, the site was visited from April 23 to 25, and June 12 to 13, 2013. During the visit, channel conditions along the study reaches were evaluated using two established synoptic surveys: the Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT). A photographic record of existing conditions taken during the site investigation is provided in **Appendix A**. RGA and RSAT field sheets are provided in **Appendix B**.

4.1 Rapid Geomorphic Assessment

The RGA was designed by the Ontario Ministry of Environment (MOE 2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planimetric adjustment. Examples of these include the presence of bar forms, exposed infrastructure, head cutting due to knickpoint migration, fallen or leaning trees and exposed tree roots, channel scour along the bank toe, transition of the channel from single thread to multiple thread, and cut-off channels. Overall, the index produces values that indicate whether the channel is stable/in regime (score ≤0.20), stressed/transitional (score 0.21 to 0.40), or adjusting (score >0.41). **Table 2** provides an explanation of the various classifications.

TABLE 2 Rapid Geomorphic Assessment Classification

Factor Value	Classification	Interpretation
≤0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics - evidence of instability is isolated or associated with normal river meander propagation processes.
0.21-0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent.
≥0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance, and evidence of instability is widespread.

4.2 Rapid Stream Assessment Technique

The RSAT (COG 1996) provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories: channel stability, erosion and deposition, instream habitat, water quality, riparian conditions, and biological indicators. Scores can be divided into three classes: low (<20), moderate (20 to 35), and high (>35).

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions: pools provide resting areas, while riffles provide feeding areas and contribute oxygen to the water; good riparian conditions provide shade and food; woody debris and overhanging banks provide shade). Additionally, the RSAT approach includes semi-quantitative measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

4.3 Rapid Assessment Results - Shirley's Brook

The main branch of Shirley's Brook was investigated from its confluence with Tributary 3 downstream to March Valley Road (SB-1A, 1B, 2A, 2B). The watercourse is generally inaccessible after it crosses under this roadway through a culvert as it runs through Department of National Defence (DND) lands. SB-4 and SB-5 were not accessed as part of the initial field investigation; however, a short segment of SB-3 that runs adjacent to March Valley Road outside of DND lands, and the upstream extent of SB-4 were documented as part of the detailed surveys outlined in **Section 6**. The RGA scores for the main branch of Shirley's Brook in the study area are summarized in **Table 3**. SB-4 was only assessed at the very upstream limit of the reach, and the observations may not be representative over the entire reach.

The downstream extent of **SB-1A** is located at the upstream end of the culvert, and overall, the reach is of low to moderate gradient and of high sinuosity. The reach received an RGA score of 0.28, indicating that the reach is in a transitional state. The primary form of adjustment was widening with major bank erosion/slumping occurring at outside meanders, and some bank slumping occurring mid-reach. The reach received an RSAT score of 25, indicating moderate ecological health. The bankfull width of the reach was approximately 6 to 7 m, and the bankfull depth was approximately 1.6 m. There is residential housing along the top of bank on both sides of the channel, and riparian vegetation consists primarily of grass with some deciduous trees present. Part of the channel in this reach may have been modified slightly near the Marconi Avenue crossing, as the stream passes through an 8 m wide arch corrugated steel pipe (CSP) under the roadway. A riffle-type feature is located immediately downstream of the crossing and appears to have been constructed. Approximately 120 m upstream of the road crossing, another constructed riffle is present and represents the upstream limit of the reach. There is an overland drainage ditch-type feature entering the channel on the left bank at the riffle, and the outlet has been lined with angular riprap.

The reach break indicating the transition to **SB-1B** is immediately upstream of the outlet and riffle feature, and the channel from this point upstream has continuous tree cover from a mixed forest/woodlot. SB-1B received an RGA score of 0.39, indicating that the reach is in a high-transitional state. Steep banks and valley wall contact were observed, and widening and degradation were the primary adjustment processes noted. Some protective riprap has been placed at sections along the right bank. The reach received an RSAT score of 23, indicating moderate ecological health. The bankfull width of the reach was approximately 7 m, and the bankfull depth was approximately 2 m. The upstream reach break is the confluence of Tributary 3 and SBT-7A.

SB-2A is a short reach of moderate gradient immediately upstream of March Valley Road. SB-2A received an RGA score of 0.30, indicating that the stream is transitional. There was major bank erosion along bends, and it is a very sinuous reach. The main process is widening, as evidenced by fallen trees, organic debris, steep bank angles, and length of basal scour exceeding 50% of the reach. The reach received an RSAT score of 27, indicating moderate ecological health. The bankfull width of the reach was approximately 6 to 7 m, and the bankfull depth was approximately 1.5 m. At the upstream extent of SB-2A is a confluence with a constructed stormwater basin, as well as a beaver dam/woody debris jam. These features mark the reach break to SB-2B.

SB-2B is another very sinuous reach of low to moderate gradient. Again, there is significant bank erosion along the entire reach, particularly at the outside of meanders, and there are a number of debris jams. SB-2B received an RGA score of 0.40, indicating that the channel is high-transitional/in adjustment. The primary form of adjustment was widening with steep bank angles observed throughout the reach and the occurrence of major debris jams. The reach received an RSAT score of 24, indicating moderate ecological health. The bankfull width of the reach was approximately 5 to 7 m, and the bankfull depth was approximately 1.5 m. The upstream extent of the reach is a rail crossing in which the stream runs through a closed-bottom double concrete box culvert.

SB-4 shows significant and long-term beaver activity, with deposits of organics and silty material in pools in the order of 1.5 m deep in a stiff clay bed. An existing beaver dam under the Perimeter Road bridge has created a backwater effect through this whole area. Undercutting is clearly present along the portion of the reach that was assessed, with channel widening occurring where the clay pavement prevents further downward erosion.

TABLE 3 Shirley's Brook Rapid Assessment Scoring Summary

Reach	Aggradation	Degradation	Widening	Planimetric Adjustment	RGA Stability Index	RGA Condition	RSAT Score
SB-1A	0.22	0.29	0.63	0	0.28	Transitional	25
SB-1B	0.22	0.57	0.63	0.14	0.39	Transitional	23
SB-2A	0.44	0.14	0.63	0	0.30	Transitional	27
SB-2B	0.43	0.14	0.88	0.14	0.40	Transitional	24

Notes:
RGA – Rapid Geomorphic Assessment
RSAT - Rapid Stream Assessment Technique

For comparison purposes, the results of the 2013 draft fluvial geomorphology existing conditions report (JTBES 2013) were reviewed. JTBES performed a detailed investigation at a site within SB-2A (JTBES reach SBDR-1), which resulted in an RGA score of 0.41, indicating that the reach was adjusting. The RSAT investigation resulted in a score of 22, which indicated a fair condition. JTBES reach SBDR-2 is located within PARISH reach SB-1A. For this site, JTBES determined an RGA score of 0.34 (adjusting) and an RSAT score of 18 (low). For both locations, the JTBES report indicated a more degraded watercourse than the current report. This can be attributed to differences in how watercourses were analyzed. For detailed analysis (including rapid assessments), the JTBES investigation targeted short lengths of stream (sites) that were known to be unstable, while the current investigation scored entire reaches. This is important, as localized forms of adjustment are not necessarily representative of the reach as a whole.

4.4 Rapid Assessment Results - Tributary Channels

The tributaries to Shirley's Brook showed wide variations in channel form. Bankfull widths ranged from 2 to 5 m, and average bankfull depths ranged from 0.4 to 0.9 m. **Table 4** summarizes the RGA scores for the tributaries to Shirley's Brook contained within the study area.

SBT-1A (Tributary 1) runs through existing residential development and did not receive an RGA score because it is a channelized drainage ditch with few natural channel features present. Approximately 40 m upstream of Houston Crescent are two human-created grade control structures consisting of large stone. There are tall grasses, small shrubs, and bulrushes present in the highly vegetated channel. Upstream, the channel runs through another small culvert at Houston Crescent. Due to the stable channelized nature of the channel, bankfull dimensions were difficult to identify; however, the bankfull width appeared to be approximately 3 to 4 m, and the bankfull depth was approximately 0.5 m. The upstream extent of SBT-1A is located at the edge of the manicured backyard lawns of the residential properties along the roadway. SBT-1A received an RSAT score of 23, indicating the reach is of moderate ecological health.

SBT-1B (Tributary 1) upstream of March Road is a vegetated drainage ditch, with water barely visible during the field investigation. The stream passes under March Road through a 1.8 m wide box concrete culvert. Downstream of March Road, the reach is a drainage ditch with little sinuosity. The reach received an RGA score of 0.23, indicating that the channel is transitional. There is significant downcutting occurring in this section of the reach, and the channel bed is composed entirely of exposed bedrock, with a number of small knickpoints present. The high degree of gullying has resulted in very steep banks that have eroded and failed. The bankfull width was approximately 3.5 m, while the bankfull depth was approximately 0.5 m. SBT-1B received an RSAT score of 18, indicating the reach is of low ecological health.

SBT-2 (Tributary 1) is a reach extending between a 0.9 m CSP running beneath the railway tracks and a 1.05 m wide arch steel culvert at March Valley Road. Although the planform appears straightened, there is significant erosion occurring throughout the reach, and the channel has a high level of sinuosity within its confined valley setting. It received a high-transitional/in adjustment RGA score of 0.39, with strong evidence of widening and degradation observed. Indicators included fallen/leaning trees, exposed tree roots, basal scour, steep bank angles, and incision into bedrock. Bank undercutting, slumping, and knickpoints are strong indicators that the channel is actively adjusting. The bankfull width, while difficult to identify due to the gullying occurring through most of the reach, was from 3 to 4 m, and the bankfull depths were from 0.75 to 1.5 m. SBT-2 received an RSAT score of 21, indicating the reach is of moderate ecological health.

SBT-3 (Tributary 2) received an RGA score of 0.20, indicating that the reach is in regime. Outside of the upstream and downstream ends of the reach, the channel was sinuous and had a bankfull width of 2.5 to 3 m and a bankfull depth of 0.5 m. At the upstream end, however, the watercourse is un-concentrated with overland flow, while the downstream end the channel is backwatered into a woodlot. The reach is unconfined throughout most of its length. The banks are well vegetated with grass, and the substrate is bedrock. The upstream extent of the reach consists of the confluences of two smaller channels contributing to SBT-3. At the downstream end, the watercourse passes through a 0.9 m CSP then under March Road through a 1.85 m wide box concrete culvert. SBT-3 received an RSAT score of 27, indicating the reach is of moderate ecological health.

SBT-4 (Tributary 2) received an RGA score of 0.41, indicating that the channel is in adjustment. Based on the planform, the stream appears very straightened/channelized; however, there are a number of geomorphic adjustment processes occurring in this reach. Indicators of degradation include channel incision into bedrock, elevated tree roots, and head cutting. Evidence of widening includes fallen trees, large organic debris, and basal scour on the inside of meander bends. The bankfull widths ranged from 3 to 5 m, while the bankfull depths were generally around 0.85 m. The high RGA score may be partially attributed to a high level of beaver activity in the reach (e.g., sinuosity due to the development of new channel paths around the dams, the formation of pools, etc.) The upstream extent of SB-4 is a concrete culvert at March Road. SBT-4 received an RSAT score of 26, indicating the reach is of moderate ecological health. A relatively large ditch drains farmland runoff to SBT-4 mid-reach, at the 90° bend in the channel.

The downstream extent of **SBT-5** (Tributary 3) is the culvert at March Road. This reach received an RGA score of 0.30, indicating a transitional condition. This reach can be considered atypical, as there are a number of online ponds, the largest of which is approximately 40 m wide, and backwatering due to flow obstructions. In addition, large sections of the reach contained un-concentrated sheet flow over bedrock, which covered a large wetted footprint (widths of approximately 25 m) at the time of survey. In sections where the flow was relatively confined to a single channel, the bankfull width was approximately 4 m, while the bankfull depth was approximately 0.4 m. SBT-5 received an RSAT score of 22, indicating the reach is of moderate ecological health. The large obstructions in this reach are human-created and include a concrete weir and a degraded concrete wall (photographs contained in **Appendix A**).

SBT-6 (Tributary 3) is another short reach, and it was not given an RGA score, as it is very much a channelized drainage ditch with few geomorphological features and little sinuosity. The bankfull width of the reach was approximately 2 to 3 m, and the bankfull depth was approximately 0.6 m. The banks are well vegetated with grass, and the channel bed is exposed bedrock. SBT-6 received an RSAT score of 26, indicating the reach is of moderate ecological health. The upstream extent of SBT-6 is the location of the twin 1.5 m CSPs at March Road.

The downstream extent of **SBT-7A** is the confluence with the main branch of Shirley's Brook (SB-1B). The reach received an RGA score of 0.25, indicating that the reach is transitional. Outside of some minor undercutting and some woody debris in the stream, the banks were vegetated with grass, and a number of trees remain along the sinuous section of channel. The bankfull width of the reach was approximately 4.75 m, and the bankfull depth was approximately 0.9 m. SBT-7A received an RSAT score of 25, indicating the reach is of moderate ecological health. The upstream extent of the reach is a bridge structure at Maxwell Bridge Road at which the stream passes through a 7 m wide arch CSP.

Upstream of the bridge structure, **SBT-7B** is a short reach consisting of a wide, shallow bedrock stream. SBT-7B received an RGA score of 0.17, indicating that the reach is in regime with few indicators of adjustment present. The bankfull width of the reach was approximately 5 m, and the bankfull depth was approximately 0.5 m. There is a knickpoint at the upstream end of the reach, and there is a collection of large boulders that appear to have been placed along the banks to increase stability. SBT-7B received an RSAT score of 20, indicating the reach is of low ecological health. At the upstream extent of SBT-7B is the confluence of two channels: SBT-6 and SBT-4.

TABLE 4 Tributary Rapid Assessment Scoring Summary

Reach	Aggradation	Degradation	Widening	Planimetric Adjustment	RGA Stability Index	RGA Condition	RSAT Score
SBT-1A	N/A	N/A	N/A	N/A	N/A	In Regime	23
SBT-1B	0.11	0.57	0.25	0	0.23	Transitional	18
SBT-2	0.13	0.57	0.88	0	0.39	Transitional	21
SBT-3	0.29	0.43	0	0.14	0.20	In Regime	27
SBT-4	0.29	0.57	0.25	0.29	0.41	Adjusting	26
SBT-5	0.29	0.29	0.25	0.14	0.30	Transitional	22
SBT-6	0	0.29	0	0	0.06	In Regime	26
SBT-7A	0.29	0	0.30	0	0.15	Transitional	25
SBT-7B	0	0.43	0	0	0.11	In Regime	20

Based on the field observations presented above, the most sensitive reaches can be identified for erosion threshold analyses. The observations also help identify reaches where local rehabilitation measures can be implemented and which measures are appropriate given the dominant processes.

5 MEANDER BELT WIDTH ANALYSIS

Streams and rivers are dynamic features that change their configuration and position within a floodplain by means of meander evolution, development, and migration processes. When meanders change shape and position, the associated erosion and depositional processes can cause loss or damage to private property and infrastructure. For this reason, when development or other activities are contemplated near a watercourse, it is desirable to designate a corridor that is projected to contain all of the natural meander and migration tendencies of the channel. It is assumed that, outside this corridor, private property and structures will be safe from the erosion potential of the watercourse. The space that a meandering watercourse occupies on its floodplain, within which all associated natural channel processes occur, is commonly referred to as the meander belt width. A meander belt width assessment is conducted to establish the hazard limits from a geomorphic perspective. The *Belt Width Delineation Procedures* (PARISH 2004) apply to a range of systems and follow a process-based method for determining the meander belt width based on background information, historic data (including aerial photography), degree of valley confinement, and channel planform.

5.1 Planform Delineation

Based on the current available mapping and digital aerial photography, a belt width was delineated for each of the study reaches by drawing lines parallel to the governing outermost meanders and following the meander axis. A number of the reaches within the study area have been altered (channelized) or are simply drainage ditches, and do not exhibit a meandering planform. This is true for SBT-1A, SBT-1B, and SBT-2, and as such, a belt width based on the existing planform was not developed for these reaches. Although SBT-4 and SBT-6 also appear to be channelized, there is sufficient meandering to delineate a belt width based on the current planform; however, there is the possibility that the planform as it currently exists has been altered. The results are presented in **Table 5**.

TABLE 5 Belt Widths Derived from Channel Planform

Reach	Measured Belt Width (m)
SB-1A	46
SB-1B	20
SB-2A	64
SB-2B	46
SB-3	64
SB-4	108
SB-5	220
SBT-1A	Ditch
SBT-1B	Ditch
SBT-2	Ditch
SBT-3	31
SBT-4	32

Reach	Measured Belt Width (m)
SBT-5	28
SBT-6	12
SBT-7A	27
SBT-7B	22

5.2 Empirical Analysis

While it is generally preferred that the belt width is determined from the delineation of existing planform, at times, it is required or is considered more appropriate to employ other methods to determine the belt width for certain reaches. An example of a situation where alternative methods are typically used is when the scale of the channel or vegetation cover is such that the planform isn't visible in aerial photographs. In this type of situation, two approaches can be used. A surrogate value obtained from a reach upstream or downstream of the reach in question can be applied, after an examination of its appropriateness based on dimensions and condition. A second approach is the use of empirical relationships. Predicted planform metrics can be approximated using standard empirical relations developed by Williams (1986), which are based on an extended dataset of 194 sites from a large variety of physiographic environments in various countries. The equations relate natural average channel cross-section metrics (width, depth, and area) to watercourse wavelength, amplitude, and radius of curvature. Similar relations to the equations developed by Williams (1986) include ones developed by Ward et al. (2002) and Lorenz et al. (1985), and are contained in **Table 6**. These relations are based on measurements of real watercourses; however, their transferability to all watercourses is potentially limited due to possible differences in hydrologic regime, drainage area, and general controlling factors. In particular, in urbanized settings, classic alluvial forms are typically limited to headwater tributaries that have not yet undergone significant morphological change.

In the KNUEA, many of the watercourses have been altered to improve drainage function. These considerations should be kept in mind when applying the empirical relations; however, often they can provide the only approximation available. In addition, even for those reaches where the standard belt width delineation procedure is possible, when reviewed collectively, the equation results provide a data set from which to corroborate results attained through planform delineation and to help ensure that values are appropriate. This is particularly important when examining reaches have been modified or altered. In applying the empirical relations, a belt width is obtained, which would contain the lateral extent of a natural watercourse that has the same dimensions.

TABLE 6 Empirical Meander Belt Width Equations

Source	Equation
Williams (1986) bankfull width (m)	$4.3W^{1.12}$
Ward et al (2002) bankfull width (ft)	$4.8W^{1.08}$
Lorenz et al. (1985) bankfull width (m)	$7.53W^{1.01}$

Bankfull channel dimensions measured during the field assessment were used as input parameters for the empirical analyses, and the results are presented in **Table 7**. The standard deviation is quite high for some reaches (up to 8 m); however, the average result of the three relationships will be used, as opposed to the largest result. By using the average, it is applying a broader data set to the analysis, as opposed to defaulting to the largest value to be conservative. In reality, for most cases, a high level of conservatism is already applied in the analysis, as the empirical results are applied to mostly well-defined, straightened reaches that have no meanders or migratory tendencies. In addition, as the primary purpose of altering the channels has generally been to provide conveyance capacity, it is possible that the bankfull dimensions of the channels as observed during the field survey may be larger than would be consistent with a natural channel under the same hydrological regime.

TABLE 7 Empirical Relationship Meander Belt Width Approximations

Reach	Bankfull Width (m)	Williams (1986) (m)	Ward et al (2002) (m)	Lorenz et al. (1985) (m)	Average (m)	Standard Deviation (m)	Planform Delineation (m)
SB-1A	6.5	34.99	43.17	53.75	41.6	7.59	46
SB-1B	7	38.02	43.17	53.75	44.98	8.02	20
SB-2A	6.5	34.99	39.85	49.87	41.6	7.59	64
SB-2B	6.5	34.99	39.85	49.87	41.6	7.59	46
SB-3	5.8	30.68	35.11	44.29	36.69	6.94	64
SB-4	5.2	27.31	31.38	39.88	32.86	6.42	108
SB-5	N/A	N/A	N/A	N/A	N/A	N/A	220
SBT-1A	4	20.31	23.59	30.54	24.8	5.22	Ditch
SBT-1B	3.5	17.49	20.42	26.69	21.5	4.70	Ditch
SBT-2	4	20.31	23.59	30.54	24.8	5.22	Ditch
SBT-3	3	14.72	17.29	22.84	18.3	4.15	31
SBT-4	4.5	23.18	26.79	34.4	28	5.73	32
SBT-5	4	20.31	23.59	30.54	25	5.22	28
SBT-6	3	14.72	17.29	22.84	18.3	4.15	12
SBT-7A	4.75	24.62	28.40	36.33	29.8	5.97	27
SBT-7B	5	26.08	30.02	38.26	31.5	6.22	22

5.3 Final Belt Width with Setback

The process of developing a final meander belt width involves (1) an evaluation and selection of which method is most appropriate to obtain a preliminary belt width, (2) consideration of the inferred stability of the channel, and (3) the addition of a safety setback. The suitability of using each of the alternate methods (planform delineation, surrogate, and empirical analysis) to obtain a preliminary belt width was discussed in the preceding section. It is imperative that a safety setback is accommodated. From a geomorphic perspective, the 100-year migration rate typically represents a suitable erosion setback to be applied to either side of the preliminary meander belt width to account for bank erosion and channel migration over time. However, due to the scale of the channels, the high degree of planform alteration, and the vegetative cover in certain locations, 100-year migration rates were not quantified. In lieu of applying the 100-year migration rate, a standard erosion setback representing 10% of the preliminary meander belt width is typically applied to either side of the channel for each reach. A summary of final belt widths is provided in **Table 8**. For comparison purposes, included in the table are the belt width values presented in the Shirley's Brook and Watts Creek Subwatershed study (Dillon 1999) and the Greater Shirley's Brook Constance Creek environmental management study (Aquafor Beech and Brunton 2006).

5.3.1 Shirley's Brook

All of the reaches along the main branch of Shirley's Brook that were investigated during the field investigation displayed natural planform characteristics, and for this reason, the belt widths for all but one of the reaches are based on the planform delineations presented in **Section 5.1**. The exception is SB-1B, which had a planform-delineated belt width of 20 m. The tributary immediately upstream of this reach had a larger meander belt width of 27 m. In this case, a surrogate value from the planform-delineated belt width was applied for SB-1A which is the reach immediately downstream of SB-1B. For all of the reaches, a 10% setback was applied to either side of the channel. **Table 8** presents the final values, and the final belt widths are displayed on **Figure 4**. The meander belt width of all reaches of Shirley's Brook within the study area can be incorporated within a 40 m corridor.

TABLE 8 Shirley's Brook and Tributaries Final Belt Widths

Reach	Preliminary Belt Width (m)	Final Belt Width (m)	Dillon (1999; m)	Aquafor Beech and Brunton (2006; m)
SB-1A	46	55	25-40	55
SB-1B	46	55	25-40	55
SB-2A	64	77	25-40	55
SB-2B	46	55	55-70	55
SB-3	64	77	55-70	55
SB-4	108	130	70-85	55
SB-5	220	264	100+	N/A
SBT-1A	25	30	25-40	N/A
SBT-1B	22	25	25-40	N/A
SBT-2	25	30	25-40	N/A
SBT-3	31	37	40-55	35
SBT-4	32	35	25-40	45
SBT-5	28	34	40-55	35
SBT-6	28	34	25-40	35
SBT-7A	27	32	25-40	45
SBT-7B	32	38	25-40	45

5.3.2 Tributaries

The tributaries to Shirley's Brook displayed a variety of channel form and condition, thereby requiring the use of planform delineations, surrogate reaches, or empirically-derived preliminary belt width results, depending on the specific conditions of each reach. As most of the length of the tributaries has been altered/straightened, it was often appropriate to apply the empirical relations. The planform-delineated preliminary belt width was applied in the situations where the results were greater than those developed using the empirical relations. **Table 8** presents the final values with a 10% setback included. The final belt widths are displayed on **Figure 4**.

SBT-1A, SBT-1B, and SBT-2 were all highly altered, and preliminary belt widths were not delineated based on planform. As there are no surrogate reach values to use, the empirically derived belt width values will be the preliminary belt widths. The defined ditch-like nature and relatively small-scale (bankfull widths from 3.5 to 4 m) of the reaches may lead to the assumptions that little adjustment should occur in the future and that the application of equations derived from natural streams may produce an overly conservative result. However, the field observations for SBT-1B revealed that there is a high degree of gullying occurring. This has resulted in very steep banks that have eroded and failed. Any lateral movement of the channel will be a result of bank failure and widening as opposed to meander migration. SBT-2 was in a high-transitional/in-adjustment state, with strong evidence of widening and degradation. This high level of adjustment must be taken into consideration; therefore, the conservative use of the empirical formulas was applied.

SBT-3 had a planform-delineated belt width of 31 m, while empirical relationships resulted in an average belt width of 18.3 m. While the watercourse is of relatively small scale and appears to have been altered for a short section, the channel is sinuous and unconfined. Most of the bed consists of exposed bedrock, and the banks are simply grass-vegetated. As the bedrock is more resistant to erosive forces, lateral adjustment due to bank erosion is more likely. With this consideration, it is appropriate to use the larger belt width of 31 m. The upstream extent of the reach is at the confluence of two channels, which appear to have been altered within the development boundary. It is therefore considered appropriate to apply the belt width of SBT-3 as a surrogate width for these two unnamed channels (**Figure 4**).

SBT-4 had similar values for planform-delineated and empirically-derived belt widths at 32 m and 28 m, respectively. The channel has been altered/straightened, but active geomorphic adjustment was observed. Although channel adjustment may be a result of the high level of beaver activity in the channel, the larger of the two (32 m) derived belt widths will be applied to maintain conservativeness.

SBT-5 had a planform-delineated belt width of 28 m, while using the bankfull width of 4 m results in a belt width of 25 m using empirical relationships. This reach is in a transitional state, and no significant indicators of adjustment were observed. At the same time, the relatively unconfined setting and the observation that channel form was varying from un-concentrated flow over large areas of exposed bedrock, to concentrated flow in a defined channel, to backwater in on-line ponds, would suggest that the use of a conservative approach is appropriate. At the on-line pond, the width of the watercourse exceeds the final belt width. In this area, the belt width has been extended to contain the extent of the pond, as there is minimal risk of that portion of the reach undergoing significant adjustment in the future.

The existing planform of SBT-6 resulted in a delineated belt width of 14 m; however, it was an altered channel (drainage ditch). Based on a bankfull width of 3 m, empirical relationships indicate a belt width of 18.3 m. Considering that this reach is altered and that the planform-delineated belt width for the more natural reach immediately upstream (SBT-5) is much larger, the belt width for SBT-5 was used as a surrogate value for SBT-6.

SBT-7B is at the confluence of SBT-6 and SBT-4. Although it was in regime with few indicators of active adjustment, the belt widths used for the two reaches upstream are larger than that found from the altered planform of SBT-7B (22 m). The bankfull width was used in the empirical formulas to arrive at an average preliminary belt width of 32 m.

SBT-7A was sinuous, and the belt width based on the channel planform was 27 m. The banks were highly vegetated with grasses and a number of trees, aside from the upstream end, which is clear-cut. The upstream end is confined by a valley wall along the right (south) bank. The result of the empirical relationships based on the fairly wide channel is 29.8 m. As this reach was transitional and there were no major forms of adjustment, it is appropriate to use the belt width determined using the planform.

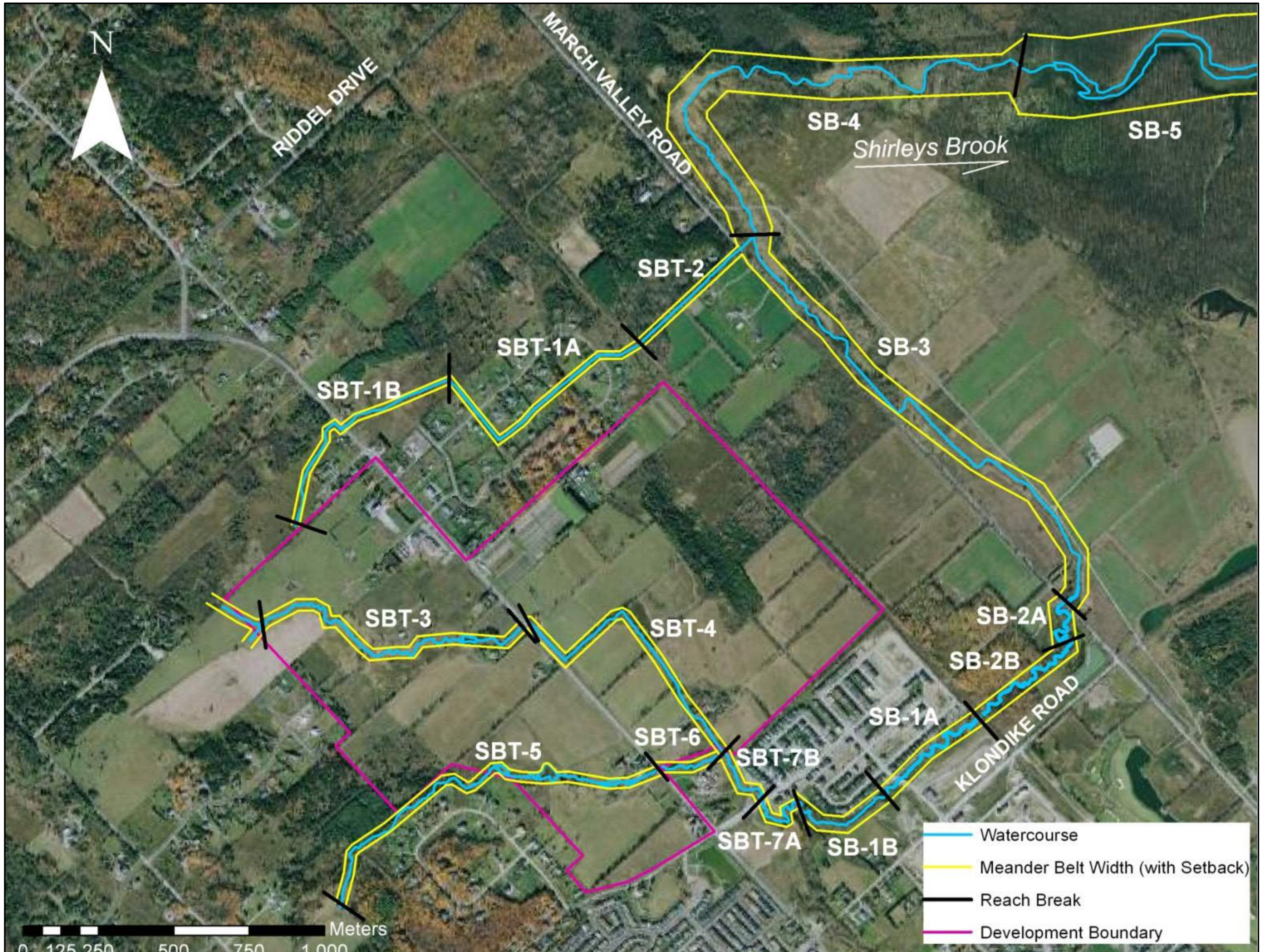

FIGURE 4 Shirley's Brook and Tributaries Final Belt Widths with Setback

6 EROSION THRESHOLDS

An erosion threshold analysis determines the hydraulics (discharge, channel depth, average channel velocity, etc.) at which the mobilization of a given particle size (critical particle size) is initiated (i.e., the threshold condition at which sediment will start to mobilize). Once this value is determined, a model is run that raises the water level within the channel incrementally until the depth and slope produce values equal to the critical values. PARISH uses a number of different established entrainment relationships to calculate erosion thresholds, including models based on critical shear stress and permissible velocity, to consider a range of results. The goal of this assessment is to determine a threshold discharge for various reaches of Shirley's Brook and its tributaries above which boundary materials are entrained. Where changes are to occur to the contributing drainage area of a channel, a typical objective is to ensure that future hydrological conditions do not result in channel flow exceeding the threshold discharge more frequently than with existing conditions. This is done to minimize potential post-development channel degradation.

Thresholds may be different along the course of a stream, and typically, the entire channel length is investigated and the condition of each reach is determined. The reach that is found to be undergoing the greatest amount of adjustment is identified as the most sensitive, and is subject to further investigation to document the existing channel form. The most sensitive reach in the threshold analysis acts as an indicator of the system, and is selected to provide conservative estimates of erosion thresholds. However, the siting of future stormwater management facilities (ponds) is also an important aspect to consider in determining where to perform the detailed survey and obtain threshold values.

6.1 Detailed Survey

A survey of just under 250 m was taken along SB-3 on June 12, 2013. Pond locations were not yet established at the time of the initial field study, and it was indicated that stormwater flows would likely be directed to Shirley's Brook downstream of March Valley Road. Most of SB-3 was inaccessible, as it is located within DND lands; however, the surveyed stretch of the river along March Valley Road was accessible, and an assessment was performed at this location. On October 2, 2015, access to SB-4 was granted downstream of the proposed Pond 3, which was surveyed and assessed.

Once pond locations were established, surveys and erosion threshold analyses were performed along four additional reaches. On September 9, 2015, SBT-3 was surveyed near March Road downstream of the proposed Pond 1 location. SBT-4, also downstream of the Pond 1 location, was also surveyed near March Road, as it was in adjustment, suggesting that a higher level of sensitivity may be present at this location than at SBT-3 upstream. Erosion assessments were performed for both of these reaches of Tributary 2 to ensure representative values were achieved. SBT-5 was surveyed near March Road downstream of the proposed Pond 2 location. The sections surveyed are shown in **Appendix C**.

6.1.1 Reach SB-3

6.1.1.1 Profile and Cross-sections

As SB-3 is parallel with the road along the section surveyed, it is straight and channelized, and contains protective materials (gabions, angular stone, etc.) along its boundaries in some locations. Sections along the left bank that are not protected with larger materials were generally slowly eroding into the channel. In addition, there are CSP stormwater outfalls that outlet to the channel draining lands west of March Valley Road. Five cross-sections were measured along the stretch, with XS-1 being the furthest downstream and XS-5 being near the upstream extent of the survey. Cross-sectional dimensions are provided in **Table 9**. Bankfull slope was approximately 0.07% over the survey (longitudinal profiles are available in **Appendix C**).

TABLE 9 SB-3 Cross-section Characteristics

	XS-1	XS-2	XS-3	XS-4	XS-5	Average
Bankfull Width (m)	5.30	6.92	5.30	6.30	5.10	**5.78**
Average Bankfull Depth (m)	0.75	0.71	0.76	0.80	0.76	**0.75**
Maximum Bankfull Depth (m)	1.00	1.16	1.09	1.12	1.03	**1.08**
Bankfull Width: Depth	7.08	9.78	7.02	7.90	6.67	**7.69**
Cross-sectional Area (m^2)	4.04	4.95	4.08	5.10	3.97	**4.43**
Wetted Perimeter (m)	6.11	7.85	6.16	7.11	5.97	**6.64**
Hydraulic Radius (m)	0.66	0.63	0.66	0.72	0.67	**0.67**
Left Bank Angle (^{o})	31.1	21.8	29.8	35.9	34.0	**30.53**
Right Bank Angle (^{o})	48.0	51.3	37.3	44.7	55.3	**47.32**
Left Bank Height (m)	0.85	1.04	1.03	0.87	0.81	**0.92**
Right Bank Height (m)	1.00	1.15	0.99	0.89	1.01	**1.01**

6.1.1.2 Sediment Characteristics

The substrate characteristics were evaluated using the modified Wolman (1954) pebble count at each cross-section. A variety of sediment sizes are present in the channel, ranging from exposed clay to gravel with the overall distribution of the combined counts (**Appendix C**) having a D_{50} of 0.0007 cm (silt) and a D_{84} of 0.92 cm (gravel). At locations where the channel has been armoured, larger sizes were found. The bed consisted mostly of a mixture of clay, silt, sand, and gravel, and there were some sections where hard-packed exposed clay was observed, primarily along the channel margins. The pebble- and gravel-sized sediment is likely a result of failed road embankment material along the left bank. Other bank materials were silt, sand, and clay. The distributions at each of the cross-sections were fairly similar, except for XS-3, which had a thick, very soft deposit of fines, likely accumulated due to a debris jam in the channel immediately downstream.

6.1.1.3 Hydraulics

Bankfull discharge was calculated based on the dimensions surveyed, the approximated bankfull gradient of 0.07%, and an estimated Manning's n value of 0.032. The results ranged from 3.47 to 4.65 m^3/s, with an average of 3.96 m^3/s. The average bankfull velocity was 0.74 m/s. The channel hydraulics are presented in **Table 10**.

TABLE 10 SB-3 Hydraulic Summary

	XS-1	XS-2	XS-3	XS-4	XS-5	Average
Bankfull Discharge (m^3/s)	3.50	4.52	3.64	4.65	3.47	**3.96**
Average Bankfull Velocity (m/s)	0.75	0.69	0.74	0.78	0.76	**0.74**
Maximum Bankfull Velocity (m/s)	0.99	1.09	1.04	1.05	1.00	**1.03**
Average Shear Velocity [u*] (m/s)	0.08	0.08	0.08	0.08	0.08	**0.08**
Average Shear Stress (N/m^2)	6.49	6.19	6.49	7.04	6.53	**6.55**
Maximum Shear Stress (N/m^2)	9.81	11.32	10.54	10.84	10.04	**10.51**

Based on past modelling (JTBES 2013), the peak flows were obtained for flow point SB12, which is located approximately along SB-3. As shown in **Table 11**, the bankfull flow obtained from the PARISH survey data (3.96 m^3/s) is lower than the 2-year return flow (5.71 m^3/s), which is a typical characteristic of bankfull discharge in natural channels.

TABLE 11 Return Period Flows

Return Interval	Flow (m^3/s)
2-year	5.71
5-year	8.38
10-year	10.8
25-year	14.0
50-year	16.7
100-year	17.9

6.1.2 Reach SB-4

6.1.2.1 Profile and Cross-sections

The main branch of Shirley's Brook was also investigated in SB-4 downstream of the location where the channel runs parallel to March Valley Road. The site was heavily backwatered due to a downstream beaver dam. Two of the five cross-sections were collected downstream of the beaver dam for completeness and to ensure upstream observations were consistent. XS-1 was the furthest upstream, and XS-5 was near the downstream extent of the survey. Cross-sectional dimensions are provided in **Table 12**. The bottom slope of the channel was approximately 0.23% over the survey.

TABLE 12 SB-4 Cross-section Characteristics

	XS-1	XS-2	XS-3	XS-4	XS-5	Average
Bankfull Width (m)	5.70	5.40	5.96	4.07	4.93	**5.21**
Average Bankfull Depth (m)	0.65	0.72	0.58	0.47	0.60	**0.60**
Maximum Bankfull Depth (m)	0.93	0.93	0.78	0.70	0.87	**0.84**
Bankfull Width: Depth	8.72	7.53	10.24	8.65	8.22	**8.67**
Cross-sectional Area (m^2)	3.87	4.18	3.63	2.22	3.26	**3.43**
Wetted Perimeter (m)	6.24	6.21	6.45	4.60	5.52	**5.81**
Hydraulic Radius (m)	0.62	0.67	0.56	0.48	0.59	**0.59**
Left Bank Angle (^{o})	37.0	49.5	39.8	48.3	41.6	**43.24**
Right Bank Angle (^{o})	32.5	41.9	32.8	41.0	41.0	**37.85**
Left Bank Height (m)	0.70	0.82	0.65	0.55	0.64	**0.67**
Right Bank Height (m)	0.70	0.79	0.65	0.50	0.64	**0.66**

6.1.2.2 Sediment Characteristics

SB-4 contains a variety of sediment sizes ranging from exposed clay to gravel. Due to the depth of backwatering onsite, a Wolman (1954) pebble count was not possible. In deeper pool areas, loose silt and organics were felt up to approximately 20 cm. Shoal areas throughout had coarse materials, including embedded cobbles and small boulders. Gravel material was felt in the void spaces between the larger materials. Downstream of XS-3, the bed was composed of a hard surface, appearing to be bedrock, covered in a small layer of grey clay. Silt deposits make up most of the channel and are likely the most easily entrained material within the reach. These silt deposits likely exist as a result of eroding banks. The banks throughout this reach were composed predominantly of silt.

6.1.2.3 Hydraulics

Bankfull discharge was calculated based on the dimensions surveyed, the approximated bed gradient of 0.23%, and an estimated Manning's n value of 0.03. The results ranged from 2.78 to 6.51 m^3/s, with an average of 4.93 m^3/s. The average bankfull velocity was 1.17 m/s. The results are presented in **Table 13**.

TABLE 13 SB-4 Hydraulic Summary

	XS-1	XS-2	XS-3	XS-4	XS-5	Average
Bankfull Discharge (m^3/s)	5.69	6.51	4.93	2.78	4.74	**4.93**
Average Bankfull Velocity (m/s)	1.26	1.33	1.17	0.95	1.15	**1.17**
Maximum Bankfull Velocity (m/s)	1.69	1.73	1.52	1.40	1.65	**1.60**
Average Shear Velocity [u*] (m/s)	0.13	0.14	0.13	0.12	0.13	**0.13**
Average Shear Stress (N/m^2)	17.66	19.15	16.02	13.71	16.80	**16.67**
Maximum Shear Stress (N/m^2)	25.41	26.29	21.78	19.39	24.61	**23.50**

6.1.3 Reach SBT-3

6.1.3.1 Profile and Cross-sections

The portion of SBT-3 that was surveyed runs parallel with a driveway leading to March Road. This section, immediately downstream of the proposed Pond 1 is straight, trapezoidal, and contains protective materials (angular stone) at the bend located at the upstream extent of the survey. Where protective materials are not found, the banks were densely vegetated. A layer of lose silt deposit is present along the channel bottom, with a small number of embedded cobbles and pebbles. Two cross-sections were measured along this stretch, with XS-1 being the furthest upstream and XS-2 being near the downstream extent. Cross-sectional dimensions are provided in **Table 14**. The bed slope was approximately 0.17% over the surveyed area.

TABLE 14 SBT-3 Cross-section Characteristics

	XS-1	XS-2	Average
Bankfull Width (m)	5.40	5.25	**5.33**
Average Bankfull Depth (m)	0.46	0.39	**0.43**
Maximum Bankfull Depth (m)	0.84	0.71	**0.78**
Bankfull Width: Depth	11.76	13.41	**12.58**
Cross-sectional Area (m^2)	2.56	2.19	**2.38**
Wetted Perimeter (m)	5.72	5.54	**5.63**
Hydraulic Radius (m)	0.45	0.40	**0.42**
Left Bank Angle (^{o})	22.7	16.7	**19.70**
Right Bank Angle (^{o})	22.3	29.7	**26.02**
Left Bank Height (m)	0.41	0.36	**0.39**
Right Bank Height (m)	0.41	0.40	**0.41**

6.1.3.2 Sediment Characteristics

Most of the channel banks and bed were composed of silt. The silt material at the bed of the channel was loose for a depth of 5 to 10 cm. The deposited silts may be a result of upstream bank erosion, where bank material had fallen into the channel and was transported downstream. Some bank toe erosion was noted along the surveyed stretch. Some embedded cobbles (5 to 10 cm) and pebbles were observed through XS-2. This larger material may be present as a result of erosion protection materials falling into the channel and being transported downstream.

6.1.3.3 Hydraulics

Bankfull discharge was calculated based on the dimensions surveyed, the approximated bed gradient of 0.17%, and an estimated Manning's n value of 0.03. The results ranged from 1.83 to 2.39 m^3/s, with an average of 2.11 m^3/s. The average bankfull velocity was 0.72 m/s. The results are presented in **Table 15**.

TABLE 15 SBT-3 Hydraulics Summary

	XS-1	XS-2	Average
Bankfull Discharge (m^3/s)	2.39	1.83	**2.11**
Average Bankfull Velocity (m/s)	0.75	0.68	**0.72**
Maximum Bankfull Velocity (m/s)	1.16	1.07	**1.12**
Average Shear Velocity [u*] (m/s)	0.09	0.08	**0.08**
Average Shear Stress (N/m^2)	7.47	6.59	**7.03**
Maximum Shear Stress (N/m^2)	13.22	11.75	**12.49**

6.1.4 Reach SBT-4

6.1.4.1 Profile and Cross-sections

The portion of SBT-4 that was surveyed runs east, immediately downstream from March Road. This section is straight, trapezoidal, and composed mainly of fairly compact silt material along the bed and banks. The channel has a moderate amount of woody debris, and banks are mostly kept stable due to dense tree rooting. Three cross-sections were measured along the reach, with XS-1 being the furthest upstream and XS-3 being near the downstream extent. Cross-sectional dimensions are provided in **Table 16**. The bed slope was approximately 0.30% over the surveyed length.

TABLE 16 SBT-4 Cross-section Characteristics

	XS-1	XS-2	XS-3	Average
Bankfull Width (m)	5.85	4.97	5.20	**5.34**
Average Bankfull Depth (m)	0.60	0.52	0.64	**0.58**
Maximum Bankfull Depth (m)	0.95	0.83	0.90	**0.89**
Bankfull Width: Depth	9.83	9.64	8.17	**9.21**
Cross-sectional Area (m^2)	3.57	2.67	3.31	**3.18**
Wetted Perimeter (m)	6.31	5.41	5.68	**5.80**
Hydraulic Radius (m)	0.57	0.49	0.58	**0.55**
Left Bank Angle (^{o})	33.0	30.6	32.7	**32.11**
Right Bank Angle (^{o})	18.4	27.7	30.6	**25.59**
Left Bank Height (m)	0.78	0.71	0.77	**0.75**
Right Bank Height (m)	0.75	0.72	0.71	**0.73**

6.1.4.2 Sediment Characteristics

The channel banks and bed were composed predominantly of silt. The silt material at the bed of the channel was compact, and banks appeared mostly stable, with tree roots providing some stability. Some bank erosion was noted where rooting density was sparser. The channel through this reach was dry at the time of the survey, and no low-flow notch was visible.

6.1.4.3 Hydraulics

Bankfull discharge was calculated based on the dimensions surveyed, the approximated bed gradient of 0.30%, and an estimated Manning's n value of 0.03. The results ranged from 3.64 to 5.16 m^3/s, with an average of 4.54 m^3/s. The average bankfull velocity was 1.17 m/s. The results are presented in **Table 17**.

TABLE 17 SBT-4 Hydraulic Summary

	XS-1	XS-2	XS-3	Average
Bankfull Discharge (m^3/s)	5.16	3.64	4.82	**4.54**
Average Bankfull Velocity (m/s)	1.19	1.07	1.25	**1.17**
Maximum Bankfull Velocity (m/s)	1.72	1.59	1.68	**1.66**
Average Shear Velocity [u*] (m/s)	0.13	0.12	0.13	**0.13**
Average Shear Stress (N/m^2)	16.63	14.54	17.13	**16.10**
Maximum Shear Stress (N/m^2)	27.44	24.27	26.49	**26.07**

6.1.5 Reach SBT-5

6.1.5.1 Profile and Cross-sections

The portion of SBT-5 immediately upstream of March Road was surveyed. This section is fairly straight and trapezoidal. The beds of XS-1 and XS-2 are composed of exposed bedrock, and the banks are mostly composed of silt with a high density of vegetation. The channel, where bedrock is exposed, has a more moderate slope of 0.22%. The slope of the channel is approximately 1.8% and is the representative slope for XS-3. Throughout the surveyed section, XS-1 was the furthest downstream, and XS-3 was near the upstream extent. Cross-sectional dimensions are provided in **Table 18**.

TABLE 18 SBT-5 Cross-section Characteristics

	XS-1	XS-2	XS-3	Average
Bankfull Width (m)	5.26	4.70	4.60	**4.85**
Average Bankfull Depth (m)	0.77	0.65	0.38	**0.60**
Maximum Bankfull Depth (m)	1.14	1.19	0.69	**1.01**
Bankfull Width: Depth	6.87	7.19	12.00	**8.69**
Cross-sectional Area (m^2)	4.28	3.13	1.83	**3.08**
Wetted Perimeter (m)	6.12	5.36	4.84	**5.44**
Hydraulic Radius (m)	0.70	0.58	0.38	**0.55**
Left Bank Angle (^{o})	28.5	23.5	14.3	**22.12**
Right Bank Angle (^{o})	52.8	39.3	21.4	**37.84**
Left Bank Height (m)	0.87	0.87	0.51	**0.75**
Right Bank Height (m)	0.87	0.90	0.51	**0.76**

6.1.5.2 *Sediment Characteristics*

The channel banks through the surveyed stretch were composed of silt and were densely vegetated with tall grasses and shrubs. Bedrock is exposed between XS-1 and XS-2, and XS-3 has a bed composed mainly of silt with a small amount of 5 to 15 cm cobbles embedded. The bank through the length of channels, where bedrock is exposed, is showing a small amount of undercutting. Toe erosion is likely a result of channel energy being focused along the banks due to the durability of the bedrock.

6.1.5.3 *Hydraulics*

Bankfull discharge was calculated based on the dimensions surveyed, approximated bed gradients at each cross-section, and an estimated Manning's n value of 0.035. The results ranged from 3.50 to 5.34 m^3/s, with an average of 4.33 m^3/s. The average bankfull velocity was 1.25 m/s. The results are presented in **Table 19**.

TABLE 19 SBT-5 Hydraulic Summary

	XS-1	XS-2	XS-3	Average
Bankfull Discharge (m^3/s)	5.34	3.50	4.15	**4.33**
Average Bankfull Velocity (m/s)	1.00	0.89	1.87	**1.25**
Maximum Bankfull Velocity (m/s)	1.46	1.47	2.95	**1.96**
Average Shear Velocity [u*] (m/s)	0.12	0.11	0.26	**0.16**
Average Shear Stress (N/m^2)	15.11	12.59	66.74	**31.48**
Maximum Shear Stress (N/m^2)	24.36	24.76	118.86	**55.99**

6.2 Bed Erosion

The detailed characteristics obtained from the field survey of each reach were used to estimate erosion threshold values of the main branch of Shirley's Brook and its tributaries. A number of analyses were performed to allow for comparison of results. **Table 20** summarizes the entrainment threshold results for each reach.

Often, a critical grain size will be used for threshold analyses. Because of the abundance of fine materials within the channels in the study area, the grain size distributions contain small particle diameters. Calculating the threshold based on a very small critical particle size can potentially produce unrealistically low values. To obtain representative erosion threshold results within the current study area, the cohesive nature of the fine-grained materials observed must be taken into consideration. Coarse particles were considered and analyzed to be used for comparison purposes, but ultimately, the results were not meaningful in this situation.

Contrary to non-cohesive sediment erosion, which occurs through the entrainment of discrete particles, cohesive sediment is eroded through the entrainment of aggregates. When considering the cohesive nature of materials, other factors must be taken into account. One such factor is the degree of compactness of the sediment deposit. The silt and clay (cohesive) component of the substrate mixture observed on the bed in some locations is fairly loose and can be considered an active layer. It is expected that the deposition and erosion of these loose particles will occur in the channel as part of the natural cyclical nature of the system. Therefore, it is likely that loose deposited materials do not exert the greatest control of the overall morphology of the watercourse. On the other hand, there were a number of locations along the reach at which exposed hard-packed clay was observed and was identified as the subpavement at locations where an examination of the material below the surficial sediment was possible. Based on the presence of this type of boundary material, a second analysis was performed in these locations. Consideration of both loose deposited materials and compact submaterials provides a complete picture of the erosive resistance of the channel.

In this study, the analysis relied on relationships developed through past studies that have been performed to determine the maximum permissible shear stresses for samples of cohesive sediment. These tests have varied widely in their results. For example, Gaskin et al. (2003) performed erosion tests on Leda clay and determined critical shear thresholds ranging from 6 to 20 N/m^2.

The following studies were used in the current analysis:

- Chow (1959): This study provides an estimate of net tractive force for a range of cohesive soil compositions, and considers the compactness of the material. For example, fairly compact, cohesive clay, with an approximate voids ratio of 0.6, has a unit tractive force of 0.2 lb/ft^2 (9.6 N/m^2). The permissible shear stress, based on this method, is then set in an entrainment equation to compute the threshold for each cross-section.

- Dunn (1959): This study uses a relationship between the percentage of the substrate that is silt-clay and the resulting permissible shear. For example, if the percent of the bed that was silt-clay is 50%, this results in a permissible shear stress of 13 N/m^2. The thresholds, based on this method, are then calculated for each cross-section.

TABLE 20 Erosion Threshold Results

Entrainment Equation		SB-3	SB-4	SBT-3	SBT-4	SBT-5
Chow (1959) Loose Deposited Layer	Critical Discharge (m^3/s)	N/A	0.69	0.47	N/A	N/A
	Critical/Bankfull Discharge	N/A	0.19	0.22	N/A	N/A
	Maximum Depth (m)	N/A	0.37	0.45	N/A	N/A
	Average Depth (m)	N/A	0.29	0.24	N/A	N/A
	Maximum Velocity (m/s)	N/A	0.63	0.61	N/A	N/A
	Average Velocity (m/s)	N/A	0.50	0.38	N/A	N/A
Chow (1959) Compact Submaterial	Critical Discharge (m^3/s)	2.23	2.36	1.32	0.73	0.57
	Critical/Bankfull Discharge	0.57	0.54	0.62	0.16	0.14
	Maximum Depth (m)	0.80	0.62	0.64	0.43	0.43
	Average Depth (m)	0.62	0.47	0.37	0.31	0.27
	Maximum Velocity (m/s)	0.85	1.14	0.93	0.73	0.79
	Average Velocity (m/s)	0.67	0.88	0.62	0.57	0.54
Dunn (1959) % of Silt and Clay	Critical Discharge (m^3/s)	8.59	4.89	6.88	4.39	6.5
	Critical/Bankfull Discharge	2.22	1.12	3.26	0.97	1.59
	Maximum Depth (m)	1.58	0.83	1.16	0.88	1.88
	Average Depth (m)	1.27	0.61	0.83	0.57	1.12
	Maximum Velocity (m/s)	1.33	1.64	1.82	1.64	2.38
	Average Velocity (m/s)	1.06	1.21	1.41	1.15	2.28

6.3 Erosion Threshold Discussion

Through the use of cohesive sediment entrainment relationships, a number of erosion threshold values have been presented. Loose deposited layers and the compact submaterials were both considered and evaluated using the methods by Chow (1959) and Dunn (1959). A comparison of the two methods provides a good range of results. This type of range is typical of erosion threshold analyses for cohesive channels.

Loose materials, which were determined to be deposited based on field observations, are the first to be entrained. However, these values are not necessarily representative of the channel boundaries, as explained in **Section 6.2**. The Dunn (1959) method typically provides higher values of shear resistance. As such, the values resulting from the use of the Chow (1959) method, considering the compact submaterial, was determined to be the most appropriate for the current study. **Table 21** summarizes final erosion threshold results that should be considered for development.

TABLE 21 Final Erosion Threshold Critical Discharge Values

Reach	Critical Discharge (m^3/s)
SBT-3	1.32
SBT-4	0.73
SBT-5	0.57
SB-3	2.23
SB-4	2.36

The fluvial geomorphology report (JTBES 2013) contains estimated stream velocity thresholds for SB-2A, which is located immediately upstream of SB-3 (current study). Based on the presented channel dimensions and critical velocity, the critical discharge for this reach was calculated to be approximately 0.0002 m^3/s. This value is of the same magnitude determined for SB-3 (0.0004 m^3/s) using a non-cohesive sediment relationship established by Fischenich (2001). The JTBES (2013) report states that these low values would indicate that initiation and transport would be occurring even at low flow, although no transport was observed during their field work of low flow measurements. These extremely low values are a result of using an entrainment relationship based on non-cohesive materials of extremely small size (mostly silt). Using the relationships that take into account the cohesive properties of the soil, the current study provides values that better represent Shirley's Brook and its tributaries.

The threshold values presented above are intended to provide erosion control criteria for the proposed development area. If it is determined during development of the stormwater management design that it is not possible, or unfeasible, to avoid significant increases in erosion potential, mitigation measures can be implemented to increase the shear resistance of the channels, effectively increasing the critical discharge. These mitigation measures can be implemented in conjunction with the potential rehabilitation and enhancement opportunities identified throughout the study area, as discussed in Section 8.

7 CROSSING ASSESSMENT

Five existing stream crossings were assessed as part of this study. The crossings assessed were identified as possibly being altered as part of the development or during future March Road modifications. Included in this section is a description of each crossing structure (**Table 22**), the condition of the crossing, and channel processes downstream and upstream of the structure. Crossing structure locations are provided in **Appendix D**.

TABLE 22 Crossing Structure Descriptions

Structure No.	Location	Size (Diameter/H × W)	Shape	Material	Culvert Condition/Comments
D-1	March Road	900 mm	Circular	CSP	Corrosion at inlet
S-2	March Road	1.0 × 1.8 m	Box	Concrete	Good condition
S-3	March Road	1.0 × 0.9 m	Box (open bottom)	Concrete	Good condition
S-6	March Road	Twin 1,500 mm	Circular	CSP	Outlet top of culverts partially crushed
S-8	March Road	1,200 mm	Circular	Concrete	Good condition

Note:
CSP: corrugated steel pipe (Appendix D)

7.1 Existing Conditions

7.1.1 D-1 Small Corrugated Steel Pipe Immediately Upstream of March Road

This crossing along SBT-3 allows for access of the local landowner to agricultural lands on the left side of the channel. Corrosion through the 900 mm CSP is present at the inlet, and pooling in the channel is occurring at the downstream end of the structure. These observations are typical of undersized crossing structures.

FIGURE 5 D-1 Photographs at the Inlet (Left) and Outlet (Right) of the 900 mm Corrugated Steel Pipe

7.1.2 S-2 March Road Crossing

S-2 is a 1.8 m wide and approximately 1.0 m deep box culvert crossing March Road along SBT-3. At the downstream end of the culvert, the channel is poorly defined and composed of gravel and small, angular cobble with silts. The banks are heavily vegetated, and instream vegetation is also present. The 90° bend immediately downstream of the outlet is heavily protected with armour stone. At the upstream end, erosion is present along the left bank immediately upstream of the invert. The channel is not well aligned with the box culvert's inlet.

FIGURE 6 S-2 Photographs at the Inlet (Left) and Outlet (Right) of the 1.8 m Wide Box Culvert

Structurally, there is some chipping of the concrete at the top of the box culvert at the inlet. Within the box culvert, siltation has occurred on the right side of the culvert, and large material, seemingly armouring the bottom of the culvert, has lined the left side.

7.1.3 S-3 March Road Crossing

This small open-bottom box culvert joins the flows from the roadside ditch on the west side of March Road to Shirley's Brook along SBT-4. The channel is overgrown at both ends of the culvert. There is a drop of approximately 1.5 m between the invert elevation of the outlet and the bottom elevation of the Shirley's Brook tributary. This suggests that no significant amount of flow emerges from this culvert. The concrete is showing a fair amount of weathering at the inlet and outlet. Rebar is slightly exposed at the inlet.

FIGURE 7 S-3 Photographs at the Inlet (Left) and Outlet (Right) of the 0.9 m Wide Box Culvert

7.1.4 S-6 March Road Crossing

S-6 is a twin 1,500 mm CSP crossing at March Road connecting SBT-5 to SBT-6. At the upstream end of S-6, it appears as though most of the flow, when it exists, passes through the left culvert. There was a large amount of debris at the inlet, including a large wood column. Angular riprap was also noted along the left and right banks of the inlet. A bend exists at the upstream end of the structure, likely due to a large tree within the valley. This bend results in a poor alignment of the creek with the crossing culverts. At the outlet, both structures are partially collapsed, and silt has accumulated (1 to 3 cm) along the bottoms. The two channels, formed as a result of the two culverts, converge approximately 3 m from the outlet.

FIGURE 8 S-6 Photographs at the Inlet (Left) and Outlet (Right) of the Twin 1,500 mm Corrugated Steel Pipes

7.1.5 S-8 March Road Crossing

S-8 is a 1,200 mm circular concrete culvert for a small drainage feature in the southwestern quadrant of the development area. Structure S-8 was visited on January 29, 2016. The inlet is partially blocked with instream debris from human activity. The structure appears to be in good condition in a low-energy system. The outlet is heavily armoured with riprap along the bed and banks. Some bank erosion and undercutting was noted as the channel narrows downstream of the large concrete outlet structure.

FIGURE 9 S-8 Photographs at the Inlet (Left) and Outlet (Right) of the 1,200 mm Concrete Circular Culvert

8 CONCLUSIONS AND RECOMMENDATIONS

In support of the community design plan for the KNUEA, a geomorphic assessment involving characterizing watercourses within and surrounding the development area has been completed. The watercourses investigated include a portion of the main branch of Shirley's Brook and a number of its tributaries. As part of this study, reach lengths and their conditions were determined, meander belt widths were delineated, erosion threshold limits were established, and crossing assessments were completed.

There exists opportunity within the development boundary for enhancements to watercourses and habitat for various land-based and aquatic species. Future efforts should provide some focus on possible enhancement opportunities within the study area.

8.1 Reach Conditions and Risk Assessment

A review of historical aerial photographs from 1971, 1991, and 2008 revealed that agricultural activity has been the predominant land use in the study area, with some sections of remnant forest. Reaches for each of the watercourses were delineated, and a field study was undertaken, which included scoring each of the reaches based on rapid assessments (RGA and RSAT). In terms of channel stability, for the Shirley's Brook RGAs, the reaches in a high-transitional to in-adjustment state were SB-1B and SB-2B. Many of the tributaries had been altered by straightening in the past, and most reaches had low RGA scores. The exceptions were SBT-2, which was transitional, and SBT-4, which was in adjustment. Overall, most of the watercourses showed moderate ecological health based on the RSAT results.

8.2 Meander Belt Width

The space that a meandering watercourse occupies on its floodplain, within which all associated natural channel processes occur, is referred to as the meander belt. The objective of determining a meander belt width is to designate a corridor that is projected to contain all of the natural meander and migration tendencies of the channel. Based on planform, channel dimensions, and relative stability, meander belt widths were developed for the watercourses in the study area .The final belt widths range from 55 to 264 m for Shirley's Brook, and from 25 to 38 m for the tributaries. These values can be used to establish the hazard limits from a geomorphic perspective. All existing meander belt widths within the development boundary can be incorporated within a 40 m channel corridor.

8.3 Erosion Threshold

An erosion threshold analysis was performed, and critical discharge values were established as part of this study. Various cohesive sediment entrainment relationships were used to provide a range of values. Consideration was made for overlying deposited materials as well as the compact sublayers of various compositions found throughout the study site. Final critical discharge rates ranged from 0.57 to 1.32 m^3/s for study area tributaries, and from 2.23 to 2.36 m^3/s for Shirley's Brook. The location of the analyses corresponded to proposed pond locations and to the sensitivity of reaches within the study area.

8.4 Crossing Assessment

Five existing stream crossings were assessed as part of this study. These crossings were identified as possibly being altered for development. The crossing assessment included a description of the structures, the condition of the crossing, and the channel processes upstream and downstream of the structure.

9 REFERENCES

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APPENDIX A
Photograph Summary

Photo 1. SB-2A: View upstream to bank erosion on outside bend

Photo 2. SB-2B: View upstream to culverts at rail crossing

Photo 3. SB-1A: View upstream towards bridge at Marconi Ave.

Photo 4. SB-1B: View upstream along Shirley's Brook

Photo 5. SB-1B: View upstream of confluence of Shirley's Brook and Reach SBT-7B

Photo 6. SBT-7A: View upstream of bend near residential properties

Photo 7. SBT-7B: View upstream to bank erosion on outside bend

Photo 8. SBT-6: View upstream towards March Road

Photo 9. SBT-5: Weir along channel reach

Photo 10. SBT-5: View downstream of unconcentrated flow

Photo 11. SBT-5: Second weir along reach view downstream towards pond

Photo 12. SBT-4: View upstream of channel

Photo 13. SBT-3: View upstream of backwater near downstream extent of reach

Photo 14. SBT-3: View upstream towards agricultural fields

Photo 15. SBT-1B: View of incising ditch downstream of March Road

Photo 16. SBT-1A: View upstream of drainage ditch

Photo 17. SBT-1A: View upstream of weir structure

Photo 18. SBT-2: Downstream view of incising ditch

APPENDIX B
Rapid Geomorphic Assessment and
Rapid Stream Assessment Technique Field Sheets

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 **Reach:** SB-1B **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	GEOMORPHIC INDICATOR		PRESENT? (√)		FACTOR VALUE	
	Num	Description	No	Yes		
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded	✓			
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed		✓		
	8	Evidence of deposition in/around structures	✓			
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	7	2	0.22222	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed		✓		
	3	Bank Height increases	✓			
	4	Absence of depositional features (no bars)		✓		
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration		✓		
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	3	4	0.57143	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓		
	2	Occurrence of large organic debris		✓		
	3	Exposed tree roots		✓		
	4	Basal scour on inside meander bends	✓			
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach		✓		
	7	Length of basal scour >50% through subject reach		✓		
	8	Fracture lines along top of bank	✓			
		Sum of Indicies:	3	5	0.625	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓		
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)	✓			
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	6	1	0.14286	7

COMMENTS:

STABILITY INDEX: 0.39038

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI $\leq$ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI $\geq$ 0.41 = In Adjustment

Rapid Stream Assessment (RSAT)

PARISH geomorphic

Date: 4-23-13 **Reach:** SB-1B **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	3
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	5
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	23

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 7 **Bankfull Depth (m)** 2

Wetted Width (m) 4.5 **Wetted Depth (m)** 0.7

Gradient moderate **Entrenchment (m)** moderately confined

Substrate (Pool) (m) consolidated clay **Substrate (Riffle) (m)** 5-30cm cobble

Straight / Sinuous low sinuous **Bend Radius**

Bank Height (m) 1.5 **Bank Angle (º)** 60-80

Bank Material si, cl **Vegetation** deciduous trees

Pool - Riffle Spacing (m) approx 10m **Woody Debris** minor jams

Channel Hardening rip rap at sections of bank

Channel Disturbance debris jams

Distance Walked **Photos Taken** ☑ Yes ☐ No DS-US

Comments Reach breaks US of crossing with tree cover and SW outfall. Coarse material along channel bed up to 30cm. Steep banks and increased LWD jams towards mid-reach. Chutes and high flow along top LB. Valley wall contact along RB near US limit. Reach breaks at confluence.

RAPID GEOMORPHIC ASSESSMENT (RGA)

PARISH geomorphic

Date: 23-04-2013 **Reach:** SB-1A **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	PRESENT? (√) No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded		✓		
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed	✓			
	8	Evidence of deposition in/around structures	✓			
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	7	2	0.22222	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed	✓			
	3	Bank Height increases	✓			
	4	Absence of depositional features (no bars)		✓		
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration	✓			
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	5	2	0.28571	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓		
	2	Occurrence of large organic debris		✓		
	3	Exposed tree roots		✓		
	4	Basal scour on inside meander bends	✓			
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach		✓		
	7	Length of basal scour >50% through subject reach	✓			
	8	Fracture lines along top of bank		✓		
		Sum of Indicies:	3	5	0.625	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	✓			
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)	✓			
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.28323

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 =	In Regime
SI 0.21 - 0.40 =	Transitional or Stressed
SI ≥ 0.41 =	In Adjustment

PARISH geomorphic

RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 ***Reach:*** SB-1A ***Crew:***
Location: Kanata North
Weather Description: ***Recorder:***

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	4
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	5
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	25

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 6-7
Bankfull Depth (m) 1.5-1.8
Wetted Width (m) 3.5-4
Wetted Depth (m) 0.3-0.75, 0.5
Gradient low-m
Entrenchment (m) 30m
Substrate (Pool) (m) silt-fines
Substrate (Riffle) (m) gravel
Straight / Sinuous sinuous
Bend Radius
Bank Height (m) 1.25-1.6
Bank Angle (º) 35-80
Bank Material si
Vegetation tall grasses/deciduous trees
Pool - Riffle Spacing (m) undefined
Woody Debris minor
Channel Hardening rip-rap along channel bed at crossing/ constructed riffle at outfall
Channel Disturbance road crossing at mid-reach
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments Reach breaks at rail crossing culvert. Residential housing at TOBs. Embedded riprap along channel bed towards DS limit. Poorly defined riffle features. Sections of exposed clay till along bed. Some bank slumping towards mid-reach. Generally consolidated clay sublayer overlain by fines. Major bank erosion at outside meanders. Realigned section near crossing mid reach at 5m open bottom culvert. Reach breaks just US of crossing.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 ***Reach:*** SBT-7B ***Crew:*** 0
Location: Kanata North
Weather Description: 0 ***Recorder:*** 0

FORM / PROCESS	***GEOMORPHIC INDICATOR*** Num	Description	***PRESENT? (√)*** No	Yes	***FACTOR VALUE***	
Evidence of Aggradation (AI)	1	Lateral Bars	☑	☐		
	2	Coarse materials in riffles embedded	☑	☐		
	3	Siltation in pools	☑	☐		
	4	Mid-Channel Bars	☑	☐		
	5	Deposition on Point Bars	☑	☐		
	6	Poor longitudinal sorting of bed materials	☑	☐		
	7	Soft, unconsolidated bed	☑	☐		
	8	Evidence of deposition in/around structures	☑	☐		
	9	Deposition in the overbank zone	☑	☐		
		Sum of Indicies:	9	0	0	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock	☐	☑		
	2	Elevated tree roots/root fan above channel bed	☐	☑		
	3	Bank Height increases	☑	☐		
	4	Absence of depositional features (no bars)	☐	☑		
	5	Cut face on bar forms	☑	☐		
	6	Head cutting due to knick point migration	☐	☑		
	7	Suspended armour layer visible in bank	☑	☐		
		Sum of Indicies:	3	4	0.57143	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	☑	☐		
	2	Occurrence of large organic debris	☑	☐		
	3	Exposed tree roots	☐	☑		
	4	Basal scour on inside meander bends	☑	☐		
	5	Toe erosion on both sides of channel through riffle	☑	☐		
	6	Steep bank angles through most of reach	☑	☐		
	7	Length of basal scour >50% through subject reach	☑	☐		
	8	Fracture lines along top of bank	☑	☐		
		Sum of Indicies:	7	1	0.125	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	☑	☐		
	2	Single thread channel to multiple channel	☑	☐		
	3	Evolution of pool-riffle form to low bed relief form	☑	☐		
	4	Cut-off channel(s)	☑	☐		
	5	Formation of island(s)	☑	☐		
	6	Thalweg alignment out of phase meander form	☑	☐		
	7	Bar forms poorly formed / reworked / removed	☑	☐		
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.17411

Condition: In Regime

~ Factor Value = # YES / Total #

~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 = In Regime

SI 0.21 - 0.40 = Transitional or Stressed

SI ≥ 0.41 = In Adjustment

PARISH geomorphic — RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 **Reach:** SBT-7B **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	8
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	2
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	2
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	2
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	2
				Total:	20

Stability Rankings: ☐ <20 = LOW ☑ 20 - 35 = MODERATE ☐ >35 = HIGH

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 2-5, 5 **Bankfull Depth (m)** 0.75, 0.5

Wetted Width (m) 4 **Wetted Depth (m)** 0.2

Gradient moderate **Entrenchment (m)** wide open plain

Substrate (Pool) (m) consolidated clay **Substrate (Riffle) (m)** consolidated clay with some med cobbles

Straight / Sinuous straight **Bend Radius**

Bank Height (m) 2 **Bank Angle (º)** 30-50

Bank Material si **Vegetation** grass, deciduous trees

Pool - Riffle Spacing (m) 0.1-0.2 **Woody Debris** none

Channel Hardening none

Channel Disturbance none

Distance Walked **Photos Taken** ☑ Yes ☐ No DS-US

Comments DS end at bridge structure. A small drainage ditch confluence exists just US of bridge. Appears to be large concrete blocks along bed. Headcut 0.6m high. Bedrock lined upstream of headcut.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 ***Reach:*** SBT-7A ***Crew:*** 0
Location: Kanata North
Weather Description: 0 ***Recorder:*** 0

FORM / PROCESS	GEOMORPHIC INDICATOR Num	Description	PRESENT? (√) No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded		✓		
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed	✓			
	8	Evidence of deposition in/around structures	✓			
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	7	2	0.22222	9

FORM / PROCESS	Num	Description	No	Yes	FACTOR VALUE	
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed		✓		
	3	Bank Height increases	✓			
	4	Absence of depositional features (no bars)	✓			
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration	✓			
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	5	2	0.28571	7

FORM / PROCESS	Num	Description	No	Yes	FACTOR VALUE	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓		
	2	Occurrence of large organic debris		✓		
	3	Exposed tree roots		✓		
	4	Basal scour on inside meander bends		✓		
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach	✓			
	7	Length of basal scour >50% through subject reach	✓			
	8	Fracture lines along top of bank	✓			
		Sum of Indicies:	4	4	0.5	8

FORM / PROCESS	Num	Description	No	Yes	FACTOR VALUE	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	✓			
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)	✓			
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.25198

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic

Rapid Stream Assessment (RSAT)

Date: 4-23-13 **Reach:** SBT-7A **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	5
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	4
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	25

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 4, 3.5, 4.75
Bankfull Depth (m) 1, 0.8
Wetted Width (m) 3, 2.2
Wetted Depth (m) 0.45, 0.27
Gradient moderate
Entrenchment (m) wide open plain
Substrate (Pool) (m)
Substrate (Riffle) (m) small cobbles, pebbles, some scattered boulders
Straight / Sinuous sinuous
Bend Radius
Bank Height (m) 0.8
Bank Angle (º) 10-90, undercut
Bank Material si
Vegetation grass, deciduous trees, in stream grass
Pool - Riffle Spacing (m)
Woody Debris small and large trees
Channel Hardening large boulders placed along LB
Channel Disturbance
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments Consolidated clay sublayer overlain by small cobbles, gravel. Culvert US end of reach. Rounded cobbles 5-15cm diam along edge inside and in middle. DS end of reach is at confluence with main branch.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 **Reach:** SBT-6 **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	PRESENT? (√) No	PRESENT? (√) Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	☐	☐		
	2	Coarse materials in riffles embedded	☐	☐		
	3	Siltation in pools	☐	☐		
	4	Mid-Channel Bars	☐	☐		
	5	Deposition on Point Bars	☐	☐		
	6	Poor longitudinal sorting of bed materials	☐	☐		
	7	Soft, unconsolidated bed	☐	☐		
	8	Evidence of deposition in/around structures	☐	☐		
	9	Deposition in the overbank zone	☐	☐		
		Sum of Indicies:	0	0	#DIV/0!	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock	☐	☐		
	2	Elevated tree roots/root fan above channel bed	☐	☐		
	3	Bank Height increases	☐	☐		
	4	Absence of depositional features (no bars)	☐	☐		
	5	Cut face on bar forms	☐	☐		
	6	Head cutting due to knick point migration	☐	☐		
	7	Suspended armour layer visible in bank	☐	☐		
		Sum of Indicies:	0	0	#DIV/0!	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	☐	☐		
	2	Occurrence of large organic debris	☐	☐		
	3	Exposed tree roots	☐	☐		
	4	Basal scour on inside meander bends	☐	☐		
	5	Toe erosion on both sides of channel through riffle	☐	☐		
	6	Steep bank angles through most of reach	☐	☐		
	7	Length of basal scour >50% through subject reach	☐	☐		
	8	Fracture lines along top of bank	☐	☐		
		Sum of Indicies:	0	0	#DIV/0!	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	☐	☐		
	2	Single thread channel to multiple channel	☐	☐		
	3	Evolution of pool-riffle form to low bed relief form	☐	☐		
	4	Cut-off channel(s)	☐	☐		
	5	Formation of island(s)	☐	☐		
	6	Thalweg alignment out of phase meander form	☐	☐		
	7	Bar forms poorly formed / reworked / removed	☐	☐		
		Sum of Indicies:	0	0	#DIV/0!	0

COMMENTS: RGA not applied to this reach.

STABILITY INDEX: #DIV/0!

Condition:

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic

RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 **Reach:** SBT-6 **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	8
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	3
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	3
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	5
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	26

Stability Rankings: ☐ <20 = LOW ☑ 20 - 35 = MODERATE ☐ >35 = HIGH

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 2, 3 **Bankfull Depth (m)** 0.6, 0.8

Wetted Width (m) 1.4 **Wetted Depth (m)** 0.2

Gradient steep at US end, moderate DS **Entrenchment (m)**

Substrate (Pool) (m) small cobbles and pebbles **Substrate (Riffle) (m)** consolidated clay

Straight / Sinuous slightly sinuous at US end **Bend Radius**

Bank Height (m) 0.4-1.4, 0.8 **Bank Angle (º)** 10-40

Bank Material si/sand **Vegetation** In channel vegetation, trees at US end

Pool - Riffle Spacing (m) 5-10m, bedrock controlled **Woody Debris** none

Channel Hardening

Channel Disturbance

Distance Walked **Photos Taken** ☑ Yes ☐ No DS-US

Comments DS end at confluence of SBT-6, SBT-4, and SBT-7B. Smaller drainage stream. Exposed bedrock outcrop on LB. Bank scour at US end, just DS of road culvert. Twin CSPs at road ditch. One CSP crushed half way.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 24-04-2013 ***Reach:*** SBT-5 ***Crew:*** 0
Location: Kanata North
Weather Description: 0 ***Recorder:*** 0

FORM / PROCESS	*GEOMORPHIC INDICATOR* Num	Description	*PRESENT?* (√) No	Yes	*FACTOR VALUE*	
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded	✓			
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed	✓			
	8	Evidence of deposition in/around structures		✓		
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	7	2	0.22222	9

Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed	✓			
	3	Bank Height increases	✓			
	4	Absence of depositional features (no bars)		✓		
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration		✓		
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	4	3	0.42857	7

Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓		
	2	Occurrence of large organic debris		✓		
	3	Exposed tree roots		✓		
	4	Basal scour on inside meander bends	✓			
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach	✓			
	7	Length of basal scour >50% through subject reach	✓			
	8	Fracture lines along top of bank	✓			
		Sum of Indicies:	5	3	0.375	8

Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓		
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)	✓			
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	6	1	0.14286	7

COMMENTS:

STABILITY INDEX: 0.29216

Condition:

~ Factor Value = # YES / Total #

~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI	$\leq$ 0.20 =	In Regime
SI	0.21 - 0.40 =	Transitional or Stressed
SI	$\geq$ 0.41 =	In Adjustment

PARISH geomorphic RAPID STREAM ASSESSMENT (RSAT)

Date: 4-24-13 **Reach:** SBT-5 **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	4
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	3
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	22

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 2-4m where concentrated flow
Bankfull Depth (m) 0.2,0.4,0.5
Wetted Width (m) 1.5-1.9 at US end, 5-7 unconcentra
Wetted Depth (m) 0.1-0.15, 0.5-0.7 ponds
Gradient moderate
Entrenchment (m) plain to semi confined
Substrate (Pool) (m) bedrock
Substrate (Riffle) (m)
Straight / Sinuous slightly sinuous
Bend Radius
Bank Height (m) 0.2
Bank Angle (º) 20-30
Bank Material si
Vegetation grasses, deciduous trees
Pool - Riffle Spacing (m) undefined
Woody Debris minor
Channel Hardening CSP at end
Channel Disturbance dam/weirs
Distance Walked
Photos Taken ☑ Yes ☐ No US-DS

Comments US end is exposed bedrock channel with low banks. DS channel widens and is backed up by two weir structures and flows over a wide open area of exposed bedrock. Series of online ponds controlled by old weir structures. BF channel not well defined. Pond outlets to bedrock channel and transitions to concentrated overland flow with in-channel vegetation. Crosses March Rd via double CSP.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 24-04-2013 **Reach:** SBT-4 **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	Description	No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded	✓			
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed		✓		
	8	Evidence of deposition in/around structures	✓			
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	7	2	0.22222	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed		✓		
	3	Bank Height increases	✓			
	4	Absence of depositional features (no bars)		✓		
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration		✓		
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	3	4	0.57143	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓		
	2	Occurrence of large organic debris		✓		
	3	Exposed tree roots		✓		
	4	Basal scour on inside meander bends		✓		
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach	✓			
	7	Length of basal scour >50% through subject reach	✓			
	8	Fracture lines along top of bank	✓			
		Sum of Indicies:	4	4	0.5	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓		
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)		✓		
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	5	2	0.28571	7

COMMENTS:

STABILITY INDEX: 0.41

Condition: High transitional/In Adjustmen

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic

Rapid Stream Assessment (RSAT)

Date: 4-24-13 **Reach:** SBT-4 **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	5
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	5
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	5
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	26

Stability Rankings: ☐ <20 = LOW ☑ 20 - 35 = MODERATE ☐ >35 = HIGH

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 4.5, 3.2, 5
Bankfull Depth (m) 0.8, 0.9
Wetted Width (m) 2.2, 1.2, 4.3
Wetted Depth (m) 0.2, 0.4, 0.3
Gradient moderate - high at some sections
Entrenchment (m)
Substrate (Pool) (m) si/FS or bedrock
Substrate (Riffle) (m) pebble-10cm
Straight / Sinuous mix
Bend Radius
Bank Height (m) 1
Bank Angle (º) 20
Bank Material silt
Vegetation grasses
Pool - Riffle Spacing (m)
Woody Debris large amount
Channel Hardening
Channel Disturbance
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments At downstream end, bedrock bottom, straight and wide. Becomes narrower and more sinuous and deep towards US end - higher gradient. Big pool caused by large debris jam. Culvert at driveway with boulders downstream 15-60cm in diam. Knickpoint (KP) US of culvert approx. 0.3m drop. Bedrock substrate US of KP. Beaver dam acts to back channel up - soft unconsolidated fines US.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 24-04-2013 **Reach:** SBT-3 **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	Description	PRESENT? (√) No	PRESENT? (√) Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	√			
	2	Coarse materials in riffles embedded	√			
	3	Siltation in pools		√		
	4	Mid-Channel Bars	√			
	5	Deposition on Point Bars	√			
	6	Poor longitudinal sorting of bed materials	√			
	7	Soft, unconsolidated bed		√		
	8	Evidence of deposition in/around structures	√			
	9	Deposition in the overbank zone	√			
		Sum of Indicies:	7	2	0.22222	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		√		
	2	Elevated tree roots/root fan above channel bed	√			
	3	Bank Height increases	√			
	4	Absence of depositional features (no bars)		√		
	5	Cut face on bar forms	√			
	6	Head cutting due to knick point migration		√		
	7	Suspended armour layer visible in bank	√			
		Sum of Indicies:	4	3	0.42857	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	√			
	2	Occurrence of large organic debris	√			
	3	Exposed tree roots	√			
	4	Basal scour on inside meander bends	√			
	5	Toe erosion on both sides of channel through riffle	√			
	6	Steep bank angles through most of reach	√			
	7	Length of basal scour >50% through subject reach	√			
	8	Fracture lines along top of bank	√			
		Sum of Indicies:	8	0	0	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		√		
	2	Single thread channel to multiple channel	√			
	3	Evolution of pool-riffle form to low bed relief form	√			
	4	Cut-off channel(s)	√			
	5	Formation of island(s)	√			
	6	Thalweg alignment out of phase meander form	√			
	7	Bar forms poorly formed / reworked / removed	√			
		Sum of Indicies:	6	1	0.14286	7

COMMENTS:

STABILITY INDEX: 0.19841

Condition: In regime

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic

RAPID STREAM ASSESSMENT (RSAT)

Date: 4-24-13 **Reach:** SBT-3 **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	6
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	5
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	5
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	27

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 2.5-3 **Bankfull Depth (m)** 0.5

Wetted Width (m) 1.2 **Wetted Depth (m)** 0.18

Gradient moderate-steep US of online pond **Entrenchment (m)**

Substrate (Pool) (m) bedrock **Substrate (Riffle) (m)** bedrock with SC at ponds

Straight / Sinuous sinuous **Bend Radius**

Bank Height (m) 0.3 **Bank Angle (º)** 20

Bank Material silt and sand **Vegetation** grass

Pool - Riffle Spacing (m) **Woody Debris** little

Channel Hardening

Channel Disturbance crossing paths

Distance Walked **Photos Taken** ☑ Yes ☐ No DS-US

Comments From March Rd through woodlot - no main channel, swampy, around trees. Enters large online pond before narrowing to single channel with bedrock substrate. Grass vegetated banks Transitions to unconcentrated flow with bend straightening. Generally a bedrock substrate channel. Fairly sinuous outside of DS end and US end that turns to unconcentrated flow.

PARISH geomorphic — RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 **Reach:** SBT-2 **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	Description	PRESENT? (√) No	PRESENT? (√) Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	√			
	2	Coarse materials in riffles embedded	√			
	3	Siltation in pools		√		
	4	Mid-Channel Bars	√			
	5	Deposition on Point Bars	√			
	6	Poor longitudinal sorting of bed materials	√			
	7	Soft, unconsolidated bed	√			
	8	Evidence of deposition in/around structures	√			
	9	Deposition in the overbank zone	√			
		Sum of Indicies:	8	1	0.11111	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		√		
	2	Elevated tree roots/root fan above channel bed		√		
	3	Bank Height increases		√		
	4	Absence of depositional features (no bars)	√			
	5	Cut face on bar forms	√			
	6	Head cutting due to knick point migration		√		
	7	Suspended armour layer visible in bank	√			
		Sum of Indicies:	3	4	0.57143	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		√		
	2	Occurrence of large organic debris		√		
	3	Exposed tree roots		√		
	4	Basal scour on inside meander bends		√		
	5	Toe erosion on both sides of channel through riffle		√		
	6	Steep bank angles through most of reach		√		
	7	Length of basal scour >50% through subject reach		√		
	8	Fracture lines along top of bank	√			
		Sum of Indicies:	1	7	0.875	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	√			
	2	Single thread channel to multiple channel	√			
	3	Evolution of pool-riffle form to low bed relief form	√			
	4	Cut-off channel(s)	√			
	5	Formation of island(s)	√			
	6	Thalweg alignment out of phase meander form	√			
	7	Bar forms poorly formed / reworked / removed	√			
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.38938

Condition: High transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic

RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 ***Reach:*** SBT-2 ***Crew:***
Location: Kanata North
Weather Description: ***Recorder:***

	Excellent	*Good*	*Fair*	*Poor*	*Points*
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	2
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	21

Stability Rankings: *<20 = LOW* ☐ *20 - 35 = MODERATE* ☑ *>35 = HIGH* ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 3-4m **Bankfull Depth (m)** 0.75-1.5m

Wetted Width (m) 1-1.5m **Wetted Depth (m)** 0.1,0.15,0.2

Gradient moderate-steep **Entrenchment (m)** entrenchment incs DS

Substrate (Pool) (m) clay, silt, ms-cs **Substrate (Riffle) (m)** clay

Straight / Sinuous some sinuosity **Bend Radius**

Bank Height (m) 1-2m, 4-6m valley wall **Bank Angle (º)** 45-70

Bank Material silt **Vegetation** tall grass, deciduous tress

Pool - Riffle Spacing (m) 5-10m ds of KP **Woody Debris** fallen tress, major DS of KP

Channel Hardening none

Channel Disturbance culvert at beginning and end of reach

Distance Walked **Photos Taken** ☑ Yes ☐ No US-DS

Comments US end at CSP under railway tracks approx 1m diameter - pool at outlet with fines accumulated. Incising channel, at house midway through reach knickpoint (KP).
Consolidated clay channel. Degraded banks at bottom of KP/headcut. Sand deposits from bank erosion
Fines deposited at pools and runs due to bank erosion. Second KP 5m US of culvert at end of reach.
CSP approx 0.75m diam. Exposed clay till at runs and riffles.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 24-04-2013 **Reach:** SBT-1B **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

FORM / PROCESS	GEOMORPHIC INDICATOR Num	Description	PRESENT? (√) No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	✓			
	2	Coarse materials in riffles embedded	✓			
	3	Siltation in pools		✓		
	4	Mid-Channel Bars	✓			
	5	Deposition on Point Bars	✓			
	6	Poor longitudinal sorting of bed materials	✓			
	7	Soft, unconsolidated bed	✓			
	8	Evidence of deposition in/around structures	✓			
	9	Deposition in the overbank zone	✓			
		Sum of Indicies:	8	1	0.11111	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock		✓		
	2	Elevated tree roots/root fan above channel bed	✓			
	3	Bank Height increases		✓		
	4	Absence of depositional features (no bars)		✓		
	5	Cut face on bar forms	✓			
	6	Head cutting due to knick point migration		✓		
	7	Suspended armour layer visible in bank	✓			
		Sum of Indicies:	3	4	0.57143	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓			
	2	Occurrence of large organic debris	✓			
	3	Exposed tree roots	✓			
	4	Basal scour on inside meander bends	✓			
	5	Toe erosion on both sides of channel through riffle	✓			
	6	Steep bank angles through most of reach		✓		
	7	Length of basal scour >50% through subject reach		✓		
	8	Fracture lines along top of bank	✓			
		Sum of Indicies:	6	2	0.25	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	✓			
	2	Single thread channel to multiple channel	✓			
	3	Evolution of pool-riffle form to low bed relief form	✓			
	4	Cut-off channel(s)	✓			
	5	Formation of island(s)	✓			
	6	Thalweg alignment out of phase meander form	✓			
	7	Bar forms poorly formed / reworked / removed	✓			
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.23313

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic RAPID STREAM ASSESSMENT (RSAT)

Date: 4-24-13 **Reach:** SBT-1B **Crew:**
Location: Kanata North
Weather Description: 0 **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	4
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	4
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	2
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	2
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	2
				Total:	18

Stability Rankings: <20 = LOW ☑ 20 - 35 = MODERATE ☐ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 3-4m
Bankfull Depth (m) 0.5
Wetted Width (m) 1-1.2
Wetted Depth (m) 0.2-0.6
Gradient Low
Entrenchment (m) Agri. Fields
Substrate (Pool) (m) si/sand/cl
Substrate (Riffle) (m) No riffles - bedrock highs
Straight / Sinuous straight
Bend Radius
Bank Height (m) ~1m
Bank Angle (º) 60-70
Bank Material si/sand
Vegetation grass lined
Pool - Riffle Spacing (m) na
Woody Debris minimal-none
Channel Hardening
Channel Disturbance culvert at March Rd.
Distance Walked
Photos Taken ☑ Yes ☐ No US-DS

Comments Starts US of March Rd. Vegetated drainage ditch with water barely visible. Ditch runs along March Rd. before crossing through a closed bottom box culvert (1998-4064) with dimensions 1.8m wide by 0.9m deep. Widens out DS of March Rd. and bedrock substrate is visible. Banks become steep and erosion causes deposition of sand and silt in channel. Gullying occurring with exposed consolidated clay substrate and bedrock highs points. Incision causing bank failure.

PARISH geomorphic — RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 24-04-2013 **Reach:** SBT-1A **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

FORM / PROCESS	GEOMORPHIC INDICATOR Num	Description	PRESENT? (√) No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	☐	☐		
	2	Coarse materials in riffles embedded	☐	☐		
	3	Siltation in pools	☐	☐		
	4	Mid-Channel Bars	☐	☐		
	5	Deposition on Point Bars	☐	☐		
	6	Poor longitudinal sorting of bed materials	☐	☐		
	7	Soft, unconsolidated bed	☐	☐		
	8	Evidence of deposition in/around structures	☐	☐		
	9	Deposition in the overbank zone	☐	☐		
		Sum of Indicies:	0	0		0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock	☐	☐		
	2	Elevated tree roots/root fan above channel bed	☐	☐		
	3	Bank Height increases	☐	☐		
	4	Absence of depositional features (no bars)	☐	☐		
	5	Cut face on bar forms	☐	☐		
	6	Head cutting due to knick point migration	☐	☐		
	7	Suspended armour layer visible in bank	☐	☐		
		Sum of Indicies:	0	0		0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	☐	☐		
	2	Occurrence of large organic debris	☐	☐		
	3	Exposed tree roots	☐	☐		
	4	Basal scour on inside meander bends	☐	☐		
	5	Toe erosion on both sides of channel through riffle	☐	☐		
	6	Steep bank angles through most of reach	☐	☐		
	7	Length of basal scour >50% through subject reach	☐	☐		
	8	Fracture lines along top of bank	☐	☐		
		Sum of Indicies:	0	0		0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	☐	☐		
	2	Single thread channel to multiple channel	☐	☐		
	3	Evolution of pool-riffle form to low bed relief form	☐	☐		
	4	Cut-off channel(s)	☐	☐		
	5	Formation of island(s)	☐	☐		
	6	Thalweg alignment out of phase meander form	☐	☐		
	7	Bar forms poorly formed / reworked / removed	☐	☐		
		Sum of Indicies:	0	0		0

COMMENTS: ***STABILITY INDEX:***

NOT SCORED AS REACH IS A CHANNELIZED DRAINAGE DITCH

Condition: NA

~ Factor Value = # YES / Total #

~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 = In Regime

SI 0.21 - 0.40 = Transitional or Stressed

SI ≥ 0.41 = In Adjustment

PARISH geomorphic — RAPID STREAM ASSESSMENT (RSAT)

Date: 4-24-13 ***Reach:*** SBT-1A ***Crew:***
Location: Kanata North
Weather Description: 0 ***Recorder:***

	Excellent	*Good*	*Fair*	*Poor*	*Points*
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	8
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	3
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	2
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	4
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	3
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	3
				Total:	23

Stability Rankings: *<20 = LOW* ☐ *20 - 35 = MODERATE* ☑ *>35 = HIGH* ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) Few indicators - approx. 3-4m
Bankfull Depth (m) Approx. 0.5m
Wetted Width (m) 0.5-3.5m
Wetted Depth (m) 0.1-0.15m
Gradient low-m
Entrenchment (m)
Substrate (Pool) (m) clay/sand
Substrate (Riffle) (m) no features
Straight / Sinuous Straight
Bend Radius
Bank Height (m)
Bank Angle (º)
Bank Material Si/VFS
Vegetation Grass, deciduous and coniferous trees
Pool - Riffle Spacing (m)
Woody Debris
Channel Hardening
Channel Disturbance Weirs
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments DS end is @ CSP @railway, going US goes through backyards to Housen Dr., then is a culvert to other side of the road. Channelized drainage the entire length. Just US of Housten Dr. is two large stone weirs with angular rip-rap/substrate. Highly vegetated in-stream with bullrushes, etc. Turns @ right angle and then cross Housten Dr. again through CSP. US end is intersection with SBT-1B and 1A continues in northerly direction.

PARISH geomorphic — RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 **Reach:** SB-2B **Crew:** 0
Location: Kanata North
Weather Description: 0 **Recorder:** 0

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	PRESENT? (√) No	Yes	FACTOR VALUE	
Evidence of Aggradation (AI)	1	Lateral Bars	√			
	2	Coarse materials in riffles embedded		√		
	3	Siltation in pools		√		
	4	Mid-Channel Bars	√			
	5	Deposition on Point Bars	√			
	6	Poor longitudinal sorting of bed materials		√		
	7	Soft, unconsolidated bed		√		
	8	Evidence of deposition in/around structures	√			
	9	Deposition in the overbank zone	√			
		Sum of Indicies:	5	4	0.44444	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock	√			
	2	Elevated tree roots/root fan above channel bed		√		
	3	Bank Height increases	√			
	4	Absence of depositional features (no bars)	√			
	5	Cut face on bar forms	√			
	6	Head cutting due to knick point migration	√			
	7	Suspended armour layer visible in bank	√			
		Sum of Indicies:	6	1	0.14286	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		√		
	2	Occurrence of large organic debris		√		
	3	Exposed tree roots		√		
	4	Basal scour on inside meander bends	√			
	5	Toe erosion on both sides of channel through riffle		√		
	6	Steep bank angles through most of reach		√		
	7	Length of basal scour >50% through subject reach		√		
	8	Fracture lines along top of bank		√		
		Sum of Indicies:	1	7	0.875	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		√		
	2	Single thread channel to multiple channel	√			
	3	Evolution of pool-riffle form to low bed relief form	√			
	4	Cut-off channel(s)	√			
	5	Formation of island(s)	√			
	6	Thalweg alignment out of phase meander form	√			
	7	Bar forms poorly formed / reworked / removed	√			
		Sum of Indicies:	6	1	0.14286	7

COMMENTS:

STABILITY INDEX: 0.40129

Condition: In Adjustment

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4
SI ≤ 0.20 = In Regime
SI 0.21 - 0.40 = Transitional or Stressed
SI ≥ 0.41 = In Adjustment

PARISH geomorphic — RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 **Reach:** SB-2B **Crew:**
Location: Kanata North
Weather Description: **Recorder:**

	Excellent	Good	Fair	Poor	Points
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	3
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	3
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	4
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	5
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	5
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	4
				Total:	24

Stability Rankings: <20 = LOW ☐ 20 - 35 = MODERATE ☑ >35 = HIGH ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 5-7
Bankfull Depth (m) 1.5
Wetted Width (m) 3.5, 4.5, 5
Wetted Depth (m) 0.35-0.85
Gradient low-moderate
Entrenchment (m) unconfined
Substrate (Pool) (m) silt and fines
Substrate (Riffle) (m) gravel and silts, dense clay subpavement
Straight / Sinuous very sinuous
Bend Radius
Bank Height (m) 1
Bank Angle (º) 30-80
Bank Material si
Vegetation tall grasses/deciduous trees
Pool - Riffle Spacing (m) undefined
Woody Debris major
Channel Hardening none
Channel Disturbance LWD, beaver dam, debris jam
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments Reach breaks at confluence with constructed SW basin and beaver dam/ woody obstruction. Backwatered with soft bed at DS limit. Consolidated sub-layer. Steep bank angles. Channel widens up to 10m with chute formation. Significant bank erosion at outside meanders. Major debris jams with localized widening. Poorly defined riffle features. Bed material fairly consistent. Consolidated pavement overlain by gravel-pebble. Reach breaks at rail crossing. Closed bottom double concrete box culvert.

PARISH geomorphic

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 23-04-2013 ***Reach:*** SB-2A ***Crew:*** 0
Location: Kanata North
Weather Description: 0 ***Recorder:*** 0

FORM / PROCESS	*GEOMORPHIC INDICATOR* Num	Description	*PRESENT?* (√) No	Yes	*FACTOR VALUE*	
Evidence of Aggradation (AI)	1	Lateral Bars	☑	☐		
	2	Coarse materials in riffles embedded	☐	☑		
	3	Siltation in pools	☐	☑		
	4	Mid-Channel Bars	☑	☐		
	5	Deposition on Point Bars	☐	☑		
	6	Poor longitudinal sorting of bed materials	☑	☐		
	7	Soft, unconsolidated bed	☐	☑		
	8	Evidence of deposition in/around structures	☑	☐		
	9	Deposition in the overbank zone	☑	☐		
		Sum of Indicies:	5	4	0.44444	9
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden/bedrock	☑	☐		
	2	Elevated tree roots/root fan above channel bed	☐	☑		
	3	Bank Height increases	☑	☐		
	4	Absence of depositional features (no bars)	☑	☐		
	5	Cut face on bar forms	☑	☐		
	6	Head cutting due to knick point migration	☑	☐		
	7	Suspended armour layer visible in bank	☑	☐		
		Sum of Indicies:	6	1	0.14286	7
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	☐	☑		
	2	Occurrence of large organic debris	☐	☑		
	3	Exposed tree roots	☐	☑		
	4	Basal scour on inside meander bends	☑	☐		
	5	Toe erosion on both sides of channel through riffle	☑	☐		
	6	Steep bank angles through most of reach	☐	☑		
	7	Length of basal scour >50% through subject reach	☐	☑		
	8	Fracture lines along top of bank	☑	☐		
		Sum of Indicies:	3	5	0.625	8
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	☑	☐		
	2	Single thread channel to multiple channel	☑	☐		
	3	Evolution of pool-riffle form to low bed relief form	☑	☐		
	4	Cut-off channel(s)	☑	☐		
	5	Formation of island(s)	☑	☐		
	6	Thalweg alignment out of phase meander form	☑	☐		
	7	Bar forms poorly formed / reworked / removed	☑	☐		
		Sum of Indicies:	7	0	0	7

COMMENTS:

STABILITY INDEX: 0.30308

Condition: Transitional

~ Factor Value = # YES / Total #
~ STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

SI ≤ 0.20 =	In Regime	
SI 0.21 - 0.40 =	Transitional or Stressed	
SI ≥ 0.41 =	In Adjustment	

PARISH geomorphic — RAPID STREAM ASSESSMENT (RSAT)

Date: 4-23-13 ***Reach:*** SB-2A ***Crew:***
Location: Kanata North
Weather Description: ***Recorder:***

	Excellent	*Good*	*Fair*	*Poor*	*Points*
Channel Stability	9 - 11	6 - 8	3 - 5	0 - 2	3
Scour / Deposition	7 - 8	5 - 6	3 - 4	0 - 2	5
Instream Habitat	7 - 8	5 - 6	3 - 4	0 - 2	5
Water Quality	7 - 8	5 - 6	3 - 4	0 - 2	5
Riparian Conditions	6 - 7	4 - 5	2 - 3	0 - 2	4
Biological Indicators	7 - 8	5 - 6	3 - 4	0 - 2	5
				Total:	27

Stability Rankings: *<20 = LOW* ☐ *20 - 35 = MODERATE* ☑ *>35 = HIGH* ☐

Channel Dimensions (Measured / Estimated)

Bankfull Width (m) 6-7
Bankfull Depth (m) 0.7-1.5
Wetted Width (m) 2-3
Wetted Depth (m) 0.3-0.6, pool 0.8
Gradient medium
Entrenchment (m)
Substrate (Pool) (m) fines, silt
Substrate (Riffle) (m) small boulders, cobbles, pebbles
Straight / Sinuous very sinuous
Bend Radius
Bank Height (m) 1.5
Bank Angle (º) 90, undercut
Bank Material sands, silt, gravel
Vegetation grasses, deciduous trees
Pool - Riffle Spacing (m)
Woody Debris fallen trees
Channel Hardening SWMP outlets US of DS culvert - 10cm angular stone lines channel
Channel Disturbance Beaver dam/debris jam at US end, CSP at DS extent
Distance Walked
Photos Taken ☑ Yes ☐ No DS-US

Comments CSP at DS end approx 2m wide. SWMP drains into stream approx 10m US of CSP. Flat floodplain along RB, LB undercut with high degree of erosion. Pebbles, 2cm over highly compacted clay. Fish observed where tree cover exists. Highly eroding banks on bends (inside and out). Point bars consist of silt, gravel, fine sands.

APPENDIX C
Longitudinal Profiles

SB-3:

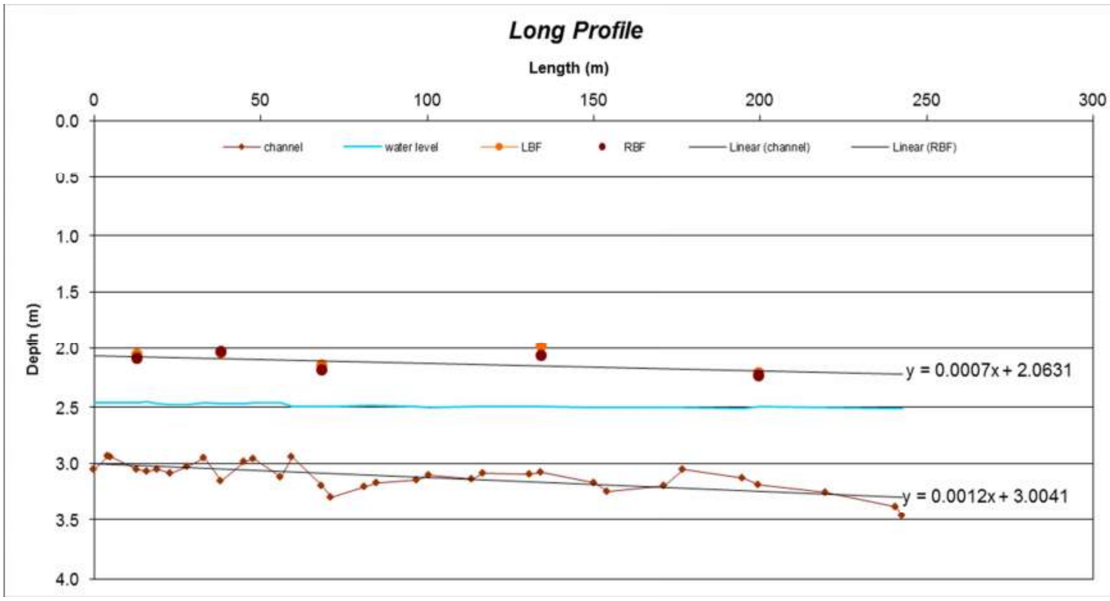


Figure C1: Long profile of detailed site along SB-3.

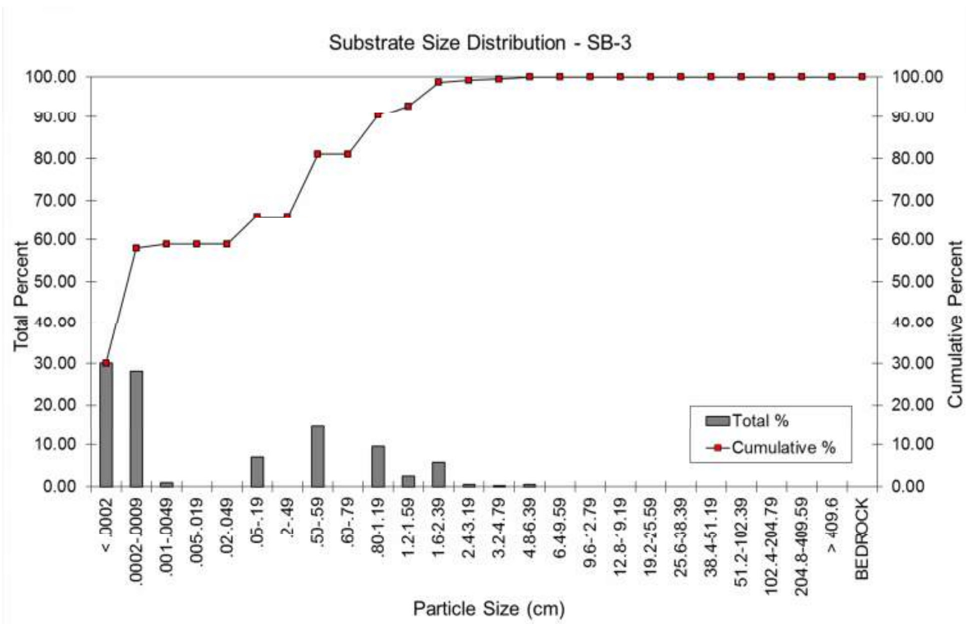


Figure C2: Substrate size distribution for SB-3 XS1-XS5.

SB-4:

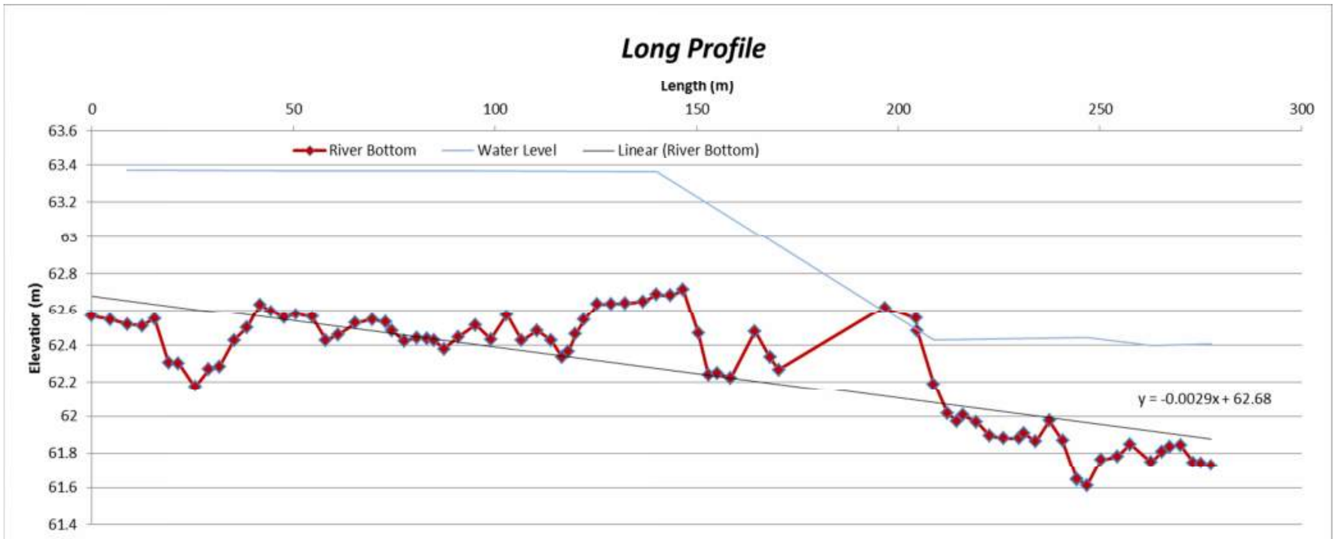


Figure C3: Long profile of detailed site along SB-4.

SBT-3:

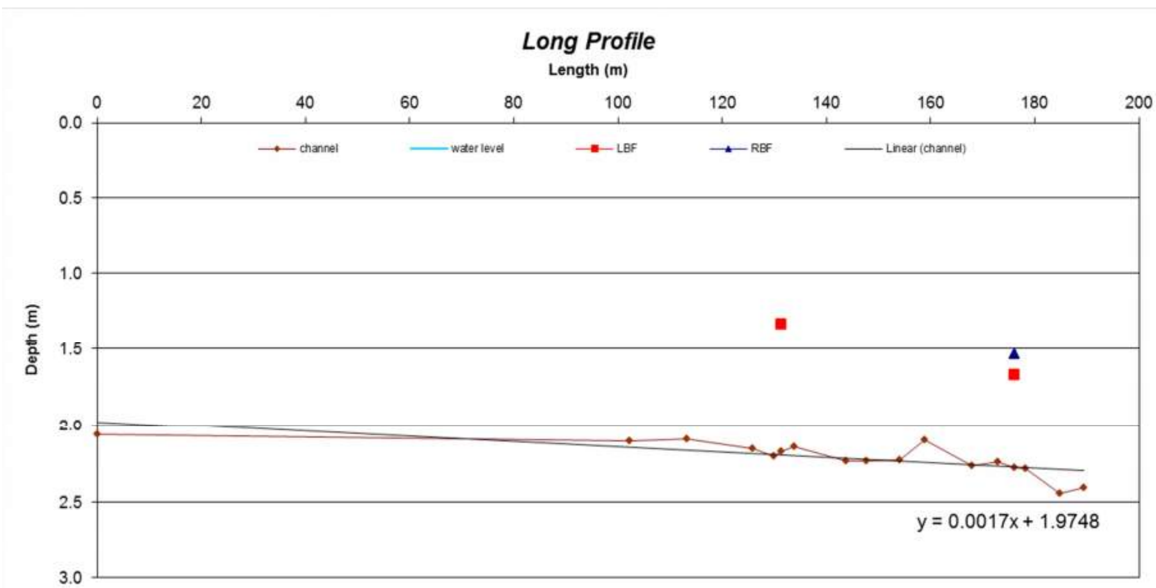


Figure C4: Long profile of detailed site along SBT-3.

SBT-4:

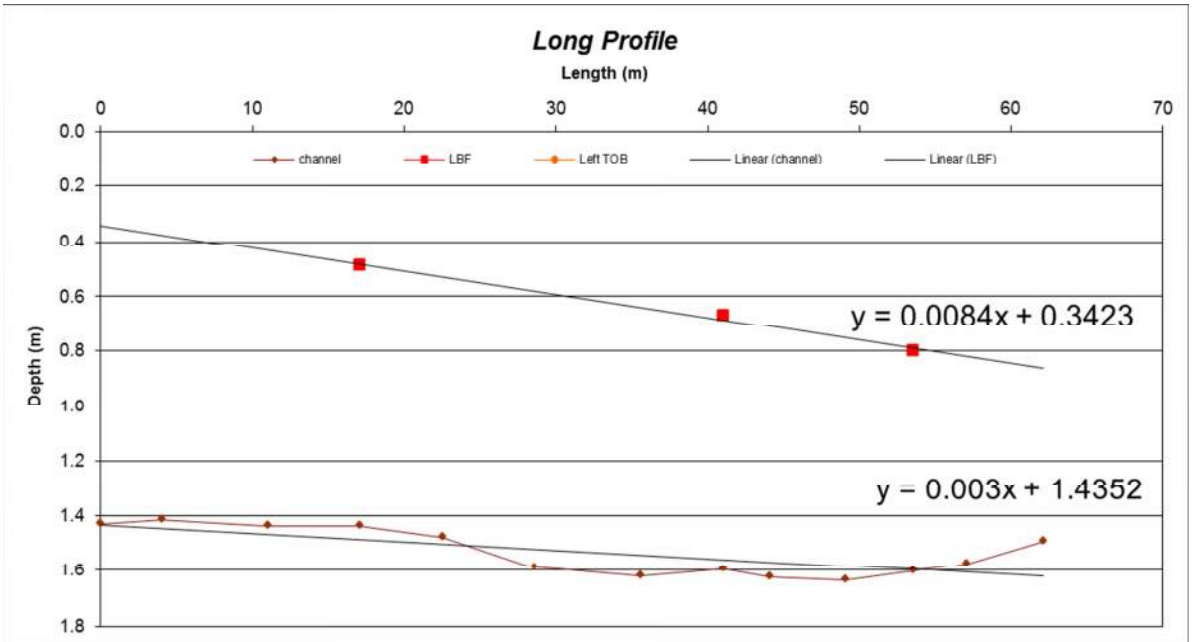


Figure C5: Long profile of detailed site along SBT-4.

SBT-5:

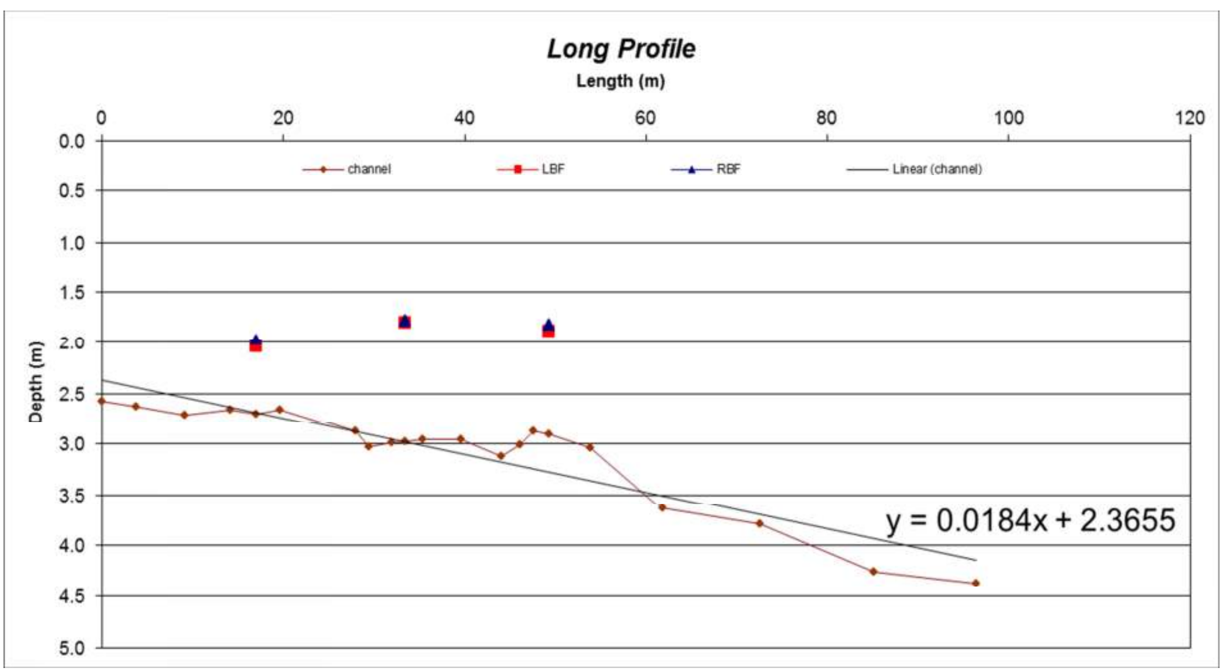
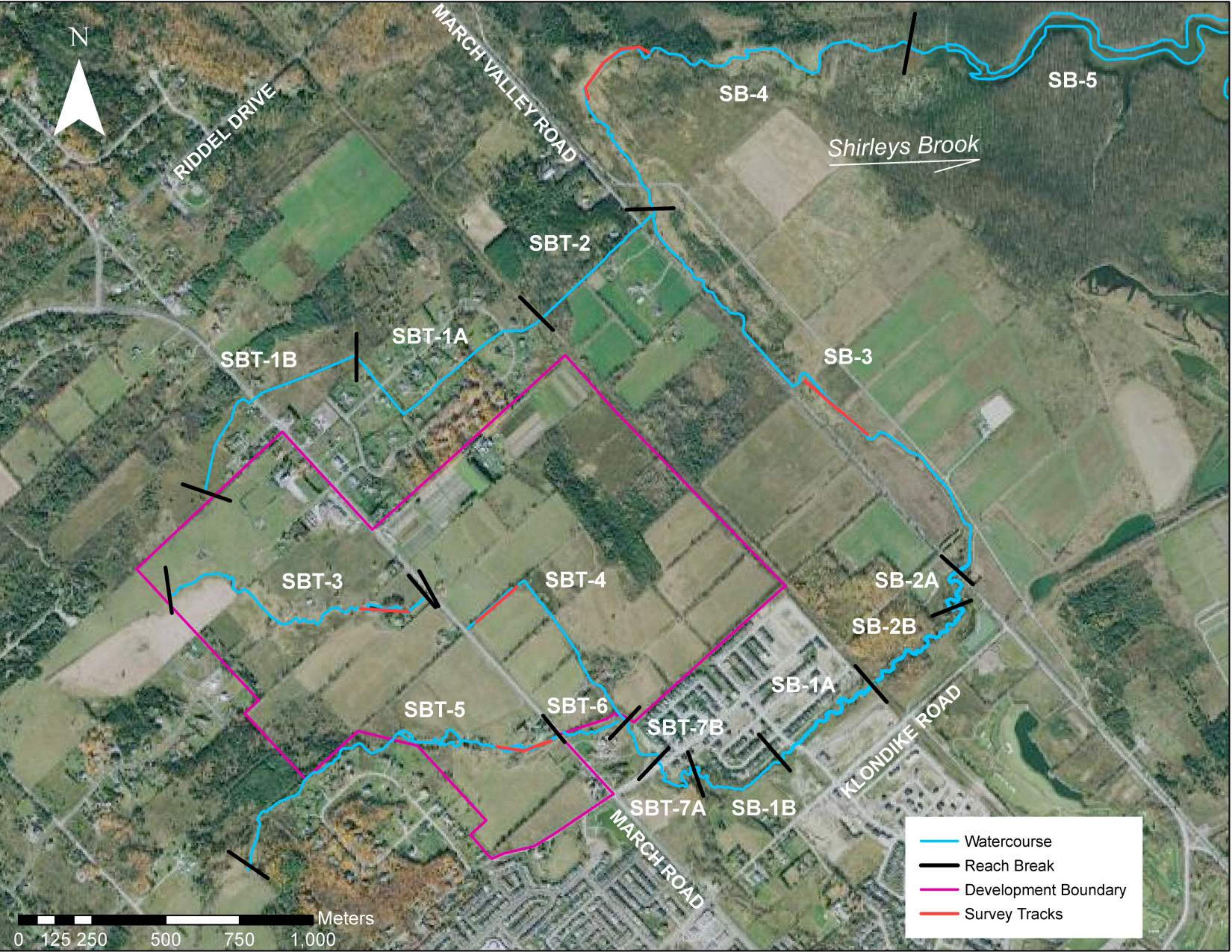
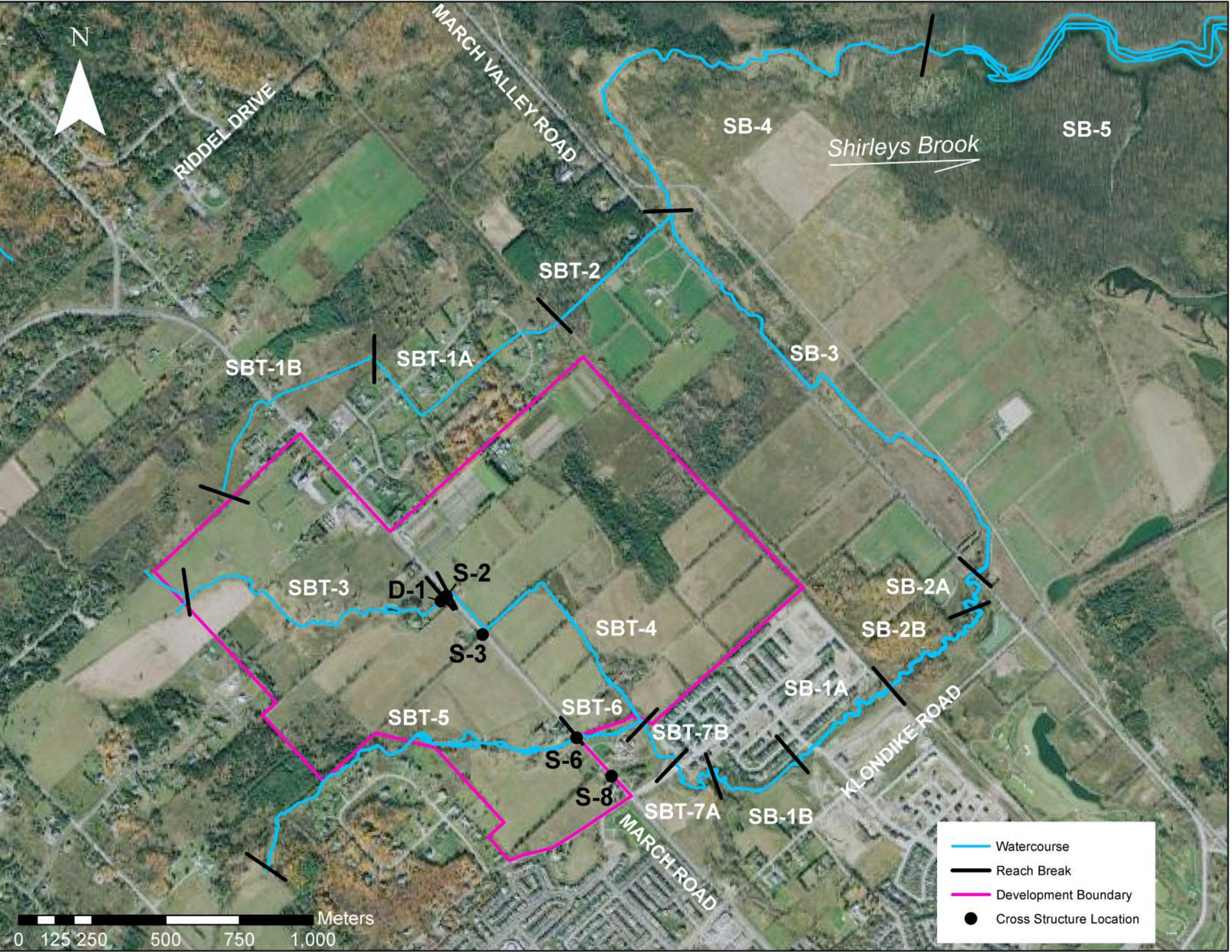


Figure C6: Long profile of detailed site along SBT-5.



N
RIDDEL DRIVE
MARCH VALLEY ROAD
SB-4
SB-5
Shirleys Brook
SBT-2
SBT-1A
SBT-1B
SB-3
SBT-3
SBT-4
SB-2A
SB-2B
SB-1A
SBT-5
SBT-6
SBT-7B
KLONDIKE ROAD
SBT-7A
SB-1B
MARCH ROAD
Watercourse
Reach Break
Development Boundary
Survey Tracks
0 125 250 500 750 1,000
Meters

APPENDIX D
Crossing Structure Locations



N
RIDDEL DRIVE
MARCH VALLEY ROAD
SB-4
SB-5
Shirleys Brook
SBT-2
SBT-1B
SBT-1A
SB-3
SBT-3
S-2
D-1
S-3
SBT-4
SB-2A
SB-2B
SB-1A
KLONDIKE ROAD
SBT-6
SBT-5
S-6
SBT-7B
S-8
SBT-7A
SB-1B
MARCH ROAD
Watercourse
Reach Break
Development Boundary
Cross Structure Location
0 125 250 500 750 1,000
Meters

Appendix P

Kanata North Urban Expansion Area

Headwater Drainage Features Geomorphic Assessment

(Parish Aquatic Services – March 2016)

PARISH aquatic services
A Division of Matrix Solutions Inc.

KANATA NORTH URBAN EXPANSION AREA
HEADWATER DRAINAGE FEATURES GEOMORPHIC ASSESSMENT

Report Prepared for:
NOVATECH ENGINEERING AND CONSULTANTS LTD.

Prepared by:
PARISH AQUATIC SERVICES
a Division of Matrix Solutions Inc.

March 2016
Perth, Ontario

15A Foster St.
Perth, ON, Canada K7H 1R5
P 613.686.5492
www.parishgeomorphic.com

KANATA NORTH URBAN EXPANSION AREA

HEADWATER DRAINAGE FEATURES GEOMORPHIC ASSESSMENT

Report prepared for Novatech Engineering Consultants Ltd., March 2016

Matthew McCombs, M.A.Sc., EIT
Water Resources EIT

reviewed by
John Parish, P.Geo.
Principal Geomorphologist

DISCLAIMER

We certify that this report is accurate and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but not guaranteed. We have exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

RELIANCE CLAUSE

This report has been prepared for Novatech Engineering Consultants Ltd., on behalf of the Kanata North Landowner's Group and in support of the Kanata North Community Design Plan. It is hereby acknowledged that Metcalfe Realty Company Limited, J.G. Richards Ltd., and 8409706 Canada Inc. (Valecraft Homes), 3223701 Canada Inc. (Junic/Multivesco) can rely upon this report for the purposes of obtaining approval of the community design plan and for their own use to seek development approval.

Any use of this report by other parties, or any reliance on decisions made based on it, are the responsibility of that party. We are not responsible for damages or injuries incurred by any other party, as a result of decisions made or actions taken based on this report.

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FIGURES

TABLE

1 INTRODUCTION

1.1 Existing Drainage Features

The *Kanata North Urban Expansion Area Fluvial Geomorphic Assessment* (PARISH 2016) report by PARISH Aquatic Services, a Division of Matrix Solutions Inc., provides geomorphic assessments of Shirley's Brook and its tributaries through the Kanata North Urban Expansion Area. There are a number of channels contained within the study area that were not discussed as part of that report. Those that were excluded are open drains/ditches that lack natural geomorphic features and were created primarily to remove excess water from agricultural lands.

Within the study area, these ditches have been designated with the letters A to I (Figure 1) and are described in the current report. There is also a ditch that runs along the railway corridor that has been identified as drainage feature T. The ditches are shown on Figure 1. Drainage features A, B, C, D, H, and I connect to a section of the ditch along the railway. Drainage features E and F outlet to Tributary 2. Feature F drains the roadside ditch system of a residential subdivision located west of the development area. The flow in drainage feature G leads to a culvert that passes under March Road, and flows along a short drainage channel on the east side of the road, which outlets to Tributary 3 of Shirley's Brook.

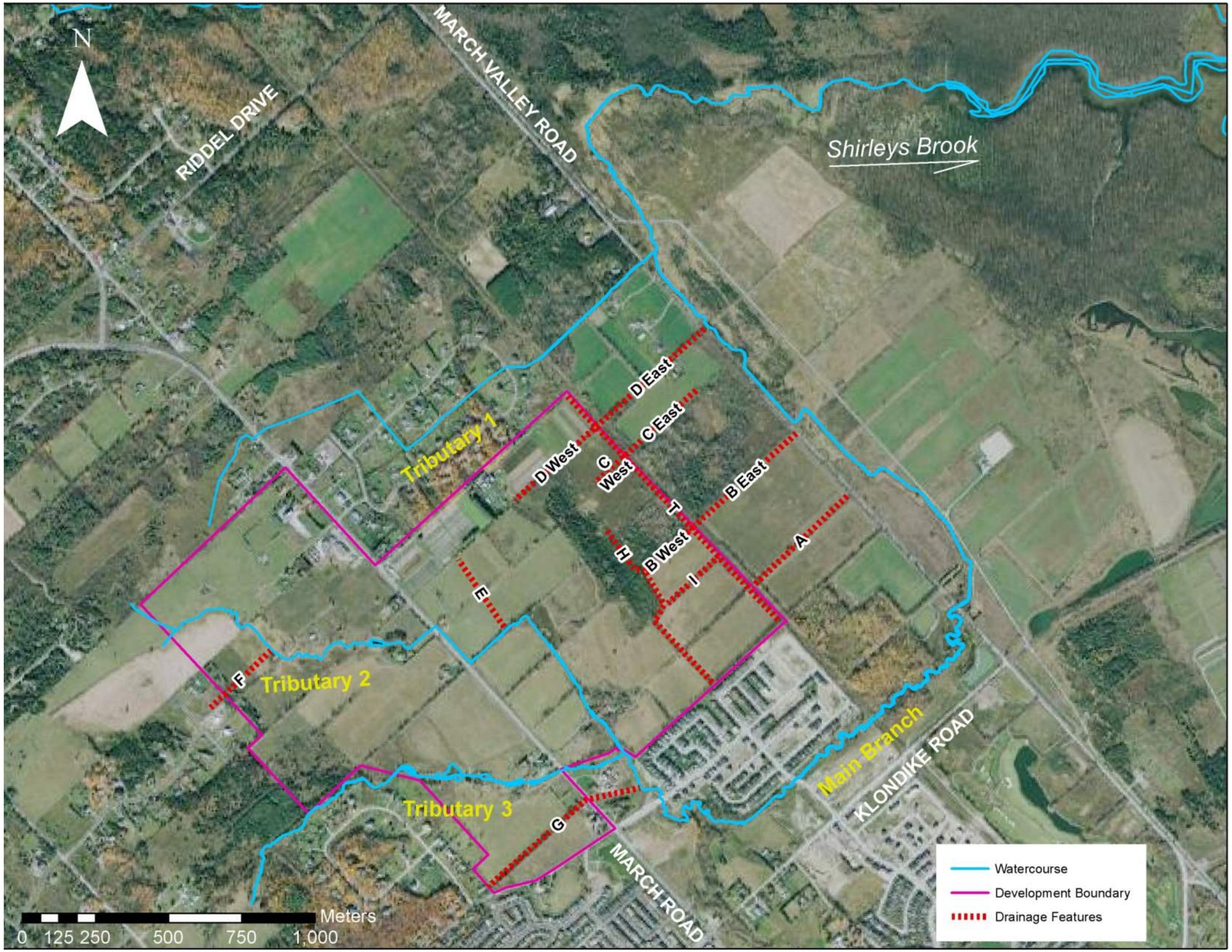

FIGURE 1 Existing Drainage Features within the Study Area

2 EXISTING CONDITIONS

As per The City of Ottawa's request, PARISH assessed the headwater drainage features within the study area. Field visits were conducted from April 23 to 25, and June 12 to 13, 2013. The features investigated are typically small, first order channels or swales. They could also represent ditches and drainage works created by humans to convey overland flow more efficiently. In this case, the human-built channels are designed primarily to drain agricultural land or to convey runoff flow from built up areas to a receiving watercourse. In general, ditches are built as defined trapezoidal channels and therefore appear unnatural in form, often leading to the assumption that they provide little value outside of flow conveyance. It is possible that some geomorphic functions may develop over time. The *Evaluation, Classification and Management of Headwater Drainage Features Guideline* (TRCA and CVC 2014) was used for this assessment. A fisheries assessment of the drainage features, *Kanata North Headwater Report* (BEC and MEPI 2015), is provided by Bowfin Environmental Consulting and Muncaster Environmental Planning Inc.

2.1 Field Observations

2.1.1 Ditch A

At the upstream extent, the Ditch A is dry for a distance, and midway between the railway and March Valley Road, the ditch runs through a degraded CSP providing access between fields. Nearer to March Valley Road, there is an increased amount of water in the ditch, and the cross-section widens out to a width of 2.5 m and a depth of 0.5 m. Substrate and bank materials were composed of silt and clay. The channel outlets at the roadside ditch along March Valley Road. Overall, the channel was densely vegetated. Natural stream features were not observed at any point.

2.1.2 Ditch B

The upstream end of Ditch B runs parallel to the rail tracks for approximately 140 m before turning 90 degrees east to run parallel to Klondike Road for the remaining length. Upstream of the bend, the ditch has a defined trapezoidal shape, with a width of 2.5 m and a depth of 0.7 m. There is a low gradient with sitting water full of dead leaves. Approximately 230 m downstream of the bend, the ditch enters a culvert (1.8 m circular concrete) running beneath the railway crossing. The portion of Ditch B upstream of the 1.8 m circular concrete culvert running beneath the railway crossing is assessed as part of BEC and MEPI (2015). Immediately downstream of the culvert, the ditch has pooled/backwatered due to debris jams downstream. Approximately halfway along the ditch between the culvert and March Valley Road, the channel becomes dry. Approximately 10 m downstream, an orange pipe (0.1 m diameter) is visible and outletting notable flow. Based on these observations, Ditch B is possibly piped or tile drained for a distance. Downstream of the pipe, the bankfull width is 3.5 m, and the bankfull depth is 1.0 m. Substrate along the ditch is clay, silt, small gravel, and pebbles, while the bank material is primarily clay and silt. At the downstream extent of the ditch, just upstream of where it meets the roadside drainage ditch on March Valley Road, the bed contains thick, silty muck deposits. There is significant tree cover along the entire ditch, and a mixed forest is located along the north side of the ditch.

2.1.3 Ditch C

Ditch C begins approximately 130 m upstream of the railway line. It crosses under the railway line through a 0.75 m CSP. Downstream of the culvert, a large pool has developed, and a wooded area was flooded at the time of the survey. This pooling occurred as the elevation of the channel does not connect to the ditch present approximately 5 m east. Only at a higher flow would Ditch C downstream of the railway culvert contain any flowing water. The ditch is much shallower than the others with a width of 1.1 m and a depth of 0.1 m. The ditch has a low gradient, and the substrate is primarily silt and very fine sand. The ditch feature extends downstream for approximately 455 m before ending at a large depression, which is currently used as a brush pile.

2.1.4 Ditch D

Ditch D extends for approximately 860 m and includes a crossing at the railway line. Upstream of the 0.9 m CSP at the railway, the channel is 2.6 m wide and 0.45 m deep, while downstream, the dimensions are 3.4 m wide and 0.45 m deep. The substrate consisted of soft, silty clay mixed with organics. The ditch is lined with trees and shrubs.

2.1.5 Ditch E

Ditch E is an open agricultural ditch that is quite wide and shallow, with a width of approximately 3.5 m and a depth of 0.35 m. Substrate was silt, clay, and very fine sand. There is a culvert mid-reach (0.6 m CSP), providing an access between fields. There are active agricultural lands adjacent to the ditch on both sides for most of its length. At the upstream end, it is lined with a single line of small trees. The ditch dries up at the upstream end.

2.1.6 Ditch F

Ditch F has a defined trapezoidal shape throughout its length with a width of 2.5 m and a depth of 0.45 m. The upstream source is a roadside drainage ditch along Nadia Lane. The substrate was unconsolidated silty clay. A few transition type features have developed, with particles 1 to 3 cm in diameter. A low flow path has developed at the downstream end of the ditch. Trees have grown in and along the ditch, and a meandering pattern exists due to trees obstructing and diverting flow.

2.1.7 Ditch G

Ditch G was not investigated during the field outing. Aerial photography indicates that it is a straightened drainage ditch that runs parallel to Old Carp Road. There are large deciduous and coniferous trees, along with shrubs lining most of the path. Some sinuosity can be observed, and the bankfull width is roughly 0.6 to 1.0 m. The ditch runs through a 1.2 m circular culvert at March Road. Downstream, the channel runs through an open field to its confluence with Tributary 3 of Shirley's Brook.

2.1.8 Ditch I

The upstream end of Ditch I appeared to have been recently dredged, and the water in this section appeared stagnant. This portion of Ditch I is described in BEC and MEPI (2015). Where the ditch begins to run east, parallel to Klondike Road, very little water was observed. The ditch is bordered by trees and shrubs, and the instream vegetation is dense. Immediately adjacent to the vegetation is farmland along both sides of the channel. The trapezoidal cross-section was 1.5 m wide and 0.4 m deep. The ditch crosses under the Canadian National Railway (CNR) line through a corrugated steel pipe (CSP) culvert approximately 1.5 m in diameter.

2.1.9 Ditch T

Drainage along the CNR line, displayed as Ditch T on Figure 2, is not considered a continuous channel as the drainage system is graded to outlet to ditches A to D. In many sections, the ditch has a width of 2.3 m and a depth of 0.3 m, with substrate consisting of silt and organic muck. In some locations, the ditch is highly vegetated within the channel, and the water appeared to be stagnant. There are trees and shrubs lining most of the length of Ditch T.

2.2 Geomorphic Assessment Results

Headwater systems are considered important sources of food, sediment, water, nutrients, and organic matter for downstream reaches. The ditches in the development area were assessed using the *Evaluation, Classification and Management of Headwater Drainage Features Guideline* (TRCA and CVC 2014). The attributes and functions of HDFs were assessed by considering the evaluation, classification, and management of each feature to address the protection, conservation, and mitigation of headwater functions. Table 1 provides a summary of the classification of headwater channels. Based on the classification of each channel, a management recommendation is made. The table was compiled in cooperation with Bowfin Environmental Consulting and Muncaster Environmental Planning Inc.

TABLE 1 Summary of Functional Classifications and Management

Drainage Feature Segment	STEP 1		STEP 2	STEP 3	STEP 4	Management Recommendations
	Hydrology	Modifiers	Riparian	Fish Habitat	Terrestrial Habitat	
A	Limited	-No natural stream features -Overgrown channel -Silt and clay substrate	Limited	Not sampled	Not sampled	No management required
B	Contributing	-Defined trapezoidal shape -Tile drained or piped -Substrate includes silty muck and clay deposits	Important	Valued to Contributing	Limited	Conservation
C	Limited	-No connectivity downstream -Substrate primarily silt	Important	None (not connected)	Not sampled	No management required
D	Contributing	-Trapezoidal Form -Soft silty clay substrate	D – East Valued	D – East unknown	Not sampled	D East – Conservation
			D – West Limited	D – West Contributing		D- West - Mitigation
E	Limited	-No natural stream features -Recently dredged -Overgrown -Siltation of silts and fine sands	Limited	Not sampled	Not sampled	No management required
F	Contributing	-Defined trapezoidal shape -Loose silty clay substrate	Upstream of Confluence -Valued	Upstream of Confluence - Contributing	Not sampled	Upstream of Confluence –Mitigation
			Confluence - Important	Confluence - Valued		Confluence - Protection
G	Contributing	-SWMF outlet	Limited	No fish habitat during summer. May provide habitat in spring but poor downstream connection.	Not sampled	Mitigation
H	Limited	-Abandoned agricultural drain - Adjacent swamp habitat	Important	Contributing	Important	Conservation
I	Limited	-Constructed agricultural drain	Limited	Contributing	Limited	No management required
T	Limited	-CNR line drain -Overgrown channel -Soft much substrate	Limited	Contributing	Limited	No management required

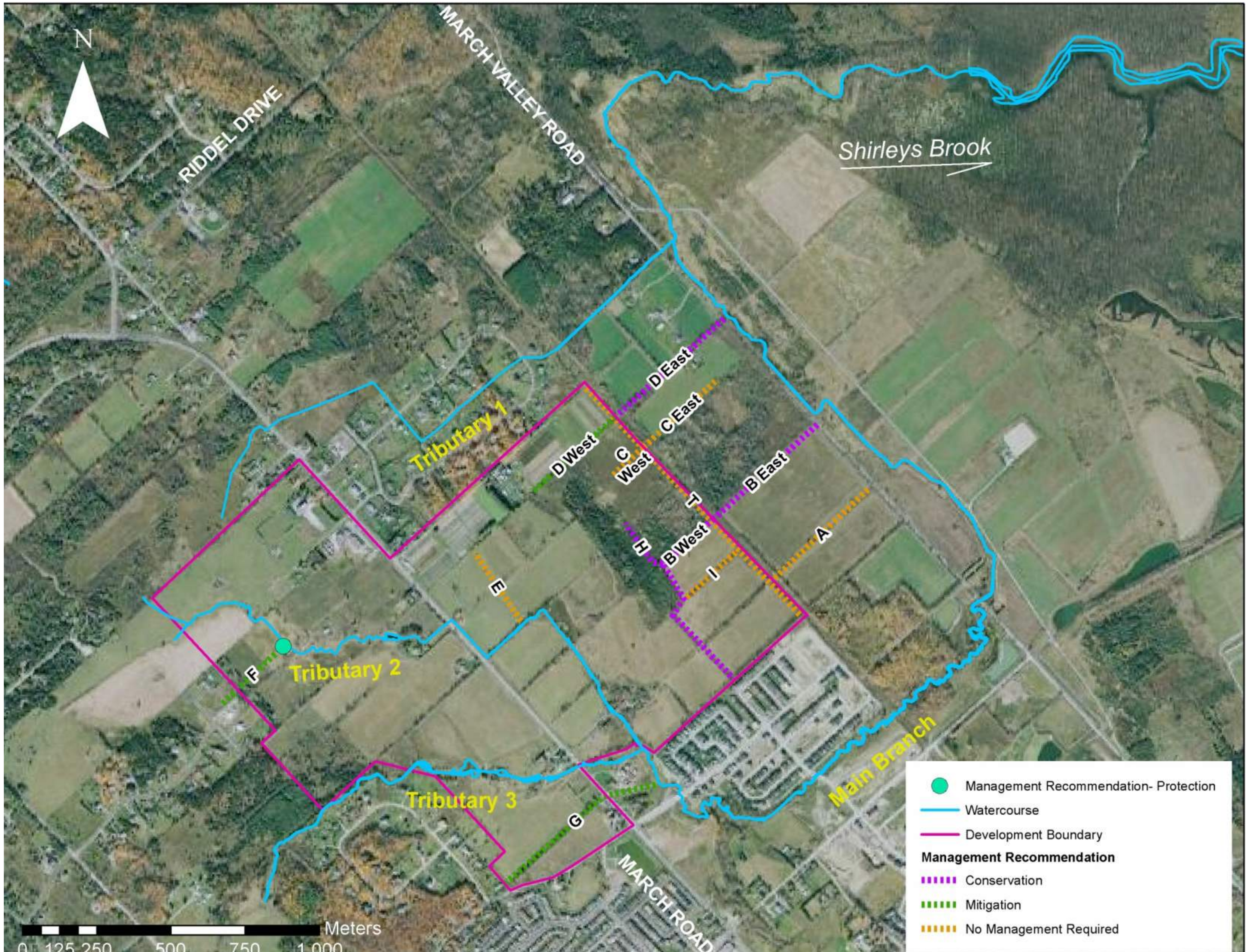

FIGURE 2 Drainage Feature Locations and Classifications

3 CONCLUSIONS

Ten open drains/ditches that lack natural geomorphic features, created primarily to remove excess water from agricultural lands, were assessed. The *Evaluation, Classification and Management of Headwater Drainage Features Guideline* (TRCA and CVC 2014) was used to assess the channels and provide management recommendations. Based on the guidelines, Ditches G, D west CNR line, and F upstream of the confluence with Tributary 2 require mitigation, Ditches B, D east of CNR line, and H require conservation, and Ditch F at the confluence with Tributary 2 requires protection.

4 REFERENCES

Bowfin Environmental Consulting (BEC) and Muncaster Environmental Planning Inc. (MEPI). 2015. *Kanata North Headwaters Report*. Prepared for: Novatech Engineering Consultants Ltd. September 2015.

PARISH Aquatic Services (PARISH). 2016. *Kanata North Urban Expansion Area Fluvial Geomorphic Assessment*. Report prepared for Novatech Engineering Consultants Ltd. Perth, Ontario. March 2016.

Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC). 2014. *Evaluation, Classification and Management of Headwater Drainage Features Guideline*. Approved July 2013. Finalized January 2014. http://www.trca.on.ca/dotAsset/180724.pdf

Appendix Q

Kanata North Headwaters Report

(Bowfin Environmental Consulting & Muncaster Environmental
Planning Inc. – September 2015)

Muncaster
Environmental
Planning Inc.

October 15, 2015

Mr. Murray Chown
Senior Planner
NOVATECH
Suite 200, 240 Michael Cowpland Drive
Kanata, Ontario
K2M 1P6

Dear Murray:

RE: Kanata North Urban Expansion Area
Headwaters Assessment

Attached is our headwaters assessment for the channels within and in the vicinity of Woodlot S20 in the east portion of the Kanata North Urban Expansion Area.

As shown in Table 9 of the report the conclusions of the headwaters assessment are based on four evaluation criteria: hydrology, riparian conditions, fish and fish Habitat and terrestrial habitat. The channels investigated yielded a very limited fish population in one area of one of the channels and no fish in the other two channels. The hydrology component was scored as contributing for two of the channels and limited for the third channel. The scores for the riparian and terrestrial habitat criteria were the highest due to the forested swamp in Woodlot S20 and presence of amphibians.

The hydrology and fish habitat functions of these man-made channels are marginal at best. Mitigation area requirements for these channels should not be comparable to off-setting mitigation for removal of channels that provide higher ecological functions such as fish habitat and with more significant hydrology characteristics. Off-setting mitigation could be provided in the vicinity of the stormwater management pond to the west of March Valley Road and the realignment of Shirley's Brook further east of March Valley Road.

Thank you for the opportunity to complete this work and please call if you have any questions on the attached report.

Yours Sincerely,
MUNCASTER ENVIRONMENTAL PLANNING INC.

Bernie Muncaster

Bernie Muncaster, M.Sc.
Principal

491 Buchanan Crescent, Ottawa, ON K1J 7V2
Tel (613) 748-3753; Fax (613) 748-6376

Kanata North

Headwaters Report

Prepared for:
Novatech Engineering Consultants Ltd.
240 Michael Cowpland Drive, Suite 200
Ottawa, ON, K2M 1P6

Prepared by:
Bowfin Environmental Consulting
168 Montreal Road
Cornwall, ON K6H 1B3

And

Muncaster Environmental Planning Inc.
491 Buchanan Crescent
Ottawa ON, K1J 7V2

September 2015

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Tables

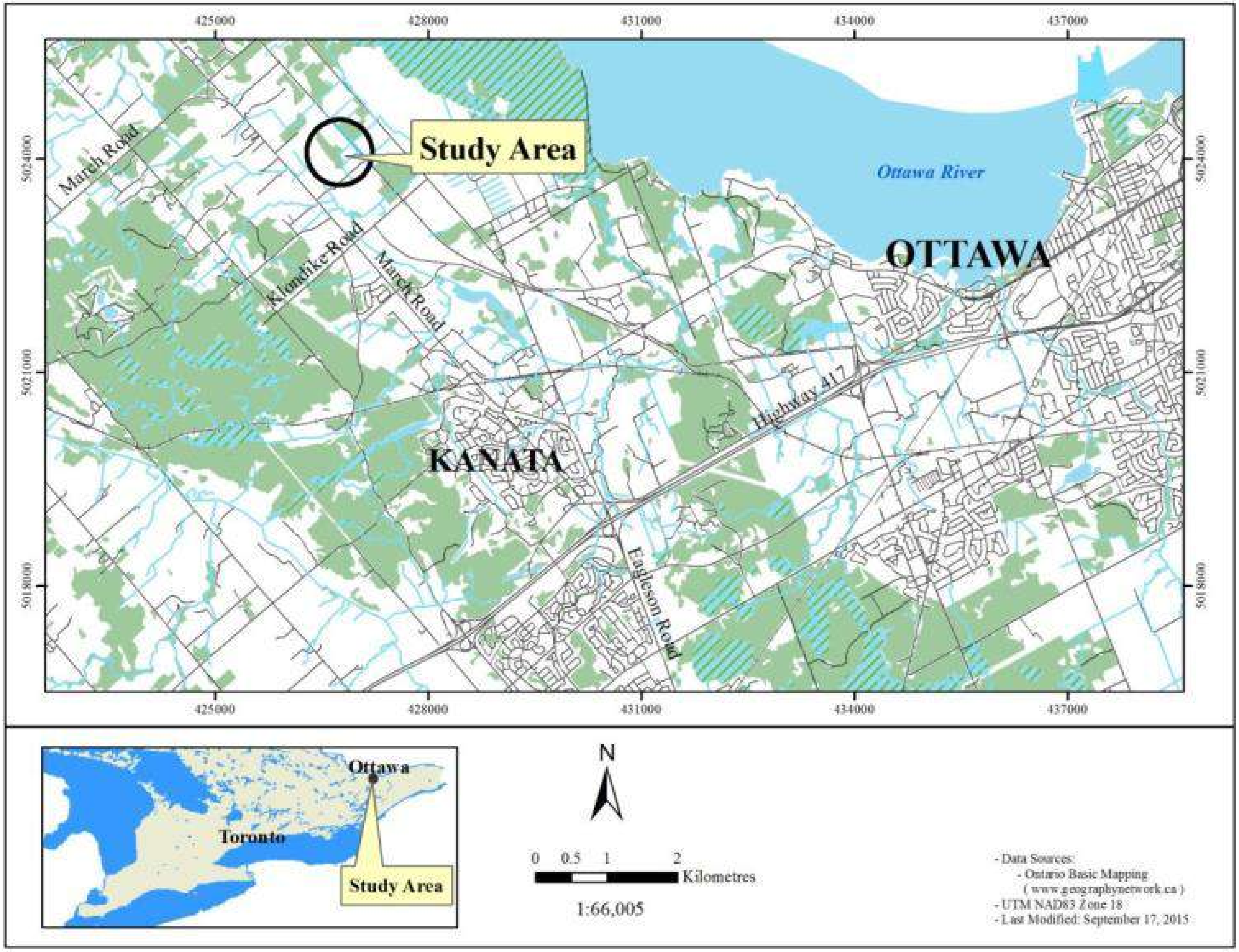
Figures

Photographs

1.0 INTRODUCTION

Muncaster Environmental Planning Inc. (MEP) and Bowfin Environmental Consulting (Bowfin) have been retained by Novatech Engineering Consultants Ltd., on behalf of the Kanata North Landowner's Group and in support of the Kanata North Community Design Plan to complete an assessment of the headwater features associated with the headwater features in Woodlot S20 between March Road and the former railway line to the east. The study area is within Lot 12 and 13, Concession 4, Geographic Township of March, City of Ottawa and forms part of the Kanata North Community Design Plan. This report provides a summary of the fisheries habitat and communities findings along with an evaluation of the headwaters as per the *Evaluation, Classification and Management of Headwater Drainage Features Guidelines* created by Credit Valley Conservation and Toronto Region Conservation (Approved July 2013, Finalized January 2014).

Figure 1 Location of Study Area



2.0 METHODOLOGY

2.1 Headwater Drainage Features

The headwater drainage features within the study area were assessed based on the *Evaluation, Classification and Management of Headwater Drainage Features: Interim Guidelines* (here after referred to as the Guidelines) (prepared by Credit Valley Conservation Authority and Toronto and Region Conservation, approved July 2013, finalized January 2014). The Guideline is divided into three parts. Part 1 is the Evaluation and discusses various suggested study designs/methods. Part 2 determines the appropriate Classification following the outcome of Part 1. Finally, Part 3 outlines the Management Recommendations. In addition to this guideline, a collection of background review, fish habitat and community assessments and amphibian surveys were completed. Incidental observations of wildlife/plant species using the features were noted (Appendix A).

2.1.1 Review of Background Information

The review of background information was conducted in order to augment the data collected during the site visit. Background information regarding fish species was obtained by reviewing Distribution of Fish Species at Risk maps published by Mississippi Valley Conservation Authority (MVCA), a search of the Natural Heritage Information Centre (NHIC) databases, and a search of the Land Information Ontario databases.

2.1.2 Habitat Description

The fish habitat features within the study area was described based on the MTO *Environmental Guide for Fish and Fish Habitat October 2006* and the *Ontario Stream Assessment Protocol*. Information on the channel morphology was collected (channel width, wetted width, bankfull and wetted depths, cover type and abundance, and substrate type). The location of specific features mentioned in the text is shown on Figure 2.

2.1.3 Fish Community Sampling

Fish community sampling was performed to document the use. The community was sampled utilizing backpack electrofishing. Areas that were too shallow for electrofishing were dip netted.

2.1.4 Amphibian Surveys

The *Environment Canada Marsh Monitoring Program* (MMP) guide was followed as described below:

- The surveys were completed twice during the spring and early summer.

Survey Number	MMP Estimated Survey Period	MMP Temperature Criteria (°C)	Survey Date	Minimum Temperature (°C)
1	April 15-30th	>5	n/a	n/a
2	May 15-30th	>10	May 25	14.8
3	June 15-30	>17	June 22	14.5

- Observations begin 30 minutes after sunset and end before midnight;
- Each station is surveyed for 3 minutes during which time the species and the calling code are recorded for each of the following distances: 0-50m, 50-100m, and >100m. The calling codes are recorded as one of:
  - 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
- Surveys are only conducted if the wind strength was Code 0, 1, 2 or 3 on the Beaufort Wind Scale.
- Amphibian survey stations should be separated by at least 500 m.

In addition to the point counts a walk around the areas surrounding the features was completed to confirm presence/absence within the subject lands.

3.0 RESULTS

3.1 Review of Background Information

The NHIC databases, Land Information Ontario, OMNRF, and MVCA indicate that there are two fish species at risk within a 10 km radius of the study area (American Eel, and Lake Sturgeon). Both these species are located approximately 2 km away from the study area in Shirley's Bay on the Ottawa River. American Eel had also been documented in Shirley's Brook (LIO).

3.2 Site Investigations

3.2.1 Summary of Visits and Sampling Site Locations

Six visits were completed between June 23, 2014 and July 27, 2015. Environmental conditions for each visit are described in Table 1 below.

Information on the aquatic habitats was collected during multiple visits in particular on June 23, 2014, May 21st, June 2nd and July 27th, 2015. Additional notes were collected on the habitats during other visits and were included were applicable. The fish community was sampled using dip netting and/or backpack electrofishing. Sampling took place on June 23, 2014, and May 25, 2015 visit, no additional sampling was conducted during the summer as the sites were dry. The electrofishing settings utilized were 200-250 volts and 1.0-1.2 amps. Figure 2 provides the locations of the sampling stations and features described below.

Table 1 Summary of Dates, Times of Site Investigations

Date	Time (h)	Staff	Air Temperature (Min-Max) °C	Weather	Purpose
June 23, 2014	1045-1430	S .St. Pierre	26.0-29.0 ()	30% cloud cover, light breeze changing to 50% cloud cover, light breeze	- Fish Habitat Assessment
May 21, 2015	0930-1215	S. St. Pierre C. Fontaine	14.0-18.0 (6.2-20.6)	20% cloud cover, gentle breeze changing to 10% cloud cover, gentle breeze	- Headwater Assessment
May 25, 2015	2015-2230	S. St. Pierre C. Fontaine	17.0-19.0 (14.2-18.9)	100% cloud cover, light breeze changing to 100% cloud cover, gentle breeze	- Fish Community Sampling - Amphibian Monitoring
June 2, 2015	1145-1300	S. St. Pierre	17.0 (5.8-16.5)	100% cloud cover, light air, rain	- Headwater Assessment
June 22, 2015	2115-2200	S. St. Pierre C. Fontaine	22.0 (15.4-27.8)	Overcast, light breeze	- Amphibian Monitoring
July 27, 2015	0930-1030	S.St.Pierre	27.0 (18.3-31.8)	20% cloud cover, light breeze changing to 40% cloud cover, gentle breeze	- Headwater Assessment

S. St. Pierre – Shaun St. Pierre – B. Sc. Biology and Fisheries and Wildlife Technologist
C. Fontaine - Cody Fontaine - Fisheries and Wildlife Technologist

*Min-Max Temp Taken From: Environment Canada. National Climate Data and Information Archive. Ottawa International Airport, Ontario. Available http://climate.weatheroffice.gc.ca/ [July 31, 2105]

3.2.2 Habitat and Fish Community Descriptions

Tables 2 provide a summary of the water temperatures and other parameters collected at the stations during 2014 and 2015. The water temperatures varied between 14.1-29.5° C, with air temperatures varying between 17.0-29.0° C.

Figure 2 Location of Headwater Features and Stations

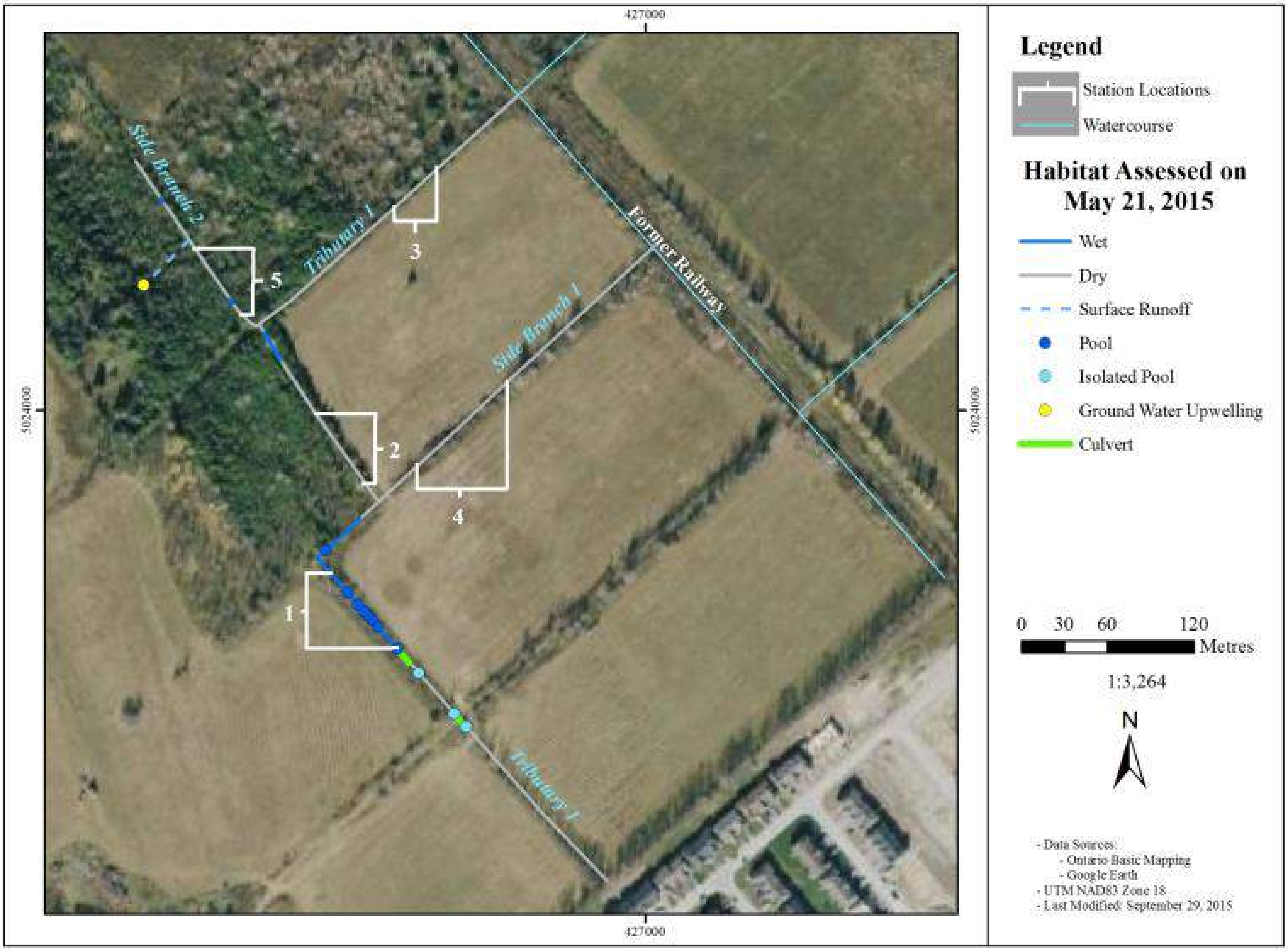


Table 2 **Features and sampling parameters from Tributary 1 and side branches (Figure 2)**

Station No.	Date	Time	Air Temp (°C)	Water Temp (°C)	pH	TDS (ppm)	Conductivity (µ)	Ave. Depth (cm)	Ave. Wetted Width (m)	Ave. Channel Width (m)
Tributary 1										
1	June 23, 2014	1306	29.0	29.5	8.74	159	340	7	1.2	2.1
	May 21, 2015	1008	18.0	14.1	8.25	271	547	7	1.0	
	May 25, 2015	2045	18.0	16.8	7.65	302	433	14	1.5	
	June 2, 2015	1216	17.0	17.6	7.58	461	670	9	1.7	
	July 27, 2015	DRY								
2	June 23, 2014	DRY								1.6
	May 21, 2015	DRY								
	June 2, 2015	DRY								
	July 27, 2015	DRY								
3	June 23, 2014	DRY								1.6
	May 21, 2015	DRY								
	June 2, 2015	DRY								
	July 27, 2015	DRY								

Station No.	Date	Time	Air Temp (°C)	Water Temp (°C)	pH	TDS (ppm)	Conductivity (µ)	Ave. Depth (cm)	Ave. Wetted Width (m)	Ave. Channel Width (m)
Side Branch 1										
4	June 23, 2014	DRY								
	May 21, 2015	DRY								1.6
	June 2, 2015	DRY								
	July 27, 2015	DRY								
Side Branch 2										
5	May 21, 2015	TOO SHALLOW						2	1.1	2.0
	June 2, 2015	1238	17.0	14.1	8.16	261	376	1	0.5	
	July 27, 2015	DRY								

Tributary 1 (Unnamed)

Of the watercourses within the study area, this is the longest. It begins on the west side travelling through the windrow between crop fields and continues to the east and north along the edge of crop fields with thickets and forests on the other side. The total length is approximately 1.2 km. The two other watercourses surveyed (side branches 1 and 2) are both tributaries to this channel. Tributary 1 was entrenched with a straight pattern and is a man-made drainage ditch.

During the primary habitat visit completed on May 21, 2015, the tributary alternated between wet and dry sections (figure 2). This poor connectivity and the seasonality of the system, which would restrict movement outside of the spring, were the only barriers to fish movement.

The channel was described and sampled along three stations (Stations 1, 2 and 3).

Station 1

The upstream end of Station 1 was located approximately 200 m downstream of the start (upstream end) of the tributary. The station length was 68 m in length. This station was originally described in 2014 and the information collected at that time matches the habitat data from 2015. The following information is summarized from the May 21, 2015 visit. The wetted width and depths recorded during the other visits are provided in Table 2. The average channel and wetted widths were 2.1 m and 1.0 m respectively. The average bankfull depth was approximately 25 cm and the average water depth was approximately 7 cm (range 1-34 cm). The habitat type consisted of glide and deep pool morphological units. The substrate consisted of fines. The in-water cover consisted of the overhanging vegetation, aquatic vegetation (algae, pondweed species, lakebank sedge, and reed canary grass), occasional piece of large woody debris, and pool habitat. The maximum pool depth ranged from 15 to 34 cm. This station had moderate canopy cover. Exposed soils and some undercutting on the banks were noted throughout the station.

The banks were fully vegetated with herbaceous species and woody species. The most common species were: reed canary grass, purple loosestrife, common sow-thistle, goldenrod species, poison-ivy, red-osier dogwood, hawthorn species, Tartarian honeysuckle, common buckthorn, green ash, black ash, American elm, Manitoba maple, and white cedar. These provided little in the way of canopy cover.

This site was sampled using backpack electrofishing and dip netting twice; once on June 23, 2014 and again on May 25th, 2015 (Table 3). Fish were only seen and/or captured during the 2014 visit. A total of eight brook sticklebacks were captured.

Table 3 Summary of Flow Data and Fish Community Sampling

Date	Wetted Width (m)	Average Depth (range) (cm)	Effort	Results (species, numbers and fork lengths)
June 23, 2014	1.2	7 (1-25)	3 s/m^2 20 dips (too shallow to electrofish)	Brook sticklebacks (8 individuals; 15-62 mm)
May 21, 2015	1.0	7 (1-34)	None	n/a
May 25, 2015	1.5	14 (3-24)	7 s/m^2	0
June 2, 2015	1.7	9 (6-22)	None	n/a
July 27, 2015		dry		

Photo 1 Looking downstream from the upstream end of Station 1 (June 23, 2014)

Photo 2 Looking downstream from the upstream end of Station 1 (May 21, 2015)

Photo 3 Looking downstream from the upstream end of Station 1 (June 2, 2015)

Photo 4 Looking downstream from the upstream end of Station 1 (July 27, 2015)

Station 2

The upstream end of Station 2 was located approximately 85 m downstream of station 1 and was 60 m in length. This station was originally described in 2014 and the information collected at that time matches the habitat data from 2015. This entire station was dry during all visits. The average channel width and bankfull depth were 1.6 m and 21 cm respectively. The substrate consisted of fines. There was no in-stream cover. This station had full canopy cover. No signs of erosion were noted at this station.

The banks were fully vegetated with herbaceous species and woody species. The most common species were: sensitive fern, purple loosestrife, poison-ivy, Virginia creeper, meadowsweet species, common buckthorn, American elm, trembling aspen, white cedar, and green ash.

No sampling was conducted at this station during 2014 or 2015 due to lack of water.

Photo 5 Looking downstream from the upstream end of Station 2 (June 23, 2014)

Photo 6 Looking downstream from the upstream end of Station 2 (May 21, 2015)

Photo 7 Looking downstream from the upstream end of Station 2 (June 2, 2015)

Photo 8 Looking downstream from the upstream end of Station 2 (July 27, 2015)

Station 3

The upstream end of Station 3 was located approximately 200 m downstream of Station 2 and was 40 m in length. This station was originally described in 2014 and the information collected at that time matches the habitat data from 2015. This entire station was dry during all visits.

The average channel width and bankfull depth were 1.6 m and 28 cm respectively. The substrate consisted of fines. Some woody debris, that would provide cover during high flows, was present. This station had full canopy cover. The banks had no signs of erosion but exposed soil was noted

The banks were fully vegetated with herbaceous species and woody species. The most common species were: field horsetail, Virginia creeper, poison-ivy, common buckthorn, staghorn sumac, speckled alder, white cedar, and green ash.

No sampling was conducted at this station during 2014 or 2015 due to lack of water.

Photo 9 Looking downstream from the upstream end of Station 3 (June 23, 2014)

Photo 10 Looking downstream from the upstream end of Station 3 (May 21, 2015)

Photo 11 Looking downstream from the upstream end of Station 3 (June 2, 2015)

Photo 12 Looking downstream from the upstream end of Station 3 (July 27, 2015)

Side Branch 1 (Unnamed)

A short, 0.3 km long, unnamed drain reaches Tributary 1 approximately 345 m downstream of its headwaters. This smaller drain travels along the edge of the windrow between two crop fields. This watercourse flows in a southwest direction. It was typical of agricultural drains in that it was entrenched with a straight pattern. This side branch was dry during all visits (figure 2). The only barrier to fish movement was the seasonality of the system which would restrict movement to the spring freshet. This drain was described at one station (Station 4).

Station 4

The downstream end of Station 4 was located approximately 36 m upstream of the confluence with Tributary 1. The station length was 80 m in length. This station was originally described in 2014 and the information collected at that time matches the habitat data from 2015. This entire station was dry during all visits. The average channel width and bankfull depth were 1.6 m and 30 cm respectively. The substrate consisted of fines. There was no in-stream cover. This station had poor canopy cover (windrow was providing cover only on the north bank). Exposed soil was noted on the banks.

The banks were moderately vegetated with herbaceous species and woody species. The most common species were: Virginia creeper, goldenrod, sensitive fern, reed canary grass, purple loosestrife, cow vetch, slender willow, choke cherry, glossy buckthorn, red-osier dogwood, green ash, American elm, and Manitoba maple.

No sampling was conducted at this station during 2014 or 2015 due to lack of water.

Photo 13 Looking upstream from the downstream end of Station 4 (June 23, 2014)

Photo 14 Looking upstream from the downstream end of Station 4 (May 21, 2015)

Photo 15 Looking upstream from the downstream end of Station 4 (June 2, 2015)

Photo 16 Looking upstream from the downstream end of Station 4 (July 27, 2015)

Side Branch 2 (Unnamed)

The second (side branch 2) was located 510 m downstream from the headwaters of Tributary 1. This branch travels through a coniferous forest and its total length was 150 m. It flows in a southeast direction. This channel was not as well defined as the other drains however it was straight and appeared to be man-made.

This site was not visited in 2014. It contained some water during the May and June 2015 visits but was dry during the July visit (Figure 2). The only barrier to fish movement was the seasonality of the system which would restrict movement outside of the spring. One station was established on side branch 2 (Station 5).

As noted on Figure 2, an upwelling was noted in the adjacent lands to Station 5. The upwelling originated within ruts along an old abandoned access road. During the spring the upwelling created a pool and some flowing water which travelled down the ruts and reached Side Branch 2. Even during the spring, there was never sufficient water being contributed by the upwelling to create flow within Side Branch 2. Side Branch 2 only ever had standing water. The upwelling was visible during all visits but it only created saturated soil conditions during the summer. The water temperature of the upwelling was 9°C. These observations are consistent with those by Paterson Group (2015) in their Shallow Bedrock Hydrogeological Assessment (August 7th, 2015). Paterson Group (2015) noted that at several locations, groundwater elevations were within the elevation of the overburden layers, or above ground surface. This suggests that the upper fractured bedrock layer is fully saturated, and that overburden soils are acting as a confining layer (Paterson Group, 2015). The presence of overburden soils of lower hydraulic conductivity overlying the bedrock aquifer units are considered to limit the potential for significant groundwater discharge in these areas (Paterson Group, 2015). Paterson Group (2015) concluded that the groundwater recharge and discharge is occurring on a localized scale within the shallow silty sand soils, while underlying silty clay soils and the limited extent of silty sand soils preclude any significant discharge or recharge from the underlying bedrock aquifer. Paterson Group (2015) also noted that Side Branch 2 (identified by Paterson Group (2015) as the drainage channel in Woodlot S20) is negatively graded in areas, allowing water to pond.

Station 5

The downstream end of Station 5 was located approximately 90 m from station 2. The station length was 56 m. This description is a summary of the May 21, 2015 visit. It was noted that even at this time portions of this drain were dry. The average channel and wetted widths were 2.0 m and 1.1 m respectively. The average bankfull depth was approximately 13 cm and the average water depth was approximately 2 cm (range 1-3 cm). The substrate consisted of fines. There was no in-stream cover. This station had full canopy cover. There were no signs of erosion.

The banks were moderately vegetated with herbaceous species and woody species. The most common species were: sensitive fern, field horsetail, grass species, and white cedar.

No sampling was conducted at this station due to lack of water.

Table 4 Summary of Flow Data and Fish Community Sampling

Date	Wetted Width (m)	Average Depth (range) (cm)	Effort	Results (species, numbers and fork lengths)
May 21, 2015	1.1	2 (1-3)	None	n/a
June 2, 2015	0.5	1 (0-1)	None	n/a
July 27, 2015	dry			

Photo 17 Looking upstream from the downstream end of Station 5 (May 21, 2015)

Photo 18 Looking upstream from the downstream end of Station 5 (June 2, 2015)

Photo 19 Looking upstream from the downstream end of Station 5 (July 27, 2015)

4.0 Headwater Drainage Features Assessment

4.1 Classification

This classification follows the four step process of the Headwater Guideline using the information collected from the portion of the tributaries in the subject lands. The four steps are: hydrology classification, riparian classification, fish and fish habitat classification and terrestrial classification.

4.1.1 Step 1: Hydrology Classification

In step 1 the flow is classified based on the amount recorded during the three visits. These are summarized in Table 5 (as per OSAP S4.M10).

Note that there is no appropriate feature type code for these systems with the exception of a part of Side Branch 2 which travels through what is identified as a coniferous forested swamp and would be considered as a (6) wetland Feature Type. All three of these features are really constructed watercourses. A review of the geoOttawa mapping indicates that all were presence since before 1965 and that the fields on both sides of Tributary 1 and Side Branch 1 were cropped since prior to 1965. The land to the northwest of Side Branch 2 was also cropped until sometime between 1971 and 1991. The field northwest of Side Branch 2 was abandoned sometime after 1971 and had become vegetated with some small shrubs by 1991.

There are three possible codes for the Feature Types:

- (2) Channelized
  - This code requires there to have been a natural channel that shows signs of channelization. There is no evidence of a channel being present.
- (7) Swale
  - This definition <u>fits the best</u> with the exception of the ill-defined banks. Since it had been dug down the banks are well defined. However the description of a system that carries water flow during rainstorms or snowmelt matches. Note that this system only would carry water during snow melt (no flowing water during rainstorms – June 2, 2015 visit was completed after a rain event).
- (8) Roadside Ditch
  - This definition fits with the constructed nature of the features however there is no roadway.

No spring runoff visit was completed by Bowfin. Information provided by others (MEP and Parish Geomorphic) indicates that there was flow in the early spring on Tributary 1 near March Valley Road in 2013. Parish Geomorphic classed this as surface flow minimal. This low flow continued to approximately 100 m upstream of the railroad after which there was only standing water. No information is available for spring freshet flows in either side branch. However, Parish Geomorphic staff walked Tributary 1 and did not notice flow entering from either side branch suggesting that there was little to no flow in these.

The guidelines use a table to direct the assessor to one of five categories:

A. Important – Perennial. These typically have water year round. Water should be flowing but may have standing or subsurface for some segments.
B. Valued – Intermittent. Flowing water are present until late spring; they are dry or surface damp by July. The benthic macroinvertebrates (aquatic insects) will include damselfly nymphs, clams and scuds but no caddisfly larvae, Mayfly nymphs, stonefly nymphs or black flies in the summer.
C. Contributing – Ephemeral. These systems have flow or water storage functions during and for a short time after spring freshet and also after large rain events. They have aquatic worms and leaches but not aquatic macroinvertebrates.
D. Recharge – Dry or Standing Water. Never have any flowing water. The soils are coarse textured allowing for infiltration.
E. Limited – Dry or Standing Water. Never have any flowing water. The soils are fine and do not permit infiltration.

Based on the above and the Table 4 in the guidelines Tributary 1 would be considered either Valued or Contributing. As described above, Valued Functions would flow until late spring. This was not the case. The definition of Contributing is a better fit to the field observations.

Side Branch 1 is a very short (<0.3km) channel that has a little drainage area. The confluence with Tributary 1 is easily observed and had there been flow during the freshet in 2013 it would have been noted by Parish. No flow was present during the 2015 site visits even after the rain event in early June. This leaves two options: Recharge or Limited. A review of the soil map for the area indicates that Jockvale and St. Thomas soils are present. These are described as being poorly to very poorly drained preventing the area from meeting the Recharge Function description. The field observations and soil types match the description of Limited Functions (Dry or Standing Water).

Following Table 4 of the guidelines, Side Branch 2 would be considered as providing a Valued or Contributing Function because of the presence of the associated coniferous forested swamp. Again, it is recognized that no spring freshet data is available. During the 2015 observations, only standing water was present even after large rain events. The confluence with Tributary 1 is not as easily found as that of Side Branch 1. As such it is assumed that flow could be possible during the freshet. As such this channel may provide Contributing Function.

Table 5 Hydrology classification features using data from OSAP S4.M10.

Tributary ID	Definitions of Flow Influence	Flow Conditions	Types of Headwater Drainage Features	Hydrology Classification
1	Spring Freshet or rainfall events	Surface Flow Minimal (assumed) (4)	Constructed agricultural drain	Contributing
	Late April-May	Standing water (2)		
	July-August	N/A (dry)		
Side Branch 1	Spring Freshet or rainfall events	N/A (dry)	Constructed agricultural drain	Limited
	Late April-May			
	July-August			
Side Branch 2	Spring Freshet or rainfall events	Standing water (2)	Abandoned agricultural drain in an area that is naturalizing. Coniferous swamp habitat is associated with portions of this channel	Contributing
	Late April-May			
	July-August	N/A (dry)		

The amount of rainfall recorded in the seven days preceding each station visit is summarized in Table 6 to provide context to the water depths in Table 2.

Table 6 Summary of Rainfall for the 7 Days Preceding the Field Surveys

Dates	Total Rainfall (mm)
June 16, 2014 – June 22, 2014	0.6
May 14, 2015 - May 20, 2015	2.0
May 18, 2015 - May 24, 2015	1.6
May 26, 2015 - June 1, 2015	20.4*
July 20, 2015 - July 26, 2015	6.6

Total Rainfall taken from: Environment Canada. 2015. National Climate Data and Information Archive – Ottawa INTL. On-line (http://climate.weatheroffice.gc.ca) accessed September 17, 2015.

4.1.2 Step 2: Riparian Classification

Terrestrial and wetland habitats adjacent to headwater feature can influence the ecological value of the headwater feature. As such, the surrounding habitat is also included in the evaluation criteria. This habitat can be assessed based on the *Ecological Land Classification* (ELC) or *Ontario Wetland Evaluation System* (OWES), as appropriate, if they have been completed as part of the Environmental Impact Study/ Natural Heritage Evaluation or through the use of the OSAP S4.M10. When the value of the land type differs from one bank to the other, the highest functioning habitat is used.

The adjacent vegetation classifications as completed by MEP in the Natural Environment Features Existing Conditions Report for the Kanata North Urban Expansion Area (Revised February, 2014) identified the adjacent lands as: Fresh-Moist Ash-Poplar Deciduous Forest, Fresh-Moist Poplar Deciduous Forest, Fresh-Moist White Cedar Coniferous Forest, White Cedar Coniferous Swamp, Cultural Woodland, Cultural Thicket, and Cleared Areas.

As defined in the guidelines on this criterion Tributary 1 and Side Branch 2 are listed as having Important Function due to the presence of forest and swamp habitat. This habitat is found along only one bank for Tributary 1 but is present on both banks for Side Branch 2. Side Branch 1 is determined to be Limited Function due to the cropped land (Table 7).

Table 7 Riparian Classification

Tributary	Riparian Classification	Comments
1	Important Functions	Within the subject land the tributary flows alongside a coniferous forest, coniferous swamp, deciduous forest and cropped land. The dominate being cropped land.
Side Branch 1	Limited Functions	Within the subject land the tributary flows along the edge of a very narrow windrow and cropped land. The dominate being cropped land.
Side Branch 2	Important Functions	Within the subject land the tributary flows within a coniferous forest, and coniferous swamp.

4.1.3 Step 3: Fish and Fish Habitat Classification

The guidelines classify fish habitat as either:

A. Important – Any fish species present in spring and mid-summer, suitable spawning habitat for any fish, the presence of species at risk (SAR) at any time, or critical habitat to downstream SAR

B. Valued – fish found only in spring or the habitat of SAR (SAR habitat may be for: feeding, cover, refuge, migration or contributing habitat)
C. Contributing – Allochthonous (i.e. insects, materials) transport through the feature to downstream fish habitat.

Fish were captured during spring 2014 in a refuge pool from one station along Tributary 1. No fish were captured along any other stations and no fish were seen or captured from Tributary 1 during 2015. The only species captured was brook stickleback, a common warm to cool water fish species. The species at risk identified for the general area (American eel and lake sturgeon) do not frequent farm ditches such as these. While fish were present during 2014 in the refuge pool they were limited in number and diversity and likely did not survive.

Tributary 1 would provide refuge habitat for fish during years with high snow melt/spring rains. During these years it would be considered a Valued Function (as per the guidelines). On years when flows are lower it would provide Contributing Functions (a lower value of fish habitat than one with Valued Function).

The other two channels (side branch 1 and 2) would at best provide Contributing Functions. However, the lack of flow limits the ability of any allochthonous transport to downstream fish bearing waters to only the brief period associated with spring freshet (flow is required to push the material/nutrients downstream). The nearest fish bearing downstream habitat is Shirley's Brook situated 0.5 km downstream.

4.1.4 Step 4: Terrestrial Habitat Classification

Step 4 of the guidelines classifies the value of the headwater feature as it relates primarily to amphibian breeding habitat and its ability to provide movement corridors. It is assessed through the use of both the OSAP S4.M10 and Marsh Monitoring Protocol. The feature must meet both of these protocols for each class. Only those features with both wetland habitat (Feature Type Code 6 - wetland) and amphibians calling can be deemed to provide Important Function.

Amphibians were heard calling on all three headwater feature however the best fit feature type Code is a 7 (swale) for Tributaries 1 and Side Branch 1. Side Branch 2 has both swale and wetland feature types associated with it. As such the terrestrial habitat would be classed as Important for Side Branch 2 and Limited for the other two.

Based on the guidelines the Contributing Function is to be listed at a landscape scale and using guidelines from the EIS. This was completed during the writing of the *Natural Environment Features Existing Conditions Report for the Kanata North Urban Expansion Area report* prepared by MEP and in discussions with the Ministry of Natural Resources and Forestry (MNRF). It has been determined that this area does not provide a movement corridor.

Table 8 Terrestrial Habitat Classification

Tributary	OSAP S4.M10 Feature Type Code	Marsh Monitoring Amphibian Results	Terrestrial Habitat Classification
Tributary 1	Constructed agricultural drain (codes 2, or 7 may fit)	Visit 1 – n/a Visit 2 - Spring Peepers, Tetraploid Gray Treefrogs, and American Toads Visit 3 - Tetraploid Gray Treefrogs	Limited
Side Branch 1	Constructed agricultural drain (codes 2, or 7 may fit)	Visit 1 – n/a Visit 2 – American toads Visit 3 – no calls	Limited
Side Branch 2	Abandoned agricultural drain in an area that is naturalizing (codes 2, or 7 may fit). Wetland habitat is associated with portions of this channel (6 - wetland)	Visit 1 – n/a Visit 2 – Spring peepers Visit 3 – no calls	Important

4.2 Part 3 – Management Recommendations

The options for management recommendations are grouped into six categories: protection, conservation, mitigation, maintain recharge, maintain/ replicate terrestrial linkage, and no management required. Utilising the guideline and the data collected at each feature the management recommendations are: Conservation for Tributary 1 and Side Branch 2 and No Management Required for Side Branch 2 (Table 9).

Conservation signifies that the feature can be left in place or relocated. Relocate may consist recreating the feature ensuring that a similar hydroperiod is achieved and that nearly, the same or more habitat is provided. The new habitat may be created on or off-site. For features with important riparian habitat function, the relocated feature will also include similar riparian function.

Table9 Evaluation, Classification and Management Summary and Study Conclusion

Drainage Feature Segment	Hydrology Classification	Riparian Classification	Fish and Fish Habitat Classification	Terrestrial Habitat Classification	Guideline's Management
Tributary 1	Contributing	Important	Contributing to Valued depending on spring freshet	Limited	Conservation
Side Branch 1	Limited	Limited	Contributing	Limited	No Management Required
Side Branch 2	Contributing	Important	Contributing	Important	Conservation

4.3 Next Steps

As discussed above, Side Branch 1 has No Management Required and can be removed. For Tributary 1 and Side Branch 2, a calculation of the available habitat (channel width x length) and the riparian habitat will be required. Based on these calculations new habitat will be created on-site or offsite. For example the habitat creation may be associate with the stormwater management ponds west of March Valley Road or the proposed re-alignment of Shirley's Brook further east of March Valley Road. Engineering solutions such as directing clean flow from the roofs or basements to the newly created habitat will be investigated.

Reliance Clause

This report has been prepared for Novatech Engineering Consultants Ltd., on behalf of the Kanata North Landowner's Group and in support of the Kanata North Community Design Plan. It is hereby acknowledged that Metcalfe Realty Company Limited, J. G. Rivard Limited and 8409765 Canada Inc. (Valecraft Homes) can rely upon and utilize this report for the purpose of obtaining approval of the community design plan and for their own use to seek development approval.

It is further acknowledged that future confirmed participating landowners within the Kanata North Landowner's Group can rely upon and utilize this report for the purpose of obtaining approval of the community design plan and for their own use to seek development approval.

Appendix A

Incidental Observations

Common Name	Scientific Name	SRank	Provincial Status (SARO)	Federal Status (SARA)	Coefficient of Conservatism
AMPHIBIANS					
American Toad	*Bufo americanus*	S5			
Tetraploid Gray Treefrog	*Hyla versicolor*	S5			
Spring Peeper	*Pseudacris crucifer*	S5			
Northern Leopard Frog	*Rana pipiens*	S5			
BIRDS					
Wild Turkey	*Meleagris gallopavo*	S5			
PLANTS					
Algae sp.	*Algae sp.*				
Sensitive Fern	*Onoclea sensibilis*	S5			4
Field Horsetail	*Equisetum arvense*	S5			0
Eastern White Cedar	*Thuja occidentalis*	S5			4
Manitoba Maple	*Acer negundo*	S5			0
Western Poison-ivy	*Rhus radicans ssp. rydbergii*	S5			0
Staghorn Sumac	*Rhus typhina*	S5			1
Goldenrod sp.	*Solidago sp.*				
Common Sow-thistle	*Sonchus oleraceus*	SNA			
Speckled Alder	*Alnus incana spp. rugosa*	S5			6
Tartarian Honeysuckle	*Lonicera tatarica*	SNA			
Red-osier Dogwood	*Cornus stolonifera*	S5			2
Purple Loosestrife	*Lythrum salicaria*	SNA			
Black Ash	*Fraxinus nigra*	S5			7
Green Ash	*Fraxinus pennsylvanica*	S5			3
Common Buckthorn	*Rhamnus cathartica*	SNA			
Glossy Buckthorn	*Rhamnus frangula*	SNA			
Hawthorn sp.	*Crataegus sp.*				
Choke Cherry	*Prunus virginiana ssp. virginiana*	S5			2
Narrow-leaved Meadowsweet	*Spiraea alba*	S5			3
Trembling Aspen	*Populus tremuloides*	S5			
American Elm	*Ulmus americana*	S5			3
Virginia Creeper	*Parthenocissus inserta*	S5			3
Lakebank Sedge	*Carex lacustris*	S5			5
Grass Family	*Poaceae*				

Common Name	Scientific Name	SRank	Provincial Status (SARO)	Federal Status (SARA)	Coefficient of Conservatism
Reed Canary Grass	*Phalaris arundinacea*	S5			0
Pondweed sp.	*Potamogeton sp.*				

Status updated: September 17, 2015

SRANK DEFINITIONS

S5 Secure, Common, widespread, and abundant in the nation or state/province.

SNA Not Applicable, A conservation status rank is not applicable because the species is not a suitable target for conservation activities.

Coefficient of conservatism ranking criteria

0 Obligate to ruderal areas.
1 Occurs more frequently in ruderal areas than natural areas.
2 Facultative to ruderal and natural areas.
3 Occurs less frequent in ruderal areas than natural areas.
4 Occurs much more frequently in natural areas than ruderal areas.
5 Obligate to natural areas (quality of area is low).
6 Weak affinity to high-quality natural areas.
7 Moderate affinity to high-quality natural areas.
8 High affinity to high-quality natural areas.
9 Very high affinity to high-quality natural areas.
10 Obligate to high-quality natural areas.

Appendix R

Sensitive Groundwater Assessment: Discharge and Recharge Area Evaluation Woodlot S20

(Patterson Group – October 24, 2014)

patersongroup

consulting engineers

MEMO

to:	**Mr. Greg Winters** Novatech Engineering Consultants Ltd
re:	**Sensitive Groundwater Assessment: Discharge and Recharge Area Evaluation Woodlot S20 - SUPPLEMENTAL** **Proposed Kanata North Urban Expansion Area**
date:	November 27, 2014
file:	PH2223-LET.05
from:	Robert A. Passmore, P.Eng.

During the Technical Advisory Committee (TAC) meeting at the City of Ottawa (the City) City Hall, several questions were raised by City Staff concerning the findings of our Sensitive Groundwater Assessment report prepared on the Woodlot S20. Specifically, there appears to be confusion in the understanding of the nature of surface water infiltration into the subsurface.

In that report, we presented evidence to suggest that some groundwater infiltration into the shallow overburden soils was occurring. In addition, the shallow ditch structures were noted to exhibit characteristics of a gaining stream, where essentially water is infiltrating through the sidewalls of the overburden into the ditch.

It was evident, based on the nature of the questions posed by City Staff, that there is some confusion surrounding the discussion of these two above noted observations. As a result, Paterson Group Inc. (Paterson) has issued this supplemental memo to assist City Staff in better understanding our conclusion by presenting a discussion in plain terms.

The subject woodlot area, as it has already been established, sits in a topographic low area extending in a northwest to southeast manner (roughly parallel to March Road) bordered to the west-southwest by a steeply upwards sloping ridge line and to the east-northeast by the CN Rail line (for the purposes of this discussion, March Road is taken as running northwest to southeast direction). In addition the topography rises eastward from the low area towards the rail line, effectively creating a bowl shaped depression.

The underlying soils consist of a transitional layer of silty sand to sandy silt with trace clay (silty loam) of varying thickness which, in turn, is underlain by a stiff silty clay to dense glacial till. Moreover, based on available area soils mapping (Ontario Geologic Survey) the subject area is noted to be situated the northwestern edge an alluvial deposit (i.e. historic sandy silty-silty sand deposit) which was identified in Paterson's Existing Conditions: Hydrogeology Report (2014). The alluvial deposit was identified in that report as having the potential to receive infiltrating surface water and convey in a southeasterly direction towards Shirley's Brook based on surface topography.

Having re-established this known baseline data, the discussion can now turn to following the hydrologic cycle in this area. When rain falls on the top of the ridge, or snow melts, the water is directed downwards along the surface of the slope towards the low lying area where the woodlot is located. This condition has been more recently exacerbated due to the crop planting choice by the landowners to plant row crops instead of retaining the historic use as pasture land. Pasture land provides a greater resistance to surface water runoff and promotes more infiltration into the underlying soil.

The surface water, in the absence of the woodlot area, would continue to flow along the surface of the ground and lose velocity along the way. Eventually, the surface water runoff would lose all velocity as it began flowing upwards to the east of the low area. The presence of the woodlot only acts to retard the horizontal flow of the surface water, thereby seeking to promote infiltration of surface water into underlying soil.

Essentially, a “bath tub” effect is created in this area as the surface water runoff flows easily into the area, but it does not flow easily out of the area. Drainage potential is particularly poor in this area given the boundary conditions created by the rail line and ridge.

Based on available historic information, the section of the former Arnprior, Ottawa and Parry Sound Railway (Beachburg subdivision) that stretches through this area was completed in 1915 by Canadian Northern Railway. The presence of the woodlot was first observed in the available air photos from 1945. At that time, the woodlot was very sparse and appears to have been limited to the bottom of the ridge line. Land on both sides of the woodlot appeared to be farmed. However, all subsequent air photos show the woodlot increasing gradually in size and much of the surrounding lands were left fallow or turned from row crops to pasture land. This indicates that the surficial drainage in the area may have been adversely affected by the construction of the railway and, over time, the landowners could no longer use the confined lands for anything productive.

Building on the poor surficial drainage issue, it is important to discuss the fate of the water retained in the “bath tub”. Given that only a relatively thin portion of the underlying soil horizons are permeable enough to allow for some vertical infiltration, much of the impounded surface water retained in the subject area is taken up in the evapotranspiration portion of the hydrologic cycle. The remaining water infiltrates into the ground.

It is imperative when discussing infiltration, that a clear distinction be made: all infiltrating surface water becomes groundwater by definition, but not all groundwater becomes groundwater recharge. In areas where there is a permeable shallow receiving soil underlain by a lower permeable soil (i.e. silty sand over clay) the infiltrate collects at the interface of the lower soil horizon. As the water collects, some of it is drawn vertically upwards by capillarity and made available to plants with roots in the root zone where the interface is shallow. Where the interface is deep, the infiltrate builds up hydraulic head with some of the water pushing further into the lower permeable soil horizon and the rest moving laterally directed by topographic relief.

In the case of the subject area, the underlying soil interface is shallow and the infiltrate is available in the root zone. This is evidenced by the capillary effects noted in the monitoring piezometers and the neutral gradients to slightly downward gradients established in the field testing program completed by Paterson in September/October 2014. As such, much of the water must be currently taken up by evapotranspiration in the area with some of the infiltrate moving laterally along the surface of the lower permeable soil layer in a general southeasterly direction.

Paterson noted in Report No. PH2223- REP.02 that there was no flow in the shallow ditches during the field work program. Relatively static conditions were noted in the monitoring piezometers installed in the ditch bisects and in the mini piezometers put down in the ponded surface water areas. Water only moves out of the area when sufficient surface water accumulates to move laterally along the shallow ditches to the southeast. At all other times, the surface water must inevitably be considered to be impounded.

The works completed by Paterson were done from a purely hydrogeologic perspective. While it is beyond the expertise of the undersigned to comment on the significance of the woodlot in the overall picture from a cultural perspective, Paterson can comment on the significance of the woodlot area from a hydrogeological perspective. The subject area may have had some historical hydrogeological significance prior to the construction of the railway in 1893 as the alluvial deposit may have allowed for the movement of shallow infiltrate towards the Ottawa River to the east or to Shirley's Brook to the south. However, the subject area, in present day, has no significance from a hydrogeological perspective. The surface water is impounded by topography and the railway and is primarily only contributing to the hydrologic cycle through evapotranspiration and not through groundwater recharge/discharge.

The subjected area, from a hydrogeological perspective, does not show the characteristics of a headwater feature based on the information obtained through the field investigation. Moreover, contribution to either baseflow to watercourses (i.e. Shirley's Brook and its tributaries) through intermittent interflow, or to deep bedrock aquifers appears to be extremely limited, and effectively insignificant.

Best Regards,

Paterson Group Inc.

Robert A. Passmore, P.Eng.

Appendix S

South March Highlands Blanding's Turtle Conservation Needs Assessment

(Dillon Consulting Limited – January 31, 2013)

City of Ottawa

South March Highlands Blanding's Turtle Conservation Needs Assessment

FINAL

January 31, 2013

On behalf of:

City of Ottawa

Land Use and Natural Systems

Project No. 12-6060

Submitted by

Dillon Consulting Limited

FORWARD

The City of Ottawa contracted Dillon Consulting Limited in March 2012 to prepare the *South March Highlands Blanding's Turtle Conservation Needs Assessment* in March 2012 (hereafter called the *Conservation Needs Assessment*). It is a planning study intended to provide the City, property owners, regulatory agencies and the public with the information necessary to make good planning and regulatory decisions. Its purpose does not differ from other technical planning studies, such as geotechnical, hydrological or transportation studies.

Although the findings of the Conservation Needs Assessment may have implications for land use planning and specific development applications, the study itself does not address questions that can only be answered through *Planning Act* or other established regulatory processes. Consequently, the name of the study has been changed from the originally proposed title, which referred to it as a "conservation plan". A conservation plan includes implementation actions. In this instance, any implementation will require further consideration and decisions by the City, property owners and agencies. Necessarily, however, the study does assess the likely impacts of planned land use changes and developments on the environment – in this case, the long-term viability of the South March Highlands population of Blanding's turtles. It also identifies and assesses the potential options for mitigating those impacts. In this way, it functions like any other planning study.

The Conservation Needs Assessment does, however, differ from more typical technical planning studies in two important ways. First, it has a greater level of uncertainty. Not only is the information on which it is based more difficult to collect and interpret, but the study attempts to predict the responses of living organisms – i.e. turtles – to a complex environment undergoing continuous natural and human-induced changes. Second, there is no officially approved methodology, no professionally-sanctioned standard, for conducting this kind of study. Best practices have been established primarily through the scientific publication and peer-review process. In response to these differences, the report discusses at length the limitations of the information and methodology. The City and Dillon Consulting Ltd believe than an explicit recognition of these limitations increases, not decreases, the credibility of the conclusions. The report also employs the "precautionary approach" in assessing the potential magnitude of the threats to the population and their potential long-term effects on the viability of the population. The Ontario *Natural Heritage Reference Manual 2010* recommends such an approach and defines it as one, "that is designed to prevent environmental degradation where there are threats of serious or irreversible damage or lack of full scientific certainty (adapted from Principle 15 – 1992 UNEP Rio Declaration on Environment and Development). Finally, the Conservation Needs Assessment includes two peer reviews by experts in the field of turtle biology and conservation. The purpose of the peer reviews is to provide the readers with an independent assessment of study methodology, and, hopefully, to provide some measure of confidence in its objectivity.

The two peer reviews, and the response by the City and Dillon Consulting Limited, form an important part of this document. They should be read in conjunction with the main Conservation

Needs Assessment. Not only do they address technical aspects of the assessment, but they also provide a broader conservation context, in which the assessment must be understood. Two related issues raised by the peer reviewers deserve particular mention. Dr. Blouin-Demers warns of the "shifting baseline syndrome" in conservation: the tendency to regard an already degraded ecosystem as "normal". In this case, he points to the likelihood that the South March Highlands population of Blanding's turtles has already been reduced through habitat loss and fragmentation. Similarly, both Dr. Blouin-Demers and Dr. Congdon clearly state their belief that the South March Highlands population of Blanding's turtles cannot be viable in the long-term without the maintenance or re-establishment of protected linkages to other populations of Blanding's turtles, in order to increase the effective habitat area and to prevent genetic isolation of the population. These are larger issues that the City, the Ministry of Natural Resources and other agencies must consider as they work with the public and property owners to manage the landscape in the future.

Dr. Nicholas Stow (Ph.D., B.Sc., B.A.)

Senior Planner

Land Use and Natural Systems

City of Ottawa

PREFACE

The City of Ottawa is privileged to have an abundance of natural heritage and a diversity of flora and fauna. Some of these species are threatened or endangered because of characteristics that make them vulnerable to development and human activities. To improve the likelihood that threatened or endangered species can recover, strategies can be implemented to manage the species and their habitats in a manner that promotes wildlife population growth and threat reduction.

Conservation management plans are developed for individual species (or populations of a species) to provide guidance for wildlife management, land and resource management decisions, and protection for the species and their habitat. Conservation management plans are intended to be a resource tool for the principal stakeholder (in this case, the City of Ottawa), and they provide other stakeholders, such as the Ministry of Natural Resources and private land owners, with the necessary information to make informed regulatory, management and stewardship decisions. Conservation management plans are "living" documents and should be revised continuously as new information is collected.

In order to potentially support a future conservation management plan for Blanding's turtle in Ottawa, the following needs assessment provides information on Blanding's turtle biology and habitat needs, identifies threats to the species and their habitat, and analyzes available data associated with the species population demographics and habitat. The assessment targets specific objectives for promoting the conservation of the species (or population) in question and makes recommendations for implementation of the objectives.

Although conservation management plans and needs assessments are often prepared by government biologists who are part of the teams that designate species, occasionally reports can be written by other qualified persons. In the case of the South March Highlands Blanding's Turtle Conservation Needs Assessment, the plan has been written at the request of the City of Ottawa by biologists working with Dillon Consulting Limited. Dillon has been assessing the South March Highlands Blanding's turtle population for several years as part of the Terry Fox Drive Extension environmental assessment, contract administration and post-construction monitoring. To ensure the integrity of the needs assessment and the ideas and analyses presented, the report has been peer-reviewed by two experts. One is a conservation biology expert, Professor Gabriel Blouin-Demers of the University of Ottawa, and the other an internationally recognized Blanding's turtle expert, Professor Emeritus Justin D. Congdon of the Savannah River Ecology Laboratory.

Abstract

A small population of Blanding's turtle inhabits the South March Highlands (SMH) Conservation Forest, part of a larger population in the surrounding areas of northwest Ottawa. Parts of the surrounding lands have been and are being developed for residential uses, and this imposes an immediate threat on the already at-risk animal. It appears that, due to a variety of historic, current, and future stressors, the SMH population is at high risk of decline and eventual extirpation. Several specific actions, such as measures to reduce adult turtle road mortalities, increase hatchling success, and limiting urban development in sensitive areas, may curtail the expected population decline. Suitable habitat is abundant in the area, though improved connectivity linkages to other habitats and populations should be investigated to support the SMH population. Blanding's turtle conservation and management in the SMH must remain a priority of the City of Ottawa and other stakeholders to help preserve this threatened, unique species. Should the objectives, targets and recommendations of the Conservation Needs Assessment not be implemented, the Blanding's turtle in the SMH will continue to face threats to their core habitats, survivability and population abundance. Approaches to the successful implementation of the Conservation Needs Assessment must consider the outlined species, habitat, research, education, awareness, collaboration and legislative aspects. In addition, the recommendations made to curtail habitat degradation and other threats to the SMH Blanding's turtle should be explored prior to any further urban development in the area. The protection of species at risk requires collaboration and enforcement by government, landowners, researchers, non-governmental organizations and the public.

Executive Summary

Blanding's turtle (*Emydoidea blandingii*) is a species at risk found in the South March Highlands (SMH) of North Kanata, in the City of Ottawa. The species is long-lived and associated with wetland and upland habitats. Nesting occurs in the late spring/early summer and typically involves movements of varying lengths, often through upland forests, to sandy nesting areas. The species is sensitive to urban development, primarily from increased risk of road mortality, but also from loss and fragmentation of habitat. The species is also targeted frequently for poaching as part of the exotic pet trade. Blanding's turtle is thought to be abundant in the Ottawa region, with several populations identified throughout Ottawa and Gatineau. The field research reported herein represents one of the first in-depth studies conducted on an individual population in the urbanized area of the Ottawa and Gatineau region.

In 2011, an extension of Terry Fox Drive was completed through the South March Highlands, along the municipal urban boundary. Residential land development and municipal infrastructure work is already on-going on the urban side of Terry Fox Drive, and more is planned over the next five to ten years. As part of the permitting requirements for the Terry Fox Drive extension, the City has undertaken a 4-year mark-recapture population estimate and range study of the SMH Blanding's turtles. The first year, 2010 should be considered as organizational, with the most relevant mark: recapture and radio telemetry data having been collected during 2011 and 2012. Field work, analysis, and reporting is being conducted by Dillon Consulting Limited and currently will continue for 1 more field season until the end of 2013. To date, 97 turtles have been identified and several key areas have been determined to be important for life processes such as overwintering and nesting. The data from 2013 will be added to this baseline, but the data set is now rich enough to begin drawing conclusions on the important habitats and distribution of Blanding's turtle in the South March Highlands.

The City of Ottawa has contracted Dillon Consulting Limited to prepare a Conservation Needs Assessment based on the data collected to date. The assessment consists of a review of turtle biology, a threat assessment, a population viability analytical model, a characterization of suitable habitats, potential and observed movement corridors, and specific objectives and recommendations to manage Blanding's turtle conservation in the SMH.

The specific threats to the Blanding's turtle population in the SMH were evaluated, with vehicle collisions and habitat loss due to urbanization being most significant. Other potential threats included poaching, natural predation, disease and parasites, climate change, plastic floatables, and bioaccumulation.

A population viability analysis (PVA) was completed using life-history information collected over the span of an almost 50-year study in Michigan, and with SMH-specific data collected during the population estimate and range study. The PVA was used to identify threats to which the population is most sensitive, and to identify effective management strategies. A key finding of the PVA is that

the SMH Blanding's turtle population is already vulnerable to decline and extirpation, and that planned development will exacerbate the risks. The analysis shows that adult survivorship is the most important factor for viability and should be the main focus of conservation actions. However, variables such as fecundity, hatchling survivorship, and juvenile survival are also important factors in determining long-term population viability and should not be overlooked.

Identification of habitat is important for conservation management. Habitat quality was determined using desktop GIS methods and on the ground knowledge of the SMH. Trapping and radio telemetry movement data allowed us to identify some areas in the SMH as being key to the life processes of Blanding's turtles. Furthermore, we also conducted a GIS linkage analysis to determine suitable areas for movement corridors and made comparisons with radio telemetry-derived movements.

In general, the conservation needs assessment makes recommendations to support a productive, viable Blanding's turtle population in the SMH. Specifically, the assessment establishes seven objectives for discussion, ranging from rather simple mitigation measures to broader collaborative and potentially costly actions. The objectives are listed below (detailed examples are provided in the report):

> Objective 1- Reduce the direct and indirect causes of Blanding's turtle mortality.
>
> Objective 2- Continue to improve local and global knowledge and an understanding of the SMH Blanding's turtle population through research and monitoring.
>
> Objective 3- Protect, conserve and manage Blanding's turtle habitat.
>
> Objective 4- Improve understanding of Blanding's turtle habitats through research and monitoring.
>
> Objective 5- Raise public awareness of the Blanding's turtle and the need for conservation.
>
> Objective 6- Enhance cooperation between municipal, provincial, federal, international agencies and non-governmental organizations.
>
> Objective 7- Promote lawful protection of the Blanding's turtle.

In addition to these objectives, recommendations have been made to handle the current issues surrounding land development and Blanding's turtle conservation in the SMH, including, but not limited to, residential development, stormwater management, road restructuring, emulating the Terry Fox Drive Wildlife Guide System, adult turtle protection and hatchling enhancement programs.

Within the study area, a large residential subdivision is draft-plan approved, the potential effects of which were evaluated for this Assessment. In the absence of planned mitigation measures and/or compensation, it is assumed that Blanding's turtle habitat in the development area would be lost.

Similarly, a review of the proposed use of the Kizell Wetland for stormwater servicing of the new development suggests that it would have substantial implications for the protection of Blanding's turtle in the wetland.

Blanding's turtle conservation and management in the SMH should remain a priority of the City of Ottawa and other stakeholders to help preserve this threatened, unique species. Should the objectives, targets and recommendations of the conservation needs assessment not be implemented, the Blanding's turtle population of the SMH will continue to face threats to its core habitats, recruitment success and population abundance. Approaches to successfully implement the conservation needs assessment must consider the outlined species, habitat, research, education, awareness, collaboration and legislative aspects. In addition, the recommendations made to curtail habitat degradation and other threats to the SMH Blanding's turtle should be explored prior to further urban development in the area. The protection of species at risk requires collaboration, research, awareness and enforcement by government, landowners, researchers, non-governmental organizations, interest groups and the public. At the same time, it can inspire our youth, through educational field programs, hands-on involvement and participation in the conservation process.

DATA PAGE

Project Title:	South March Highlands Blanding's Turtle Conservation Needs Assessment
Project Area:	City of Ottawa, South March Highlands Provincially Significant Wetland Complex, Carp River, and the Kizell Wetland Provincially Significant Wetland Complex
Proponent:	City of Ottawa, Construction Services Division and Planning Division, Land Use and Natural Systems
Respondent:	Nick Stow, Ph.D.
Ministry of Natural Resources (MNR):	Kemptville District
Permits:	Endangered Species Act; Scientific Collectors Permit; Animal Health Protection Protocols.
MNR Species-at-Risk Biologist:	Marie-Ange Gravel, Ph.D.
Primary Researcher 1:	Shawn Taylor, M.Sc., R.P. Bio.
Primary Researcher 2:	Caleb Hasler, Ph.D.
Biologist:	Sarah Larocque, M.Sc.
Ecologist:	Alex Zeller, M.Sc.
Research Assistant:	Kevin Robinson, B.Sc.
Peer Reviewer 1:	Gabriel Blouin-Demers, Ph.D.
Peer Reviewer 2:	Justin Congdon, Ph.D.
Prime Consultant:	Dillon Consulting Limited
Final Draft Date:	January 31, 2013
Reporting Period:	February 9, 2012-October 16, 2012

Suggested Citation:

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Appendix C: Supplementary Information for Population Viability Analysis.

Appendix D: Supplementary Information on Contaminant Bioaccumulation.

Appendix E: Supplementary Information for Habitat Study.

1.0 Introduction

The South March Highlands (SMH) is an outcrop of Canadian Shield on the western edge of Ottawa's urban boundary, in the old City of Kanata (Figure 1). It covers approximately 895 ha and is bounded by March Road in the north, Second Line Road to the east, Kanata Avenue in the south, and Huntmar Drive to the west (**Figure 1**). It is a continuation of a ridge that runs northwest for approximately 30 km to Fitzroy Harbor on the Ottawa River. The exposed bedrock base of the SMH has not been extensively developed for agriculture and likely has had little commercial logging since the late 1800's. Consequently, much of its forest cover has reached maturity, and portions are beginning to acquire old-growth characteristics. According to a review of the existing conditions conducted for the City of Ottawa (Brunton, 2008), there are 10 vegetation types, with much of the SMH area being comprised of Deciduous and Mixed Forests. The area also has two provincially significant wetland - complexes centered around - Shirley's Brook and the Kizell Wetland. The combination of maturity, multiple vegetation types and wetlands results in a high level of native biodiversity. This includes nine known species at risk with a conservation ranking of threatened or endangered, and nine additional species with a conservation ranking of "special concern" (Brunton, 2008).

The City of Ottawa has protected 400 ha of the South March Highlands as the South March Highlands Conservation Forest (**Figure 2**). However, urban development has occurred in the past in the SMH and continues. In the past thirty years, consistent population growth in Kanata has created an increasing demand for land to accommodate commercial and residential development. Development planning within the urban portion of the SMH is partly constrained by a legal agreement and OMB decision establishing the ratio of developable land to "greenspace" land at 60/40. In 1983, the Ontario Municipal Board (OMB), in response to a development application, was asked to consider the impact of the Kanata Lakes (KNL) development on natural areas, primarily the Kizell Wetlands and the associated forest lands. The OMB decided that 40% of the Kanata Lakes land holding was to be protected permanently as Natural Environment, and that the remainder could be developed for residential housing and associated infrastructure (OMB, 1983). This decision was reinforced in a 2006 decision by the OMB, which ordered that the draft plan of subdivision should proceed as proposed (OMB, 2006). Major municipal infrastructure developments like the expansion of Terry Fox Drive (TFD), electricity transmission corridors and the planned realignment of Goulbourn Forced Road (GFR) have relied on the 40% rule to define the developable land limits, their spatial layout and zoning composition since the 1983 decision.

The Kanata Lakes development has proceeded as planned on the south side of the Kizell Wetland. However, the draft plan of subdivision for the areas north of the Kizell Wetland – KNL Development Inc., Phases 7, 8 and 9 – has been delayed by environmental concerns. The 2006 draft plan proposed to divert most of the surface water drainage (i.e., stormwater) on Phases 7 and 8 from the Shirley's Brook subwatershed to the Kizell Wetland – Watt's Creek subwatershed, to alter the Kizell Wetland to accommodate additional stormwater, and to relocate a long section of Shirley's

Brook. The Kizell Wetland is already a licensed City of Ottawa stormwater facility, servicing areas of the development to the south of the wetland. However, in early 2012, the City of Ottawa released a study that raised questions regarding compliance of the facility with its Certificate of Approval. In addition, the Blanding's turtle population monitoring work conducted for Terry Fox Drive had identified a significant number of Blanding's turtles and their habitat in the Kizell Wetland and in KNL Phases 7 and 8. Consequently, KNL Developments Inc. advises that it is revising its plan of subdivision for Phases 7 and 8 and redesigning its stormwater management plan to address the requirements of the Ministry of Environment and the Ministry of Natural Resources.

The urban boundary currently lies along Terry Fox Drive. However, Ottawa City Council has identified a new urban expansion study area immediately north of Terry Fox Drive, between the edge of the South March Highlands and the Carp River. Final inclusion of that property in the urban boundary is conditional upon acceptable environmental studies and impacts, including potential impacts on species at risk.

Urban development permanently alters natural landscapes and the habitats that are necessary for the survival of most plant and animal species in the SMH. Direct impacts consist of such activities as vegetation clearing, root grubbing, removal of topsoil, blasting and grading. Construction can also generate large volumes of sediment in storm water run-off. Noise, dust, vibration, and spills of gasoline and oils from construction equipment further degrade the remaining habitat. Once development is complete, disturbances from domestic animals, increased human activities, motor vehicle emissions, noise and vibration, and the use of chemicals further degrade habitat resources. Mitigation measures can reduce or minimize many effects, but most habitat losses are permanent. Compensation can also be used to counter-balance some of the unavoidable negative impacts of land development, and if property planned and implemented, can provide a net benefit to some species in certain cases.

Development is always accompanied by the construction or improvement of roads. In 2011, the City completed the extension of Terry Fox Drive through the SMH in an arc from Hazeldean Road to March Road (**Figure 2**). Currently completed as a two lane collector, the road base has been built for an eventual four lane arterial road, with the roadbed, culverts and stormwater servicing already occupying the ultimate footprint. Future water and sanitary sewer pipes may be placed within the right-of-way without removing or altering additional habitat. Construction of the road required extensive tree cutting, the destruction of two small portions of the South March Highlands Provincially Significant Wetland Complex, and loss of floodplain along the Carp River. It also resulted in the severing of the urban portion of the South March Highlands from the Conservation Forest. Compensation for the lost wetlands, floodplain and forest has been provided by the City along the Carp River to offset these impacts. In addition, a system of wildlife passages was constructed under Terry Fox Drive, consisting of dry passages and enhanced wet culverts, along with an integrated guide system of fencing and stone walls.

Plans also exist for the realignment of Goulbourn Forced Road through the urban portion of the South March Highlands. The 2005 environmental assessment (Dillon 2005) proposed to improve the road as a two lane collector and to route the road to connect with the Terry Fox Drive extension 400 m west of the TFD/Second Line Road intersection. This route was intended to protect the highly-diverse Trillium Woods, currently owned by KNL Developments Inc., and intended for transfer to the City under the 60:40 agreement. However, based upon the results of the Blanding's turtle monitoring work, it may be necessary to update the environmental assessment to assess the potential impacts of the realignment on the Blanding's turtle population and habitats.

Second Line Road, Old Carp Road and Huntmar Drive also surround the South March Highlands Conservation Forest. Second Line Road was recently extended south to connect to the Terry Fox Drive extension. Further improvements to create an urban road cross-section are planned. No work is currently proposed for either Huntmar Drive or Old Carp Road. The latter road bisects the northern half of the South March Highlands, but because it is narrow and heavily forested on both sides it may not be a significant barrier to movement of Blanding's turtle in its' unimproved state.

In summary, the South March Highlands has experienced multiple, cumulative effects of urbanization, including direct loss of habitat, fragmentation, and alteration of drainage patterns. These impacts are projected to continue in the future, resulting in the permanent loss, isolation or degradation of approximately half of the natural landscape. The remaining 400 ha of Conservation Forest will be largely bound by urban development, arterial and collector roads, and estate lot developments. At present, a semi-natural landscape connection exists between the Conservation Forest and the floodplain of the Carp River. However, that connection could be lost if development were to occur in the newly approved urban expansion study area.

Blanding's turtles are particularly vulnerable to urbanization and the kinds of cumulative effects occurring in the South March Highlands. Due to their reproductive cycle, life history, movement behaviour and habitat requirements (described below), the species has experienced population decline and is considered to be at risk across much of its geographic range. In Ontario, the species is designated as "threatened" under the *Endangered Species Act, 2007*. Under that legislation, the animals are legally protected from harassment, harm or killing. On June 30, 2013, habitat protection will come into force for the Blanding's turtle under the ESA 2007, however some level of habitat protection during the planning process is already in place under the *Provincial Policy Statement, 2005* and Ottawa's Official Plan.

In 2011, as part of the permitting requirements for the extension of Terry Fox Drive, the City undertook a study to determine the population size, distribution and movements of Blanding's turtles in part of the South March Highlands. Using live trapping and release, tagging, as well as radio tracking, the study has revealed a much larger SMH population of Blanding's turtles than originally expected: thus far, 97 adults and juveniles have been identified and there are undoubtedly many more hatchlings and very young animals too secretive to observe. . The animals are found throughout the SMH, including the Conservation Forest, KNL Phases 7 and 8, the Carp River

Floodplain and the western half of the Kizell Wetland. Consequently, any future development activities within the SMH will almost certainly require permits from the Minister of Natural Resources under the ESA 2007.

The City has commissioned the preparation of this Blanding's Turtle Conservation Needs Assessment to provide general guidance and concrete recommendations for promoting the long-term viability of the SMH population of Blanding's turtles. It is a management document, intended to guide the City in the management of the Conservation Forest, adjacent City roads and City facilities. It is also a planning document, intended to provide information and guidance in planning processes and decisions to the City, the Ministry of Natural Resources, the Ministry of Environment, the Mississippi Valley Conservation Authority, and private landowners. As recommended by the Provincial *Natural Heritage Reference Manual 2010*, as well as best conservation practices, the Conservation Needs Assessment incorporates the *precautionary principle*, which requires a cautionary approach to species protection and conservation, especially in the absence of strong evidence or scientific consensus. The Conservation Needs Assessment also reflects the assumption that impacts on individual Blanding's turtles or their habitats in the South March Highlands cannot be evaluated piecemeal, but must be assessed in terms of their long-term, cumulative effects on the viability of the full SMH population. This assumption reflects a basic principle of conservation biology, which is that recovery for a species at risk, begins with the protection of existing, viable populations and their habitats.

Conservation management plans and needs assessments are developed to provide support for decisions that impact at risk species and their habitat; and are very much a resource tool. First, conservation management plans/needs assessments include background information related to the biology of the species, the risk of threats to it and its habitat, and any information related to monitoring history and known population dynamics. Second, long term population modeling is conducted to identify the most vulnerable stages of the life cycle, in order to identify when and where management actions will have the greatest benefit for long-term viability. Third, management plans/needs assessments recommend management strategies, identify research opportunities, educational imperatives and monitoring needs. Essentially, conservation management plans/needs assessments are a holistic approach to identifying the relevant information, data gaps, and managing a species population with the intent of promoting population longevity and sustainability.

Specifically, the intent of this Blanding's Turtle Conservation Needs Assessment is to:

1. Review existing literature on Blanding's turtle biology and habitat needs;
2. Investigate natural and anthropogenic risks which may negatively influence SMH Blanding's turtles, their critical habitats and reproductive life cycle;
3. Describe the state of the SMH Blanding's turtle population, their biology and their habitats;
4. Using a population growth model, complete a population viability analysis;

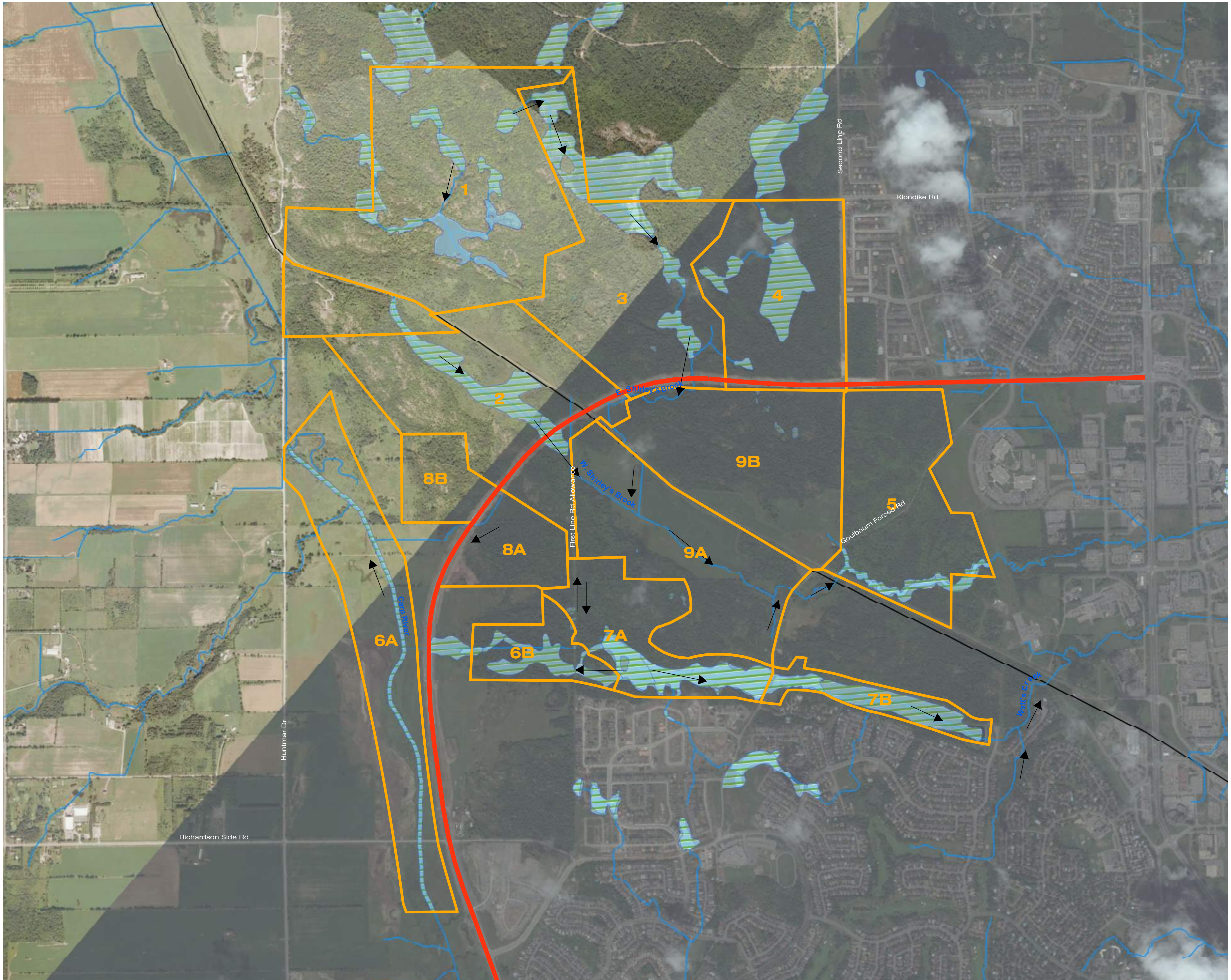
5. Determine the sensitivity of the model and model scenarios to assess the future of the SMH Blanding's turtle population;

6. Identify the core habitats for the SMH Blanding's turtle population;

7. Identify the extent of suitable habitat in the SMH and explore possible corridors to neighbouring Blanding's turtle populations; and,

8. Make long term planning recommendations based on specific objectives which are intended to support the long-term sustainability of the SMH Blanding's turtle population.

To assess the conservation needs assessment applicability to supporting the population, two research scientists have provided peer-reviews of the report. Their letters of review and *curriculum vitas* have been included in **Appendix A**.



Ottawa

City of Ottawa

South March Highlands Blanding's Turtle Conservation Needs Assessment

Study Area

Figure 1

- Study Area Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway
- WaterFlowDirection

0 75 150 300 450 600 Meters

SCALE 1:17,000

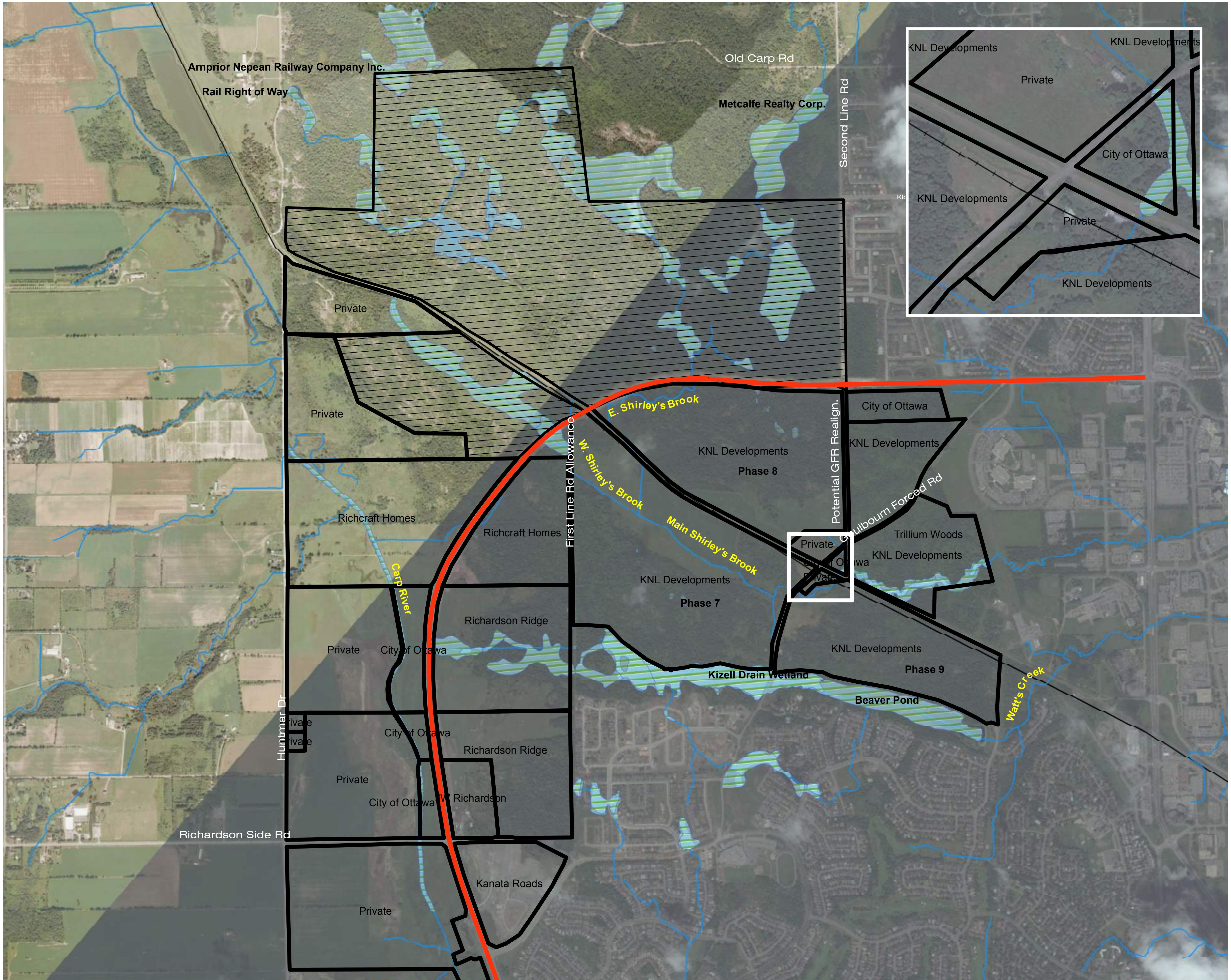
MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: CTH
MAP CHECKED BY: ST
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\1-StudyArea and Ownership.MXD

DILLON CONSULTING

PROJECT: 12-6060
STATUS: FINAL
DATE: 01/07/13



City of Ottawa

South March Highlands Blanding's Turtle Conservation Needs Assessment

Property Ownership Map

Figure 2

Terry Fox Drive

Wetlands

Watercourse

Property Boundaries*

Conservation Forest (City of Ottawa)

*Property lines and ownership has not been confirmed with City records

0 75 150 300 450 600 Meters

SCALE 1:17,000

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

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DILLON CONSULTING

PROJECT: 12-6019

STATUS: DRAFT

DATE: 10/16/12

2.0 Blanding's Turtle Biology and Habitat Needs

Blanding's turtles are a medium-sized freshwater turtle distributed throughout parts of North America. Blanding's turtles range from central Nebraska and Minnesota to southern Ontario/southwestern Quebec and Northern New York. There are isolated populations further east in New England and Nova Scotia (**Figure 3**). The species is known for its domed shaped carapace which resembles a German World War II era helmet and their bright yellow chin and throat (**Plate 1**). The turtle is also called a "semi-box" turtle because the plastron (bottom plate) is hinged and allows the turtles to tightly close their plastral lobes for protection.

Blanding's turtles are opportunistic, omnivorous predators in aquatic environments and are known to eat insect larvae, carrion, snails, leeches, crayfish, small fish, frogs, fish and frog eggs, plant matter and seeds from macrophytes (Congdon *et al*., 2008). While on drier terrestrial habitats, they eat grasses, herbaceous plants, earthworms and slugs (Natural Heritage and Endangered Species Program, 2007). The species live in wetlands with abundant vegetation surrounded by upland wooded habitat (Congdon *et al*., 2008). Hatchlings and very young juveniles may use dense aquatic vegetation to shelter themselves from their predators, however, habitat selection by young Blanding's turtles is largely unknown (Pers Comm, Dr. Justin Congdon). Hatchlings are vulnerable to herons, diving ducks, raccoons, skunks and aquatic mammals like mink and river otter. Permanent pools, which are deep enough to remain ice-free at the bottom over the winter and have a sufficient amount of dissolved oxygen, are required for adult and juvenile hibernation (COSEWIC, 2005). Recent work suggests that hatchlings spend the first winter on land under wood piles, logs and roots (Dinkelacker *et al*., 2004).

Plate 1. A typical Blanding's turtle (source: Dillon Consulting Limited).

Blanding's turtles are long-lived and have been known to survive more than 80 years in the wild. Fecundity rates are low, because females take up to 25 years to become sexually mature, often only lay one clutch per year, and may not reproduce every year. Clutches of 10-15 eggs are commonly laid in loose soil, sand or gravel, in pits 20-25 cm deep, located with exposure to sunlight, which is needed to warm the soil and aid incubation. After the eggs are laid there is no maternal care given by the parents. The egg shells are soft, smooth, white and ovoid shaped, and can be as large as 3 cm on the long axis. Eggs take approximately 60-90 days to hatch depending on the average number of degree-days at an adequate temperature. Typically, hatchlings emerge in September or early October. The flexible shells of turtles readily exchange water with the incubation environment, therefore wetter conditions result in greater hatching success and higher quality hatchlings (Packard, 1999).

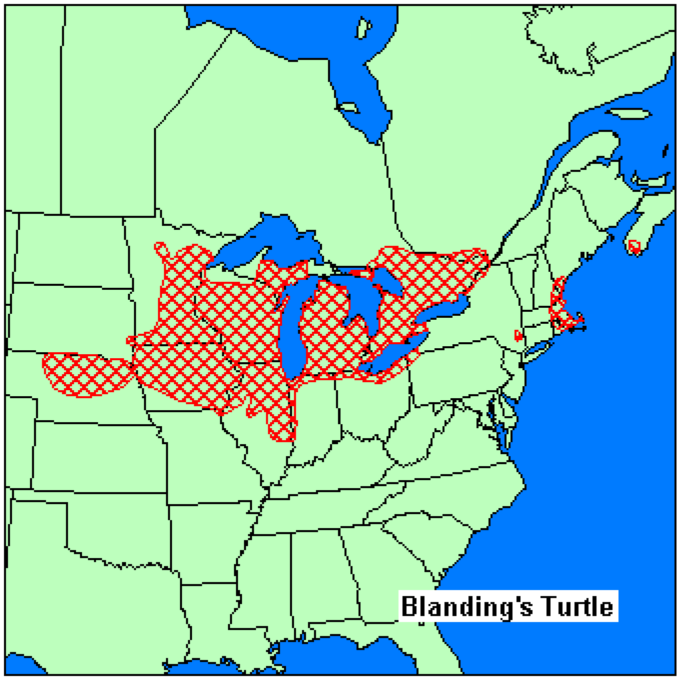


Figure 3. Geographical Distribution of Blanding's Turtle (source: http://www.dec.ny.gov/animals/7166.html)

Adult Blanding's turtles have few natural predators, though nest predation is very common. Animals such as foxes, raccoons, snakes, and skunks frequently consume newly laid eggs within minutes of being laid. Parasitism from sarcophagid fly larvae contributes to low nest success. Once grown beyond the 10 cm mark, most turtles have few predators capable of attacking and killing an individual, though attacks during nesting and other periods when turtles are in the open have been known to occur. A long-term (37 year) mark-recapture study conducted in Michigan found that annual survivorship of juveniles (ages 1 to 13) needed to be 72% to replace the number of adults that had died over the course of the study (Congdon *et al.*, 2008). Blanding's turtle reproductive success is limited by low fecundity rates and the vulnerability of eggs and hatchlings, meaning many reproductive females are needed to counterbalance the losses.

With respect to movement behaviour, Blanding's turtles are known to undertake frequent long-distance and long-duration terrestrial movements (Ross and Anderson, 1990; Rowe and Moll, 1991; Kinney, 1999; Dillon Consulting Limited, 2011b; Millar and Blouin-Demers, 2011). Gravid females have been found to move further distances and have larger home ranges than males and non-gravid females (Millar and Blouin-Demers, 2011; Dillon Consulting Limited, 2011b). Mean home range size for males is less than 10 ha, whereas for gravid females it can be as high as 30+ ha (Millar and Blouin-Demers, 2011). In general, gravid adult females, which are the most important to population viability, move around more so than other adults, and thus are more sensitive to mortality from motor vehicles.

In many jurisdictions, including Ontario, the species has been listed as either threatened or endangered. In Ontario, the current status under the *Endangered Species Act, 2007*, (ESA) is "threatened". In 2003, a recovery strategy for the Nova Scotia population was released by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (The Blanding's Turtle Recovery Team, 2002). Major risks to the species include habitat fragmentation and destruction, low recruitment due to nest predation, increased adult mortality from movement patterns intersecting with roads, and poaching of turtles for the exotic pet trade. These risks will be discussed in detail in **Section 3.0**.

2.1 Local Blanding's Turtle Population Distribution

The Canadian Wildlife Service (Hamill and Seburn, 2010) conducted a study of the Ottawa region to determine the presence and distribution of Blanding's turtles, based on recent and historical observations, as well as some limited field work. They determined that Blanding's turtles occur sporadically in the central and eastern areas of the City, but are concentrated primarily around wetland complexes in the west and southwest. Mapping prepared by Hamill and Seburn (2010) appears to show four main sub-populations: in the Marlborough Forest, in the Huntley Wetland – Long Swamp Wetland area, in the Carp Hills Wetland – SMH Highlands Wetland area, and along the Constance Creek – Shirley's Bay corridor (**Figure 4**). Blanding's turtles are also found across the Ottawa River, in West Quebec and Gatineau Park. When taken together, the five sub-groups may constitute a larger single Population, now fragmented by urbanization.

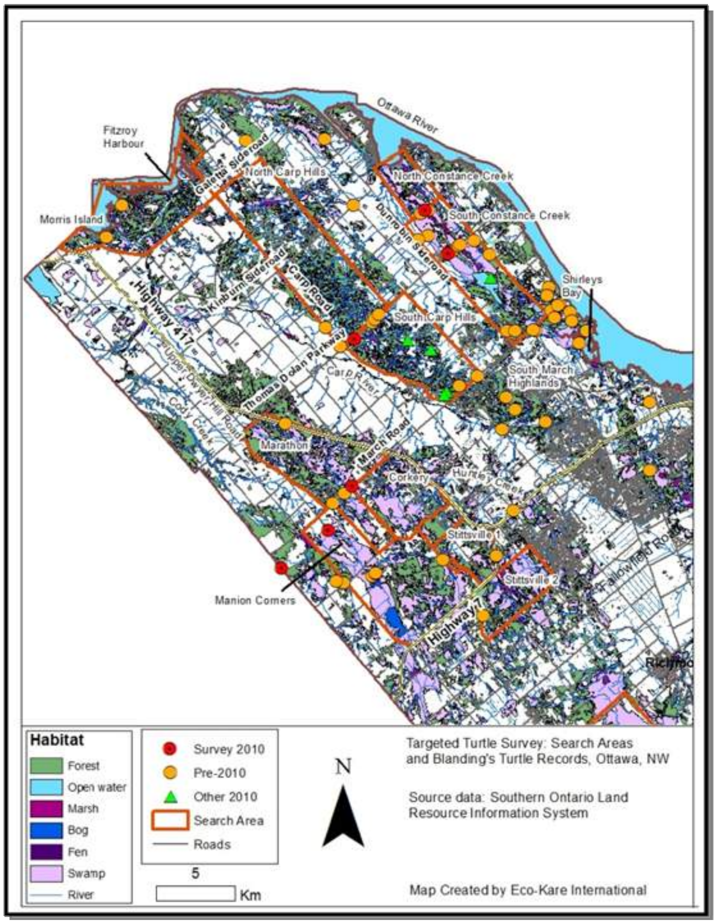


Figure 4. Blanding's Turtles in Ottawa (Source: Hamill and Seburn 2010)

No work has yet been done to determine how well or how recently these sub-populations have been connected. We know, however, that approximately 30% to 40% of Ottawa's wetlands have been converted to agricultural and urban uses over the past 200 years and we can speculate that all sub-populations were connected prior to European settlement. Opportunities for migration between sub-populations may still exist, especially along creek and river corridors. The Carp Hills – SMH sub-population and the Constance Creek – Shirley's Bay sub-population appear to come within 2 – 3 km of each other in the vicinity of March Road, and Shirley's Brook may have provided a functional movement corridor in the recent past, prior to adjacent urban development in Kanata North. At present, the Carp Hills – SMH sub-population appears at high risk of being split into two isolated sub-populations by estate lot development, by increasing road traffic, and by the proposed expansion of the urban boundary further west along the Carp River. In fact, for the purposes of this study, it has been assumed that fragmentation of this population has already occurred. Fragmentation of populations in this way greatly increases the vulnerability of each sub-population to decline and failure, by exposing each one to more intense, human impacts, by increasing their vulnerability to localized, catastrophic events, by eliminating the potential for migration between habitat areas in response to environmental changes (to drought for example), and by reducing genetic flows, biodiversity and long-term evolutionary potential.

Although this conservation needs assessment focuses on the long-term viability of the SMH sub-population, consideration should be given to the ways in which the recommended strategies and actions could be applied to reconnecting isolated sub-populations and making each one more robust.

2.2 State of the SMH Blanding's Turtle Population

In the fall of 2010, a 4 year population estimate, distribution and range study began with the purpose of predicting the size of the Blanding's turtle adult population and to determine habitat-use and movement patterns. The mark and recapture study is still on-going and is expected to end in the fall of 2013. Adults have been sampled by up to 35 trap nets for over 20 weeks during the 2011 and 2012 mark and recapture program. Current findings have identified that at least 97 adult and juvenile Blanding's turtles inhabit the South March Highlands and the Kizell Drain Wetland (number includes recently deceased turtles). Females outnumber males by about 2 to 1. Field sampling procedures have a low efficiency rate for the collection of juveniles and hatchlings, thus it is uncertain as to how many juveniles and hatchlings are present.

<u>Blanding's Turtle Distribution and Range</u>

The majority of Blanding's turtles in the SMH population have been found in the SMH Conservation Forest, along the Shirley's Brook drainage, while clusters or activity centres of turtles have been found in the Kizell Wetland and along the Carp River floodplain at Huntmar Drive (**Figure 5**). It is unclear at this time how the population is spatially distributed, but movement and recapture data suggest that there are three sub-populations in the SMH population (Kizell Wetland, SMH-central, and SMH-upland; see Section 5.0 below). Currently (October 2012) 19 adults have radio transmitters attached to their shells in order for their movements to be tracked using radio telemetry. Each is tracked 5 times a week in May and June, then 3 times a week in July and October. The number of tagged individuals represents about 26% of the sampled adult population. Distance traveled for tagged turtles has ranged up to 10 km for one female during the spring/summer of 2011, while some males and females remained in the resident wetland where they were first captured and tagged, traveling less than 500 m annually.

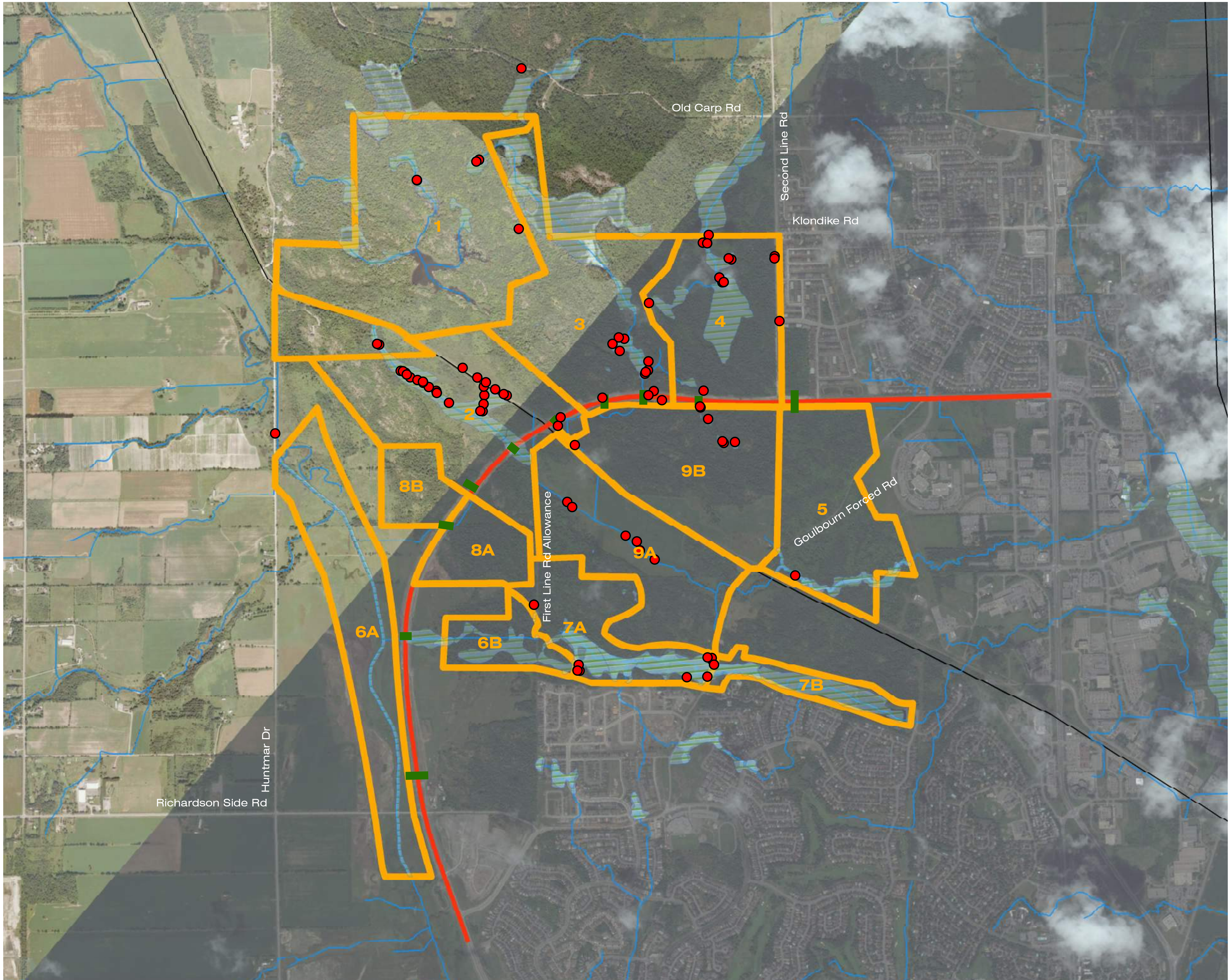
Results from the radio telemetry portion of the study have shown movement among the Blanding's turtles of the SMH to be highly variable, and gender dependent. Males and non-gravid females typically stay within their "resident" wetland for the entire year, while a minority of males may move between distinct wetlands over the course of the year. Gravid females have been found to move over longer distances than males during nest searching. For the most part, gravid female movements typically occurred during mid-June to early July. In some cases the movements crossed Terry Fox Drive, and, based on the telemetry observations and *in situ* trail cameras, we believe that the Wildlife Guide System (see below) is allowing these movements to occur beneath the road through the culverts (Unpublished Data, Dillon Consulting Limited). Of note, no Blanding's turtles have been found dead on Terry Fox Drive as a result of vehicle impacts since the road was opened in July 2011.

Despite the frequent tracking schedule, not all tagged turtles have been tracked continuously throughout the study period. They are often lost for a few days from detection. This may be the result of the turtles moving beyond the area of the study or deep in a wetland, and thus outside of the reception of the radio receivers. In some cases we currently cannot rule out transmitter malfunction or battery failure. However, some of the disappearances occur in the upland habitat of Zone 1, where larger water bodies make consistent tracking more challenging. Furthermore, Blanding's turtles are known to disappear from study areas for long periods of time before returning (Pers Comm, Dr. Justin Congdon). For a more complete discussion of the radio telemetry tracking, figures, and trail camera statistics see the annual summaries (Dillon Consulting Limited; 2011 a, 2011 b; 2012 a, 2012 b).

<u>Blanding's Turtle Nesting Distribution</u>

In the early summer of 2012, Dillon conducted late day targeted nest searches and radio telemetry tracking to locate the specific areas where gravid Blanding's turtles may be laying their eggs. The increased level of effort resulted in a number of depredated nests being found in the upland habitat of Zone 1, though species cannot be confirmed (Blanding's eggs and Painted turtle eggs are easily confused once predated because it is difficult to infer size). Radio tracking however, revealed several confirmed gravid females moving beneath Terry Fox Drive and into Zone 9B. Zone 9B has a string of ephemeral vernal pools, marsh wetlands along East Shirley's Brook, upland mixed forest habitat and hay fields. The Arnprior-Nepean railway bed also bisects the area, separating zones 9A and 9B. Tagged gravid females were tracked to the forest - hay field edge where turtles were again confirmed by hand to be gravid. No nests were found; however, subsequent tracking and handling of the turtles revealed that upon leaving the general area, the turtles were no longer gravid, having laid their eggs overnight. Similar observations indicate that some females move beyond Second Line Road to find nesting grounds, though this is based on an adult female mortality during the nesting season and another radio tracked female near the road; reproductive status of both females was not determined.

A Blanding's turtle was observed nesting on Old Carp Road near the junction with Huntmar Drive, and several predated turtle nests (no species determined) were observed along Huntmar Drive (Pers Comm, Dr. Nick Stow, City of Ottawa Environmental Planner).



Ottawa

City of Ottawa

South March Highlands Blanding's Turlte Conservation Needs Assessment

Blanding's Turtle Distribution in South March Highlands

Figure 5

- Zone Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway
- Wildlife Culvert Crossings
- Blanding's Turlte Observations, excluding radio-telemetry data

0 85 170 340 510 680
Meters
SCALE 1:17,000

W N S E

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\4-BT_distribution.MXD

DILLON CONSULTING

PROJECT: 12-6060
STATUS: FINAL
DATE: 10/17/12

2.2.1 Connections to Other Populations

Given that the study has only been collecting data for two years, concrete evidence suggesting that the SMH population is connected to the Carp Hills population has not been found. Two radio-tagged turtles and at least one other adult Blanding's turtle have been found to use the Carp River Plain, but it is unclear as to whether the habitat is being used as a movement corridor or just for daily habitat use. A roadside assessment of turtle habitat between the SMH and the Carp Hills suggest there may be sufficient habitat connecting the two areas, however there is low density housing and a busy arterial road separating the areas. Sampling of wetlands in the Carp Hills may provide evidence that the two populations are connected, especially if turtles tagged in the SMH are found in the Carp Hills and *vice versa*.

2.2.2 Terry Fox Drive Wildlife Guide System

A Wildlife Guide System (WGS) was built within the Terry Fox Drive roadway, integrating a system of culverts, barrier walls and fencing that directs or guides wildlife (small and mid-sized mammals, amphibians and reptiles, including turtles), through the culverts to safely cross under the road. Research into the effectiveness of the WGS using high definition, "trail" cameras mounted in each culvert is ongoing with one year of data analysis complete (Dillon Consulting Limited, 2011a). Although only a few turtles have been visually observed moving through the culverts, we suspect based on radio telemetry that the turtles are using the culverts regularly. As a result of the camera mounts in 2011, there were 783 observations made on 19 species over a 93 day period following the opening of Terry Fox Drive. Thirty three animals were found dead on the road over the 93 day period, of which 23 were snakes, which could pass through the fence mesh. None of the mortalities were Blanding's turtles. Monitoring continued through 2012 with the cameras installed during June and removed in October, providing for a broader time period of study than in 2011. A second year report on the 2012 observations will be due to the regulatory agencies by January 31, 2013.

During the 2012 studies, continuous monitoring was completed between June 4 and October 3, however due to water in several culvert, a few of the cameras were not installed until July 7 so the data set for each camera varies in length (Dillon Consulting Limited, 2012b). Over the study period and 10 culverts, there were 2392 confirmed observations of 24 species of wildlife. The first observation of Blanding's turtle using a culvert was made in this year. The four purpose-built wildlife culverts were monitored for an average of 2048 hours each, saw an average of 288 animals, and an average of 13 species. The hydraulic culvert on East Shirley's Brook (CV6) had 259 observations and 17 species although was monitored for 1393 hours as it was flooded until July 5. Blanding's turtle was observed in two culverts, CV6 and TCV3 which lie side by side near East Shirley's Brook. The results from the 2012 season are indicating that turtles are occasionally using the culverts for their movements, but there were only 8 different observations over the three species found in the study area, but thus far the movements we've observed cannot be called 'frequent' or 'regular'.

Plate 2. A Blanding's turtle moving through culvert CV6 that carries East Shirleys Brook..

3.0 Threats to Blanding's Turtle

An understanding of threats and risks is important for assessing the long-term viability of the SMH Blanding's turtle population. Threats can be natural or anthropogenic and individual animals may differ in their level of risk depending upon behavior, movement, sex and age. Cumulative effects are important. Exposure to a greater number of threats in a confined area is clearly detrimental to a population, but equally so, a single threat over a wide area may be equally as detrimental. Some threats, however, create a greater magnitude of risk than others. Priority should be placed on management strategies that reduce the risks with the highest impact on a population, although the cumulative effects of lesser risks should not be ignored.

In order of magnitude of risk to Blanding's turtle, below we outline some of the most significant risks to the SMH population:

3.1 Road Mortality

Vehicle strikes represent the highest threat to Blanding's turtle, as they are often killed while crossing roads. During the course of the City of Ottawa studies in 2010-2012, three Blanding's turtles, two Common Snapping turtles and four Midland Painted turtles are known to have been killed on the roads in and around the South March Highlands. Huntmar Drive, Goulbourn Forced Road and Old Carp Road have each existed for several decades and we speculate that many Blanding's turtle mortalities have occurred on them over the years, especially where the roads bisect wetlands and water bodies. Mortalities are expected to be highest in May and June when gravid females are nest-searching, then again in September as the eggs hatch and the young move towards nearby wetlands. The on-going study on the effectiveness of the Terry Fox Drive Wildlife Guide System suggests that culverts work to reduce the potential for road mortality in turtles and other SMH animals, but they may be a learned behaviour and the frequency of their use will improve over time. Other solutions, like turtle crossing signs and seasonally-adjusted reduced speed limits, may decrease the risk of road mortality to Blanding's turtle.

3.2 Habitat Loss Due to Urban Expansion

Key Blanding's turtle habitat has the potential to be lost when urbanization occurs in areas with known populations of Blanding's turtles. Blanding's turtles naturally make their resident habitat in areas where there are permanent wetlands and prefer swampy/marshy environments with lots of woody structure. Blanding's turtles are known to use forested upland habitats and connecting water bodies as travel corridors. Urban land development requires the clearing of agricultural and forested lands, fragments the habitat connectivity, creates movement barriers, fills or alters creeks, drainage ditches or wetlands, and covers over nesting areas with pavement, lawns and buildings. Development may lower groundwater tables and change groundwater movement patterns, causing vernal pools to dry up and become encroached with herbaceous vegetation, shrubs and trees. Natural soil structure may be altered by site grading, leaving compacted subsoil overlain by a skim of topsoil, devoid of earthworms, fungi and other beneficial microorganisms. Consequently, urbanization is almost always incompatible with the protection of Blanding's turtle habitat.

3.3 Predation

Predation is a threat in any naturally occurring population. Adult Blanding's turtles can be predated or harmed if their extremities are not enclosed in the shell, but this is rare and usually only happens when turtles are laying eggs (Pers Comm, Dr. Justin Congdon). Several authors have reported that Blanding's turtle eggs are most vulnerable to predation while in their nest and shortly after hatchling emergence (Congdon *et al.*, 2008). Nest predation over a 34 year study in Michigan was highly variable, and averaged 43.8% (ranged 7-78%) (Congdon *et al.*, 1993). Nests were regularly predated by raccoons and foxes, with predation occurring within three days of nest construction (Congdon *et al.*, 1983, 2000). Skunks and mink are also known predators of nests. Caging programs, aimed at reducing predation by protecting known nests, have been effective at reducing predation in and around Kejimkujik National Park in Nova Scotia for over 20 years and have become an important management tool for protecting the Blanding's turtle population there (Standing *et al.*, 2000).

3.4 Poaching

Poaching presents a very significant risk to Blanding's turtle populations, because large numbers of turtles can be easily collected and transported for the exotic pet or medicinal drug trade. Although poachers are unlikely to find and remove young turtles, it may only require the poaching of a few reproductive adults from a population to cause a precipitous drop in the population size. One poacher in Ontario was found in possession of up to 35 Blanding's turtles in the trunk of a car (Canadian Gazette, 2009). For this reason the specific locations of habitats and individuals are kept as confidential information by the City. Educating the public and monitoring of sensitive areas may reduce the risk and potential for turtles to be removed by poachers.

3.5 Diseases and Parasites

Parasites have the potential to reduce immune response and cause mortality. Blanding's turtle are parasitized by protozoans, trematodes, nematodes, acanthocephalans, leeches, and mosquitos (Ernst and Barbour, 1972). Due to a paucity of research, levels of infestation have not been quantified. One of the more researched Blanding's turtle parasites are leeches, specifically the Smooth turtle leech (*Placobdella parasitica*) and the Ornate turtle leech (*P. ornate*) (Samure, 1990, Davy *et al.*, 2009). A concern is that both leeches can transmit blood parasites (Siddal and Dresser, 1992). With respect to diseases, shell diseases have been identified as a potential factor in the global decline of turtles. Shell diseases include lesions and abnormal shell growth (Gibbon *et al.*, 2000) but no reports of shell disease in Blanding's turtles were found during our literature review.

3.6 Invasive Species

Invasive species are animals and plants which are non-native species that can move into areas naturally but most often come to an area because of human introduction (either purposefully or by mistake). Many invasive species never take hold in new environments because conditions are too harsh for them to carry out their life processes, however for species that do successfully invade new ecosystems, they often out-compete native species and fill similar functional niches. Below we outline several invasive species that have the potential to inhabit the SMH and what their impacts on the local Blanding's turtle population may be.

Red-eared slider (*Trachemys scripta elegans*) is a turtle native to the southern U.S. and sold as pets. So far, the turtle has been reported to be able to overwinter in the Ottawa Region, however biologists do not believe it can reproduce here due to cooler temperatures. The red-eared slider competes with native turtles for food, basking sites and occupies similar nesting areas.

The rusty crayfish (*Orconectes rusticus*) is native to the central United States and has been spread by anglers into non-native waters through emptying of bait buckets and livewells. Rusty crayfish were first observed in the Ottawa Region in 1986 and has spread to several water bodies, including the Rideau River. Rusty crayfish out compete native crayfish for resources and have drastically reduced native crayfish populations in many areas of Ontario. SMH Blanding's turtles may be impacted by Rusty crayfish as the diversity of food available to Blanding's turtle may be lower than in the past.

Zebra mussels (*Dreissena polymorpha*) occur in large open water lakes and some of the larger rivers of Ontario, such as the Rideau and Ottawa Rivers. Zebra mussels are very efficient filter feeders and will drastically alter the turbidity and water clarity of a water body which has cascading effects on native species. We would not expect zebra mussel to invade the waters of the SMH in any significant way due to the overall lack of suitable, hard substrates for attachment and growth.

Semi-aquatic invasive plant species such as Purple Loosestrife (*Lythrum salicaria*), and Common Reed Grass (*Phragmites australis*) have been spreading north-east throughout Ontario for several years, invading wetlands, riverbanks and wet ditches. Both of these species can out-compete the native cattail (*Typha latifolia*) as well as the smaller, less robust emergent macrophytes, softstem bulrush (*Scirpus validus*), rushes (*Juncus sp.*) and the spike rushes (*Eleocharus sp.*) common in freshwater marshes. Competition may affect the cover diversity and food sources of the prey organisms. *Phragmites*, which grows to 5 m tall, is known to totally dominate an area, choking out other species and making it nearly impassable. Once *Phragmites* enters a system, it can grow so quickly, with so much biomass, that the open water areas important for turtle basking and feeding may become closed, overly shaded and inaccessible. Within dense stands of *Phragmites*, there are no resources for other flora and fauna, there are no frogs or crickets, and the colonized area essentially becomes a barren environment.

Eurasian milfoil (*Myriophyllum spicatum*) a submerged aquatic plant transported primarily through anthropogenic means (fouled boat motors), does not seem to have invaded the wetlands of the SMH waterways, and may not be expected to do so unless directly transplanted. It has become common in lakes, ponds and relatively large, open water-bodies with clear water and a muddy bottom. If it does start to occur in the SMH, it will provide an alternative food source for turtles and their prey. However, in waterbodies with high nutrient levels (*e.g.* urban runoff), the biomass may accumulate to a density where swimming through the areas may become difficult for turtles. In the fall and winter when the large biomass decomposes, dissolved oxygen levels in the water column may become depressed, potentially leading to winterkill of hibernating Blanding's turtles.

The SMH study area was inspected for invasive species in June 2012 during the radio tracking studies (unpublished data, Dillon Consulting Limited). Of the six species noted above, only Purple Loosestrife (*Lythrium salicaria*) was found in two locations. One of the earliest species known to affect wetlands in Eastern North America, this species has become a common plant along the Carp River riparian zones. Fortunately, the introduction of biological control agents in Ontario appears to have successfully controlled populations of Purple Loosestrife. Consequently, the densities around the SMH remain quite low and do not appear to be significantly affecting the population of other native plants and animals.

3.7 Plastic Floatables

Roadways and urban areas generate significant volumes of floatable or windblown plastic and styrene products. Bottle caps, cigarette lighters, cigarette butts, water bottles and plastic bags commonly are found floating in waterways around urban areas. Turtles may mistakenly consume smaller items in the belief they are food items. These items are indigestible and can get lodged in the gut, cannot be passed, and may reduce an animal's ability to absorb nutrients from the food. In extreme cases, the accumulation of many plastic items can permanently occlude the intestines, resulting in death. Non-photodegradable plastic shopping bags can be persistent in the environment and can entangle or trap animals below the water where they may drown.

3.8 Climate Change

As with most predictive biology, the effect of a changing climate on Blanding's turtle is currently not well known. No studies have been done to look at the impact of long-term climatic variation and Blanding's turtle ecology, therefore we only speculate here. Historical climate records and climate modeling for Ottawa suggest that the main effects of climate change in this area are warmer, more variable winters, drier and earlier spring thaw, and drier summers with more frequent severe summer storms. Warmth earlier in the spring may result in an earlier onset to breeding and nesting. Irregular weather during the winter can result in premature warming of water and potentially cause early emergence. Drier summers may reduce the availability of suitable wetland habitats, requiring longer or more frequent overland movements by turtles and thereby increasing physiological stress and exposure to other hazards.

3.9 Inbreeding

When the rate of recruitment to a population is low and adult mortality potentially high, there is a potential for inbreeding, either sibling with sibling or parent with offspring. There is evidence that young hatchlings find a different water body to grow and develop in separate from the parents (Butler and Graham, 1995; Standing *et al.,* 1997). In large conservation areas like Kejimkujik National Park or Algonquin Provincial Park, the availability of suitable habitats is quite diverse and maintaining separation is relatively easy. However, it may be that the SMH is too small and maintaining separation between related individuals is difficult. For instance, a population genetic study done in 2001 suggests that a habitat-limited population of Blanding's turtles near Chicago, IL is experiencing loss of genetic diversity, potentially from inbreeding (Rubin *et al.*, 2001). Loss of genetic diversity is a problem because it may limit how the population can respond to future environmental change. Dispersal of eggs by gravid females is an important variable modeled in Section 4.0 which reflects the need to minimize inbreeding.

3.10 Bioaccumulation

Few comparative studies of bioaccumulation of pollutants have been conducted on Blanding's turtles, however there has been extensive work done on the Common Snapping turtle as a sentinel indicator of pollutants in estuaries and freshwater ecosystems. Snapping turtles share many of the same habitats as Blanding's turtles, have a similar lifespan, and like Blanding's turtles, they sit high on their food chains. In theory, both Blanding's turtles and snapping turtles may be susceptible to negative effects on individual health or reproduction due to bioaccumulation of toxins. It is important to note that within the Testudines Order of Reptiles, the various turtle species have evolved along separate pathways and therefore will reflect different risk profiles with respect to their vulnerability to bioaccumulation of pollutants; so interspecies comparisons should be interpreted with caution.

Common snapping turtles stay in one general area from year to year, often for their whole life span, so are likely to remain exposed to the same chemicals year after year. As in most carnivorous or omnivorous species, persistent contaminants accumulate in the fatty adipose tissues, liver, skeletal muscles and may be passed through to their young in the lipid content of eggs. Studies from New York State, Southern Ontario, the St. Lawrence River and Algonquin Park have found evidence of bioaccumulation of polyaromatic hydrocarbons, organochlorines and metals in snapping turtles (Herbert *et al.*, 1993; Bishop *et al.* 1995, 1996). However, the evidence of negative impacts on health or reproduction appears mixed and inconclusive.

Historically, the South March Highlands has been relatively undeveloped, save from the railway routed through the wetlands, a single electricity line, farming in the drier areas and further back in time, lumber extraction from the hillsides. Although contaminant levels have not been sampled in this area, we hypothesize that it is quite possible that the creosote, polyaromatic hydrocarbons (PAH's) and persistent organochlorine contaminants (OCS) in the preservatives for the railway ties and hydro poles may have resulted in some low levels of OCS for the existing Blanding's turtle population prior to the development of Terry Fox Drive and the proposed residential developments.

The above is a brief summary of a complex field of study. A more complete discussion of bioaccumulation in turtles is included **Appendix D**.

4.0 Supporting Scientific Studies

4.1 Population Viability Analysis

A focus of conservation biology research is to address the fundamental issues and causes underlying species/population declines. Species and populations can be limited by environment, anthropogenic activities, and by biological characteristics including genetics, physiology, biomechanics, and behaviour. In the case of the Blanding's turtle, populations are at risk due to their low fecundity and recruitment, delayed sexual maturity, and high adult mortality associated with poaching, habitat loss, and road mortality.

In order to model the vulnerability of a particular population to extinction or extirpation, scientists have employed Population Viability Analyses (PVA) which aims to understand population growth with respect to long-term trends (**Appendix C**). If the parameters such as survival and fecundity are predictable, then biologists and managers can understand the risks to a population and can provide mitigation or management measures to improve population longevity. A PVA analyzes the factors that are known to impact a population and uses a defined model to predict the risk of extinction of that population. Consequently, PVA is also a good tool for evaluating and identifying the most beneficial mitigation and management actions for protection of a population (Gerber and Gonzalez-Suarez, 2010).

This study employed computer modeling to mimic "real" conditions and to simulate population changes over time. By running a computer simulation thousands of times, and by randomizing unpredictable factors like weather or catastrophic events (such as introduction of an invasive species or an epidemic), computer modeling can be used to assess the risk of extinction. This approach is now common because of wide access to high-powered, desktop computers. However, as with any analysis, there are limitations and uncertainty. Some important factors, such as birth and death rates, may be poorly known. Future conditions may be difficult to predict, especially random factors like weather and diseases. Nonetheless, if these limitations are recognized and acknowledged, then a computer simulation PVA is very useful for assessing the vulnerability of a population to extinction and the comparative effectiveness of different management options.

4.1.1 Overview of Model and Analysis

A primary objective of this conservation needs assessment is to analyze the long-term viability of the South March Highland's Blanding's turtle population and to assess its ability to survive planned human activities within its habitat. A PVA was used to look at the overall resilience of the SMH Blanding's turtle population, and to compare the effects of different human activities and management options on the relative risk of extinction. Due to data limitations and uncertainties about future conditions, the analysis cannot provide reliable quantitative estimates of extinction risks.

However, it can identify the impact of each threat or management option on those risks as positive, neutral, or negative and it can assess their relative importance.

The analysis combined the Blanding's turtle population information collected between 2009 and 2012 as part of the Terry Fox Drive studies by the City of Ottawa and Dillon Consulting Limited. It used information on the current population structure, habitat quality/suitability, and movements from those studies. Because the current population study for the South March Highlands has not spanned a long enough time to accurately determine birth rates and survival rates, the PVA used demographic data collected in Michigan over a span of almost 40 years at the 525 ha University of Michigan's E.S. George Reserve (1953-1991). The reserve lies approximately 900 km to the southwest of the South March Highlands. Carrying capacity (K) was calculated based on the Michigan population (7.5 turtles per hectare). This is a conservative estimate, as a Blanding's turtle population in Nebraska has been found to have over 50 individuals per hectare (Congdon *et al.,* 2008). Another distinction of the model is that only the number of female turtles was modeled. Blanding's turtles exhibit a polygamous mating system, which means that the number of females in a population is the limiting factor in the rate of reproduction.

With respect to development pressures, the study assumed that all of the land within the study area that is currently designated for urban, residential development by Ottawa's Official Plan would eventually be lost as Blanding's turtle habitat. This area comprises all of the habitat in the areas called Zone 9A and 9B in the City of Ottawa report *SMH Blanding's Turtle Population Estimate, Distribution and Range Study, Year 2 of 4* (Dillon, 2011a) and is also referred to as KNL Phases 7 and 8.

In order to improve the realism of the computer simulations, the PVA broke the SMH population of Blanding's turtles into three sub-populations based on their distribution and movement patterns across the 690 ha study area (**Figure 6**).

- The Kizell Wetland sub-population (KW)
- The South March Highlands- Central sub-population (SMH – CEN) (includes KNL Phases 7 and 8).
- The South March Highlands- Upland sub-population (SMH – UP)

The PVA also considered differences in survival, migration potential and exposure to threats for three different life stages of Blanding's turtle: (1) eggs/hatchlings; (2) juveniles; and, (3) adults.

Typical outcomes for PVAs are: (i) the probability that the local population will become extinct; (ii) the rate of the decline; and, (iii) the length of time for the population to decrease to extinction, should it occur. However, because of the uncertainty associated with the life-cycle demographic data (i.e., vital rates, initial abundances, etc.) this analysis focused on the sensitivity of the population to different human activities and threats, and assessed different situations that in the future may impact the SMH Blanding's turtle population. The scenario outcomes presented are the relative decrease in adult female turtles when compared to existing baseline conditions in the SMH.

4.1.2 Methods

Appendix C provides a detailed description of the PVA methodology, including the demographic and statistical parameters used in the computer model. The PVA was completed using the RAMAS® Metapop software (Applied Biomathematics, Setauket, New York). The software predicts changes in populations over time, incorporating normal fluctuations in factors such as birth and death rates, and can include random factors, such as weather or catastrophic events. The model spans a 500 year period and was replicated 1000 times for each scenario.

Two catastrophes were added to the model to account for randomly occurring events that may cause negative effects on the populations. One catastrophe halved *adult abundances* in each sub-population and is analogous to a large poaching event or a fatal disease outbreak. The second catastrophe halved *reproductive ability*, and is analogous to a systemic event, such as drought, which might alter survivorship, fecundity, and development over a large area. Each catastrophe was set to occur once in one hundred years.

4.1.3 Scenarios Modeled

The Population Viability Analysis consisted of 3 models (a baseline and two alternative models) and the sensitivity of the models to several scenarios, reflecting threats and possible mitigation/compensation measures. As well, given the findings in 2012 that a nesting area is located on KNL Phase 8 lands north of the rail line, a separate scenario was created and explained below independent of the other models and scenarios.

<u>Baseline Model</u>

The Baseline model is a situation in which all three sub-populations are stable, but are exposed to periodic catastrophic events. However, the selection of this scenario does not presume that the current SMH population of Blanding's turtles is, in fact, stable (we have insufficient data to make that judgment). It only represents a neutral scenario against which other scenarios can be compared. The model was altered to reflect the following scenarios. Only the number of adult female turtles is modeled.

1. **Decreased survival rates**. This scenario used a slightly decreased annual survival rate for the SMH – Central sub-population and a substantially decreased annual survival rate for the

KW sub-population. The decreased survival rates reflect the greater exposure of these sub-populations to residential developments and roads, especially the KW sub-population.

2. **Low egg survival**. This scenario may result from excessive nest predation caused by a parasitic infestation of several Blanding's turtle nests or from the cumulative effects of anthropogenic disturbances of the nesting cycle by domestic animals, increased densities of urban egg predators (raccoons, skunks), traffic noise, terrain alteration and proximity to humans.

3. **No catastrophes**. This scenario models a situation in which natural catastrophic events do not occur (note: historically, not a realistic scenario).

4. **Transplantation to the Kizell Wetland**. This scenario modeled the effects of transferring two female adult turtles from the SMH-CEN sub-population to the KD sub-population every five years, which is a possible management strategy for aiding population persistence in the KD area.

5. **Increased hatching success**. This scenario modeled increased success of egg hatching to represent a nest protection program (Section 6.3.4).

6. **High hatchling survival**. This scenario modeled increased survival of new hatchlings under a "head start program" – *i.e.* a foster program for new hatchings (Section 6.3.4).

Isolation Alternative Model

This alternative model reflects the decreased ability of turtles to migrate between the KW sub-population and the other sub-populations following the proposed development of KNL Phases 7 & 8. Similarly to the baseline model, the model was altered to reflect the following scenarios: **No catastrophe**, **Transplantation to the Kizell Wetland**, **Increased hatching success**, and **High hatchling survival** (head start program).

Urbanization Alternative Model

This alternative model reflects the full development of KNL Phases 7 & 8 and the complete loss of core turtle habitats. The model combines decreased survival rates for the SMH-Central and KW sub-populations and isolation of the KW sub-population. Similarly to the baseline and isolation models, the model was altered to reflect the following scenarios: **No catastrophe**, **Transplantation to the Kizell Wetland**, **Increased hatching success**, and **High hatchling survival** (head start program).

Removal of a Nesting Site in KNL (Kanata Lakes) Phase 8

This scenario is based on the loss of an identified nesting site in SMH-CEN (Zone 9B) due to development of the KNL Phase 8 lands. It assumes that the nesting site supports 60 eggs *per* year (before egg losses due to predation and nest failure). The loss of 60 eggs per year was assumed to start in year 5 and continuing to year 35 to represent the habitual use of the site by the current generation of adult turtles. After year 35, it is assumed that no turtles will be attempting to use the site. To relate the scenario to existing conditions, it was modeled using the Baseline model; and to relate the scenario to potential conditions should development in the area occur, it was modeled using the Urbanization Alternative Model. A potential compensation measure for the destruction of this nesting site is the commitment to run a head start program to add 30 juveniles each year for 30 years to the SMH-Central population. This management action was also modeled using both the Baseline and Urbanization models.

4.1.4 Model Elasticity

An important output of the PVA (independent of the alternative models and different scenarios) is a set of numbers related to the elasticity of the model. Elasticity refers to the change in the model output caused by a change in a single variable. The variable input that had the largest impact on the model outcome was adult survivorship, followed by juvenile survivorship (**Appendix C**). These two observations are typical for Blanding's turtle populations (Congdon *et al.*, 1993; Enneson and Litzgus, 2008). Because adult survival had the highest elasticity, or effect, it means that small changes in adult survival will have the greatest impact on the population size, and thus, management options should be prioritized to increase adult survivorship before considering management actions that influence other model variables.

4.1.5 Scenarios

Appendix C shows information about each of the scenarios described above in **Section 4.3.1** in comparison to the Baseline scenario. The following set of figures provides a qualitative description of the impacts of each modeled scenario on long-term population viability (in this case adult female abundance) in comparison to the Baseline scenario.

As PVAs are highly sensitive to model parameters and because the vital rate variables used in this model have been, for the most part, assumed from published datasets, we have limited our analysis and discussion of the model to its sensitivity. We have avoided, for example, stating absolute values for "time to extinction", "minimal viable population estimate", and "final number of adults". When interpreting the following figures, the percent decline in the number of adult females was used as a proxy for population decline/growth. Strong declines occurred when there was a greater than 50% reduction in the number of adult female turtles, declines occurred when there was between 5% and 50% reduction in the number of adult females. Similarly, strong growth occurred when there was greater than 50% increase in the number of adult females, and growth when there was an increase of between 5% and 50%. No change was defined as having between 5% reduction and 5% increase. Furthermore, it can be assumed, that if the model outcomes show decline, extinction will occur earlier than predicted by the Baseline model, and *vice versa*.

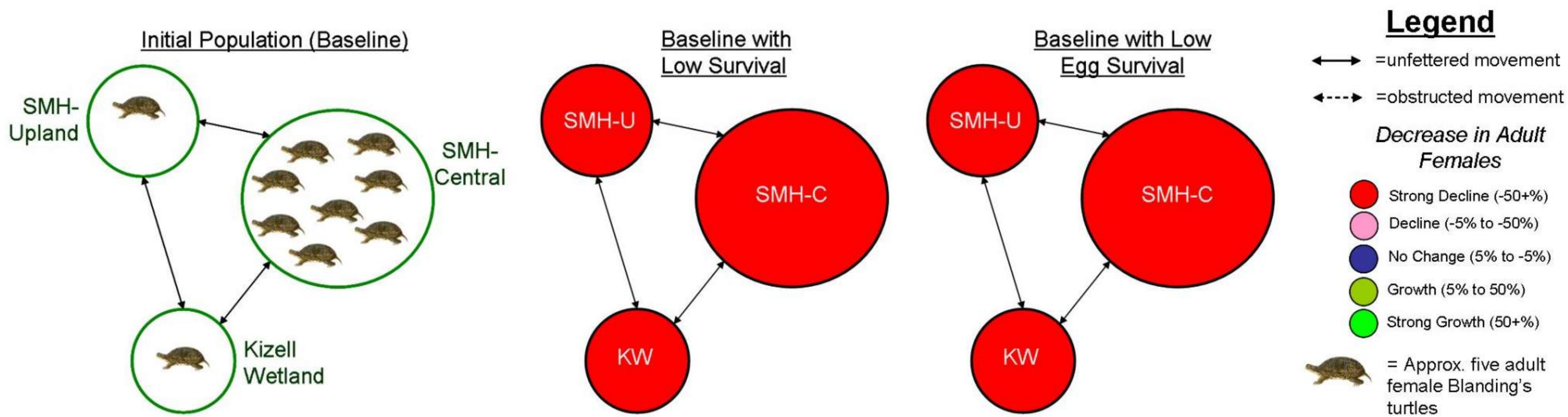


Figure 6. The initial population structure used in the PVA and the outcome of the decreased survival and decreased low egg survival scenarios.

*South March Highlands Upland (SMH-U), South March Highlands-Central (SMH-C), and Kizell Wetland (KW).

The Baseline scenario, itself, predicts eventual extinction of the SMH Blanding's turtle population due to the effects of periodic catastrophic events. Although it could be argued that the severity or the frequency of catastrophic events is too high, such a result is common for small populations of animals with low reproductive rates. The result highlights the inherent vulnerability of this population, which is clearly shown in **Figure 6** where relatively small changes in survival and egg survival result in a strong decline in adult female abundance.

To investigate the Baseline model further and to adjust the model to reflect potential management solutions, four other scenarios were run (**Figure 7**). When the Baseline model was run, omitting the potential for catastrophic events, the SMH Blanding's turtle population grows in size, which suggests that during long periods of time when no catastrophic events occur, the population is able to grow. The three remaining scenarios all relate to potential management strategies. First, if two adult female turtles every 5 years are removed from the SMH-C sub-population and transplanted in the KW sub-population, the action prevents decline in the KW sub-population, but causes the SMH-C sub-population to decline (an undesirable outcome). Second, the next management strategy modeled was to protect nests found in the area. The outcome of the nest protection scenario suggests a positive outcome, as both the SMH sub-populations grow and the KW sub-population remains unchanged, compared to the Baseline model. Third, if a head start program is implemented (eggs hatched and young reared for 2 years in captivity prior to release) both SMH sub-populations increase in size while the KW sub-population also shows positive growth.

A potential outcome of urban development in the SMH is that the KW sub-population would become isolated from the two SMH sub-populations as residential areas surround most of the wetland, with the First Line road allowance remaining forested. Should this occur, dispersion between the KW sub-population would be reduced; this model is depicted in **Figure 8**. When compared to the Baseline model, the Isolation Alternative Model shows that both the SMH-C and KW sub-populations decline, while the SMH-U grows in size. The increase in adult females in SMH-U is likely an artifact of there being few existing turtles there and the increase in turtles moving to the area because of the low dispersion rate into the KW sub-population. Again, as was seen in **Figure 7**, if no catastrophes are modeled, each sub-population grows, but this is unrealistic over the long term. The only difference in the scenario outcomes of the Isolation Alternative Model when compared to the Baseline model is for the transplantation scenario, in which case the SMH sub-populations both experience strong declines, and the KW sub-population shows less decline; meaning that transplanting turtles to the KW sub-population at the cost of turtles in the SMH-C sub-population is not a sustainable management option.

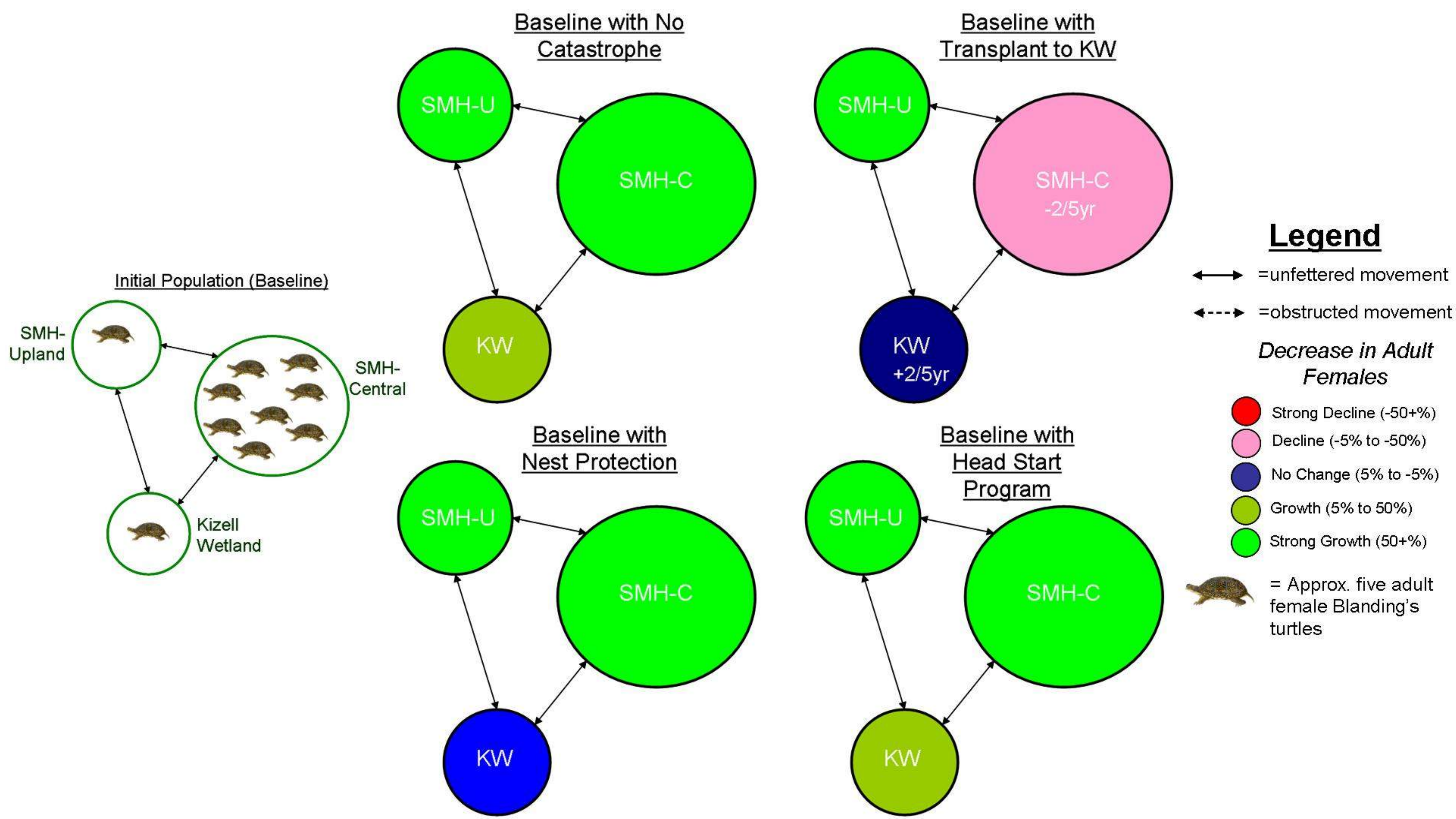


Figure 7. The Baseline model re-run with four scenarios: no catastrophe, transplanting 2 turtles from SMH-C to KW, nest protection, and head start program.

* South March Highlands Upland (SMH-U), South March Highlands-Central (SMH-C), and Kizell Wetland (KW).

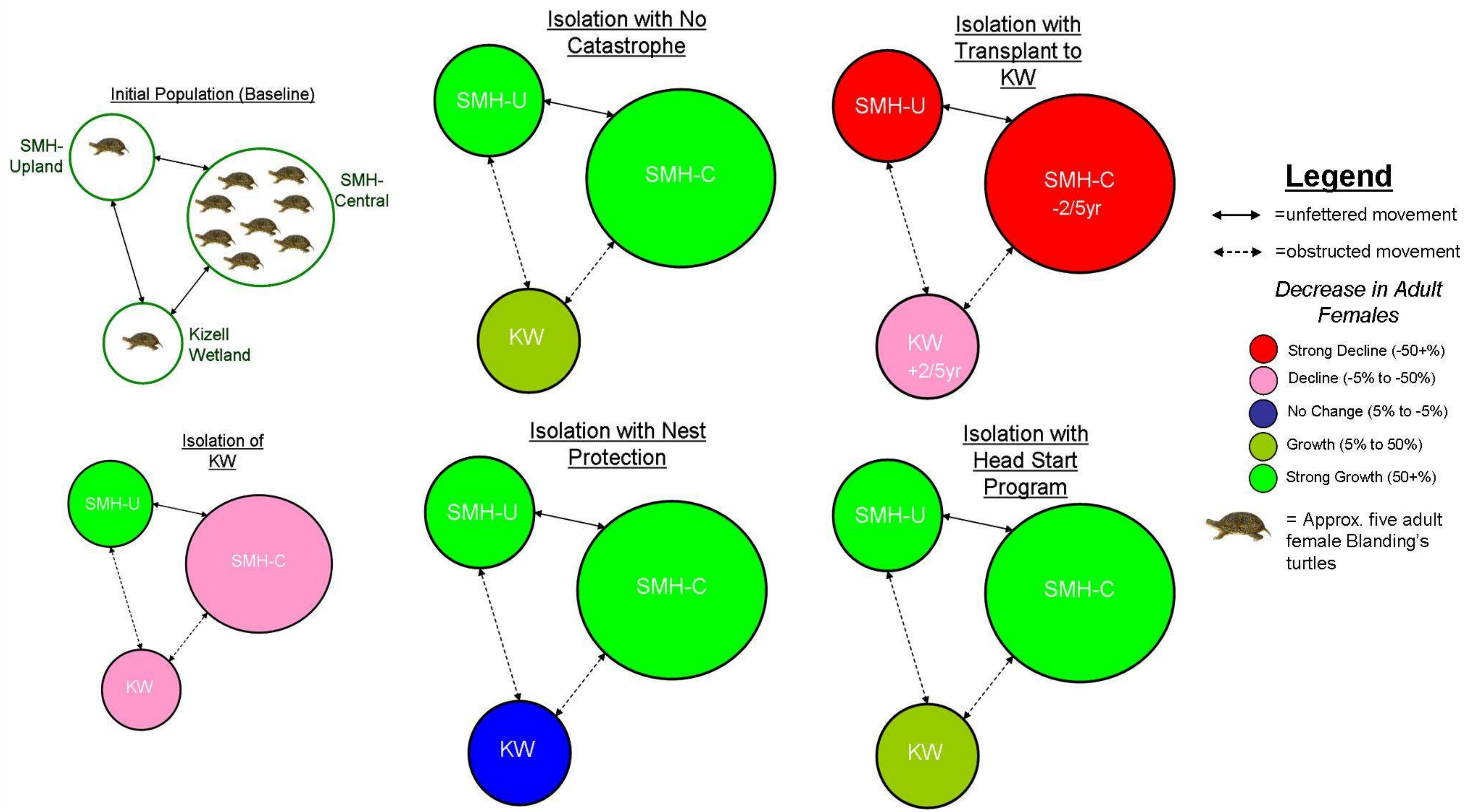


Figure 8. The Baseline model altered to reflect the isolation of KW and then re-run with four scenarios: no catastrophe, transplanting 2 turtles from SMH-C to KW, with nest protection, and head start program.

*South March Highlands Upland (SMH-U), South March Highlands-Central (SMH-C), and Kizell Wetland (KW).

Another potential outcome of development in the SMH is that the SMH-Central and KW sub-populations would have decreased survival rates (due to increased anthropomorphic disturbances or predation) and the KW sub-population would be isolated (not necessarily cut off, but reduced dispersion). This alternative model to the Baseline has been termed the "Urbanization" Alternative Model and is shown in **Figure 9**. In addition, this alternative model reflects what would be expected should KNL proceed with full development of Phases 7 and 8. Compared to the Baseline model, Urbanization would result in a strong decline of the entire SMH population. Interestingly, and somewhat of a positive outcome, if catastrophes can be avoided, the SMH sub-populations still show growth, however, the KW sub-population declines but not strongly. The potential management option of transplanting two turtles per year to the KW sub-population does not alter the outcome of the Urbanization Model, as the entire SMH population declines. Should nest protection be implemented, the two SHM sub-populations show strong growth, but the KW sub-population remains in decline (though less so than if nest protection is not implemented). The best scenario for increasing the SMH population under the Urbanization Alternative Model is to implement a head start program, as all three sub-populations show growth.

Though the Urbanization Alternative Model was developed to reflect KNL full development of Phases 7 and 8, it does not reflect the destruction of the nesting site found on the property in 2012. Given the number of adult females using the site (based on radio telemetry findings), the subset of turtles radio tagged, and the average clutch size of Blanding's turtle, it was estimated that approximately 60 eggs per year would be lost if the nesting area was removed. Furthermore, given the long generational time of turtles and the potential for habitual use of old nesting areas, it was assumed that turtles would continue to attempt to use the nesting area for another 30 years. The loss of 60 eggs per year for 30 years was run as a scenario using both the baseline and urbanization models. In both cases there is a strong decline in the entire SMH population. (**Figure 10**) Should 30 juveniles be raised in captivity and placed in the SMH to compensate for the loss of the eggs, the population declines under both baseline and urbanization models, however, the decline is less in the baseline model for SMH-C and KW (**Figure 10**). Overall, if the estimate of productivity for the nesting area is correct, and the nesting area is removed, the entire SMH population would be greatly reduced and may even result in Blanding's turtle being extirpated from the SHM. It will therefore be important to replace the value of this nesting site, either through physical replacement(s) elsewhere, nest protection strategy &/or through a headstart program.

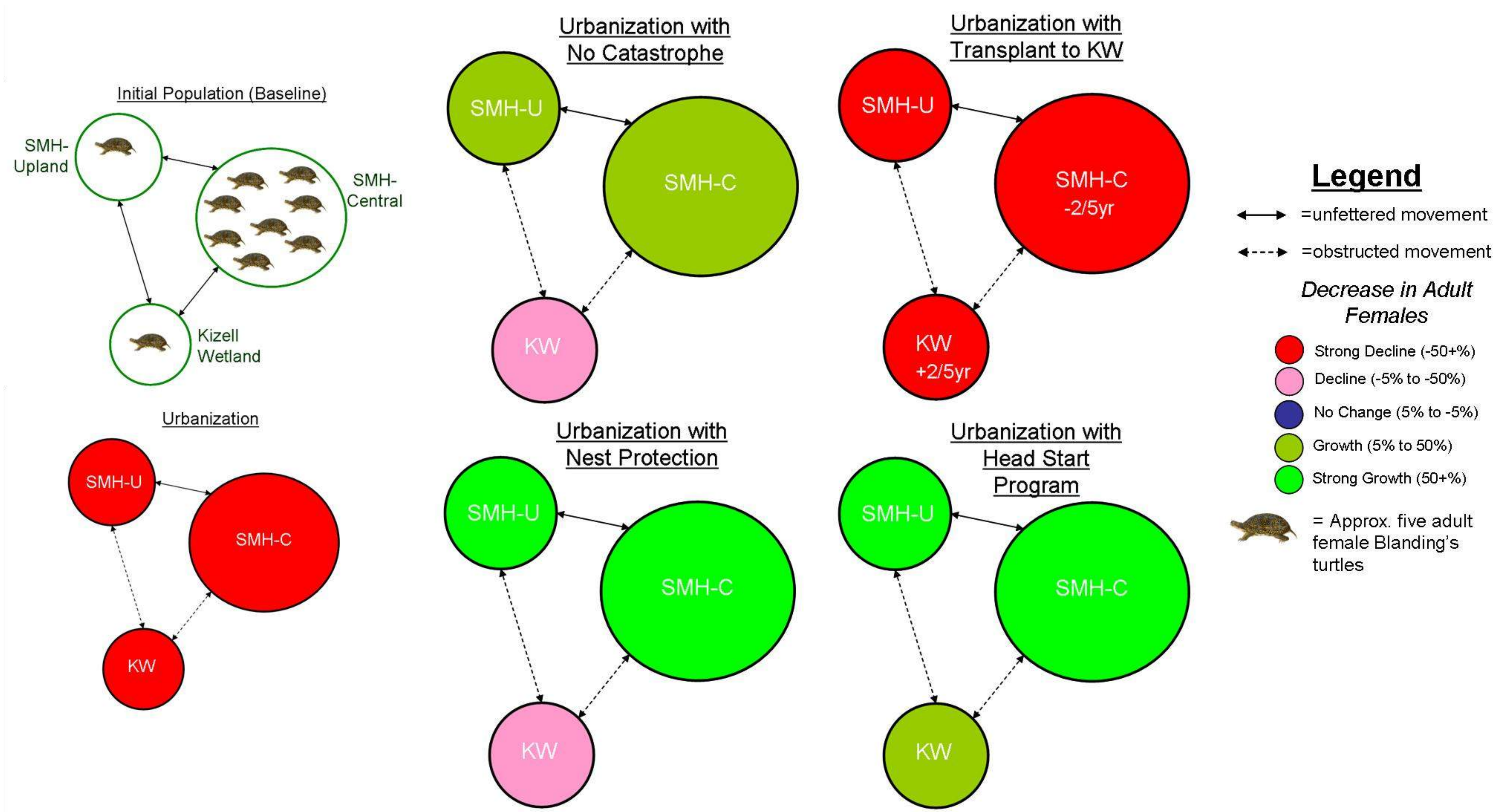


Figure 9. The Baseline model altered to reflect the Urbanization in the surrounding SMH area and then re-run with four scenarios: no catastrophe, transplanting 2 turtles from SMH-C to KW, with nest protection, and head start program.

*South March Highlands Upland (SMH-U), South March Highlands-Central (SMH-C), and Kizell Wetland (KW)

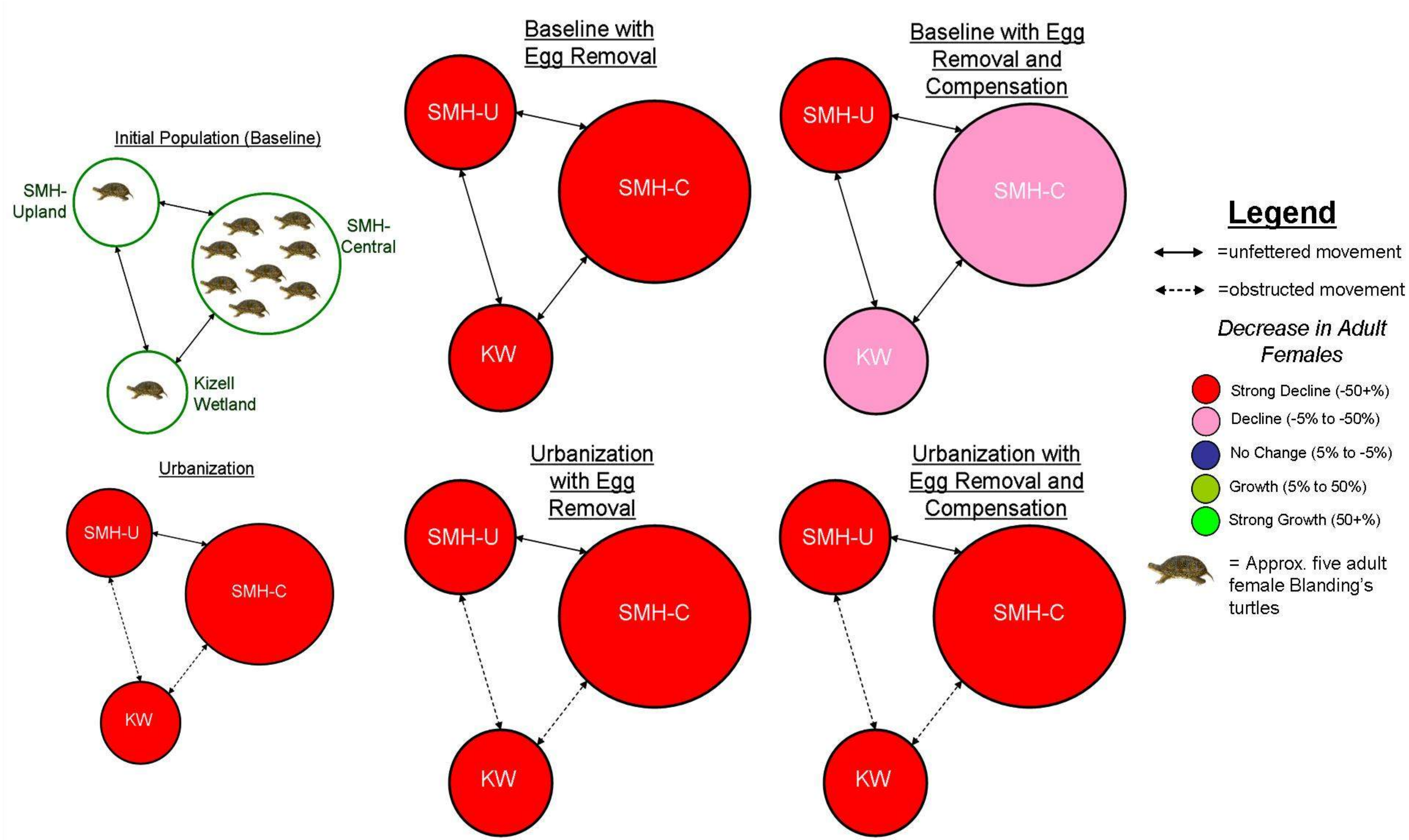


Figure 10. The Baseline model and Urbanization Alternative Model re-run twice: 1) to reflect the destruction of a nesting area in the SMH-C capable of producing 60 eggs per year for 30 years (starting year 5); and 2) to compensate for the loss of 60 eggs by introducing 60 juveniles each year for 30 years (starting year 5).

4.1.6 PVA Conclusion

The PVA produced results based on SMH-specific data collected during the 2011 and 2012 mark-recapture study and using surrogate vital rate variables from a 37-year population study in Michigan. The main finding of the analyses was the elasticity of the model to adult survivorship and this indicates that adult mortality due to any cause other than old age or disease should be minimized, and be a priority of conservation management actions. Another major result of the PVA is the model outputs and different scenarios. Essentially, the SMH population, currently estimated to contain just over 100 adults, is at a state that is very sensitive to natural events, such as catastrophes, so even if no negative changes in vital rates, such as adult survivorship and fecundity occur, the SMH population may become extinct in 500 years. Should isolation of the KW sub-population and reduced adult survivorship occur because of residential and commercial development, or for any other reason, the SMH population will become extinct at a faster rate.

The modeling shows that conservation management actions requiring significant effort such as adult protection, nest protection and head start programs can potentially reduce the likelihood of extinction, may result in population growth and be quite effective in sustaining this species despite urbanization. Management actions requiring less effort, such as transplantation of adults, should generally benefit the species but may not see the same benefit of increased population growth and may even reduce it in some sub-populations. In addition, should a significant habitat like the vernal pools and nesting site on the KNL Phase 8 lands be removed without offsetting compensation or action, the entire SMH population will be greatly reduced and there is a high potential for the entire population to be extirpated from the SMH.

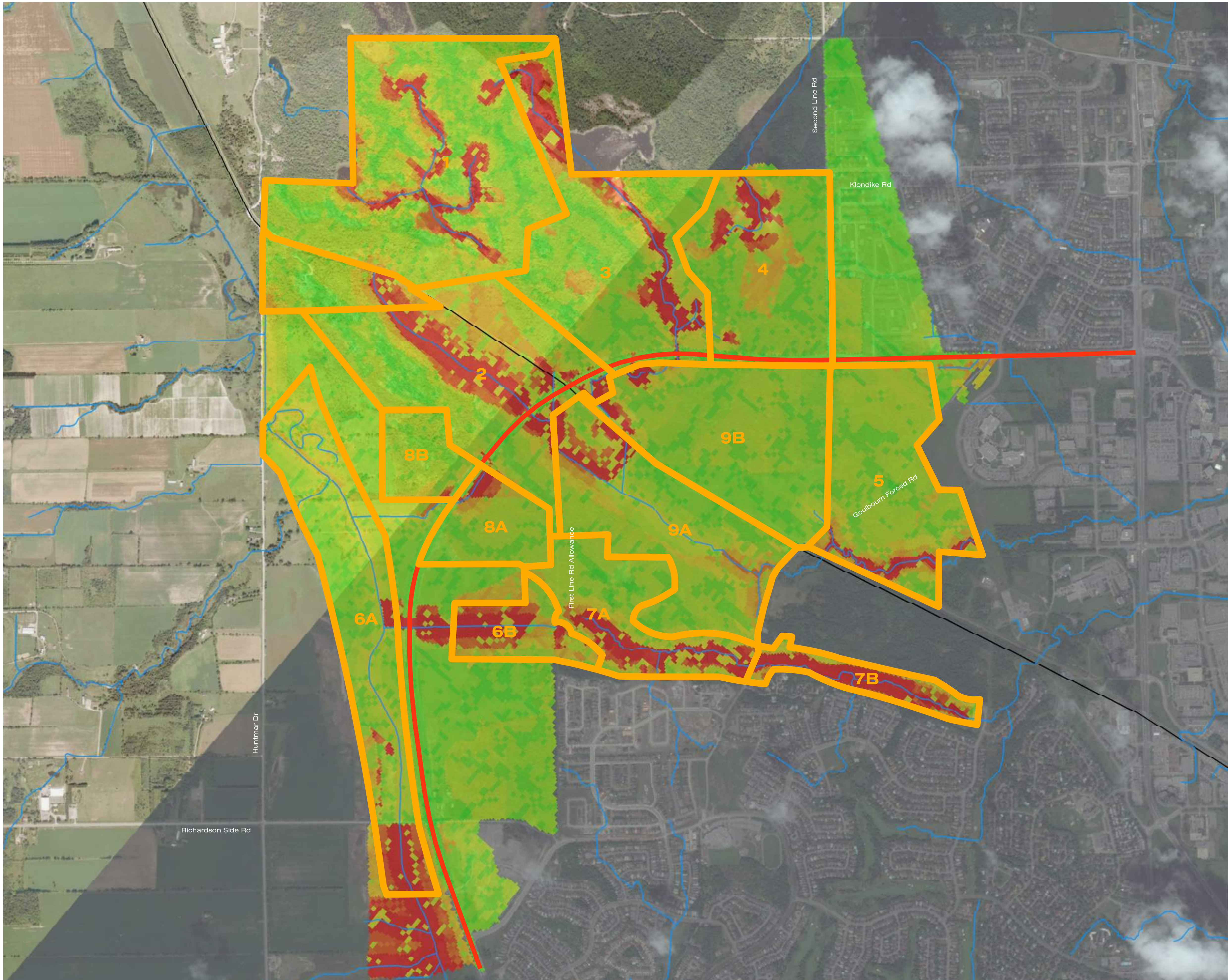
4.2 Core Habitats

4.2.1 Habitat Quality

A subjective Blanding's Turtle Habitat Quality Index (HQI_{BT}) was created to reduce biases in the one used in previous Dillon reports. The new approach uses a Geographic Information System (GIS) to model Habitat Quality based on weighted environmental variables based on researcher experiences. The updated HQI_{BT} used a vegetation classification, Topographical Wetness Index (TWI), slope, and distance to water to better classify Blanding's habitat. Refer to **Appendix E** for details on the methods used to create the new HQI_{BT}. The results for the updated 2012 HQI_{BT} are illustrated in **Figure 11A** over the Study Area. The results were generally consistent with the manually-derived results in the 2010 Blanding's Turtle Habitat Suitability Index (HSI_{BT}), but with a higher degree of precision and without the issues associated with the manual interpretation of habitat suitability. The results indicate that areas of high habitat quality are generally associated with wetlands and open water habitats as would be expected. However, the presence of smaller vernal pools was not captured within the vegetation classification or wetland mapping and was therefore not identified as quality habitat within the model. It is assumed that more refined vegetation mapping than currently exists for this area would more accurately capture these vernal pool habitats. Much of the area is identified as having low habitat quality; however, observations made during the field work for the population study suggest that vernal pools are used frequently by Blanding's turtles for movement from areas of high habitat quality to the other. Field work has also demonstrated that some vernal pools are used year-round and should be considered residential wetlands and core habitat. The modeling approach further facilitates statistical analysis and the modeling of linkages between core habitats better than the manually derived 2010 HSI_{BT} due to its increased precision, automation and transparent approach.

In addition, the HQI_{BT} model does not capture the substrate type within the wetlands and open water habitats, nor does it capture the human-induced changes to these habitats as in Zone 7B. These characteristics must be annotated to the file. Specifically, the high habitat quality values within the Beaver Pond (Zone 7B) do not accurately represent the findings from the population study, as Blanding's turtles have not been captured or observed there. The adjacent land uses have degraded substrate and water quality within this habitat, which significantly affects the habitat quality for Blanding's turtles. Substrate type and water quality were therefore not used in the model.

In addition to the study area, a gross scale analysis of Blanding's turtle habitat quality on two other properties near the SMH were investigated (**Figure 11B**). The western property lies along the Carp River and encompasses a portion of the flood plain. For the most part, only a few Blanding's turtles have been observed near the Carp River; and none this far north. However, the area does have suitable vegetation cover in the riparian zone and likely would be considered suitable Blanding's turtle habitat prior to the Carp River being channelized. This suggests that the Carp River floodplain could be a suitable target for ecological restoration, to recreate habitat suitable for Blanding's turtle.



City of Ottawa

South March Highlands Blanding's Turtle Conservation Needs Assessment

Blanding's Turtle Habitat Quality

Figure 11A

- Zone Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway

Habitat Suitability Index

100 High Habitat Quality

Moderate Habitat Quality

Low Habitat Quality

0

0 75 150 300 450 600 Meters

SCALE 1:17,000

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

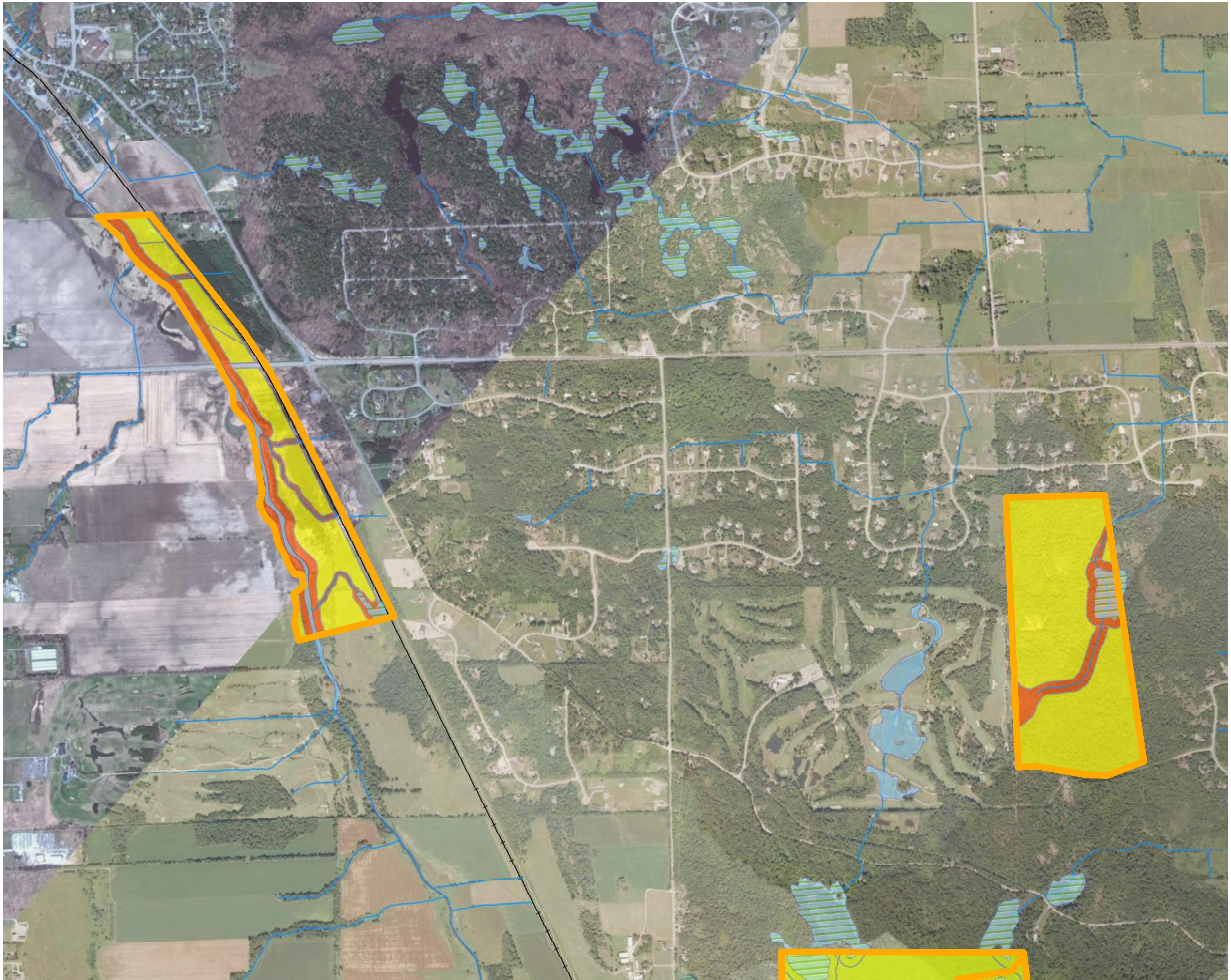
MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\6A-HabitatSuitability.MXD

PROJECT: 12-6019

STATUS: FINAL

DATE: 10/16/12



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South March Highlnads Blanding's Turtle Conservation Needs Assessment

Other Areas

Figure11B

Study Area Boundary
Terry Fox Drive
Wetlands
Watercourse
Railway
Upland Habitats
Lowland habitats

0 62.5 125 250 375 500
Meters

SCALE 1:17,000

W N S E

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\11B-OtherAreas.MXD

DILLON CONSULTING

PROJECT: 12-6019

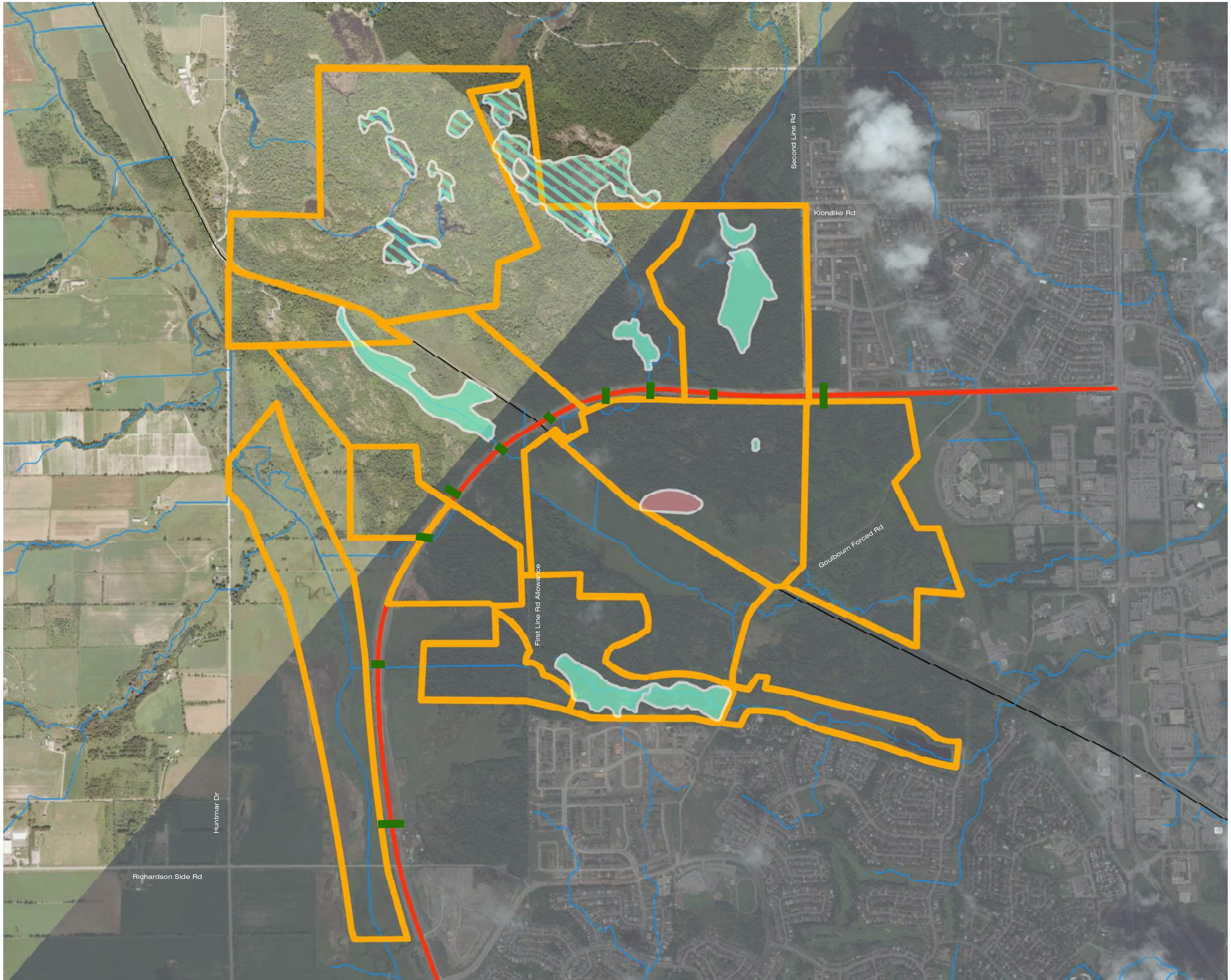
STATUS: FINAL

DATE: 10/16/12

4.2.2 Defining Core Habitats for the SMH Blanding's Turtle Population

Blanding's turtles are threatened provincially (*Endangered Species Act, 2007*) and nationally (Species at Risk Act, 1993), and require protection by both *Acts*. In Ontario, general habitat protection for Blanding's turtle will become regulated on June 30, 2013. Once a species is listed nationally, a recovery strategy is prepared by a team of experts to facilitate conservation and protection. To date, only a national recovery plan has been developed for the Nova Scotia Blanding's turtle population and it does not identify critical habitat because of data deficiencies and ongoing research (The Blanding's Turtle Recovery Team, 2002). It is neither the intent of the Conservation Needs Assessment, nor is it in the City of Ottawa's jurisdiction to identify critical habitat. That task will be guided by the Ministry of Natural Resource and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Data collected from the ongoing radio-telemetry and mark recapture population study has provided information pertaining to habitat use, and as such, we know of important core habitat areas (i.e., overwintering and nesting sites) that need to be identified as part of the conservation needs assesment for Blanding's turtle. A broad map of the core habitats in the SMH has been included with this report (**Figure 12**). In general, most of the SMH areas forested areas, stream corridors or wetlands are is core habitats or connects core habitats one to another. Existing connections between the core areas are along the First Line road allowance, the western extension of Kizell Drain wetland west of First Line and West Shirley's Brook. Both tributaries of Shirley's Brook have been modified in the past, with a significant rechannelization and entrenching of the West Branch that occurred over 40 years ago to improve agricultural drainage. There have been several observations of Blanding's turtle utilizing these corridors during the range study field work, most often along the altered watercourse in Zone 9A (Dillon 2011 b, 2012b In Print).



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South March Highlands Blanding's Turtle Conservation Needs Assessment

Overwintering Areas & Nesting Sites

Figure 12

- Zone Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway
- Wildlife Culvert Crossings
- Potential Blanding's Turtle Nesting Site
- Potential Overwintering Area
- Confirmed Overwintering Area

0 75 150 300 450 600
Meters

SCALE 1:17,000

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\12-Overwintering-Nesting.MXD

DILLON CONSULTING

PROJECT: 12-6019
STATUS: FINAL
DATE: 10/16/12

4.2.3 Potential Corridors for Blanding's Turtle Movements

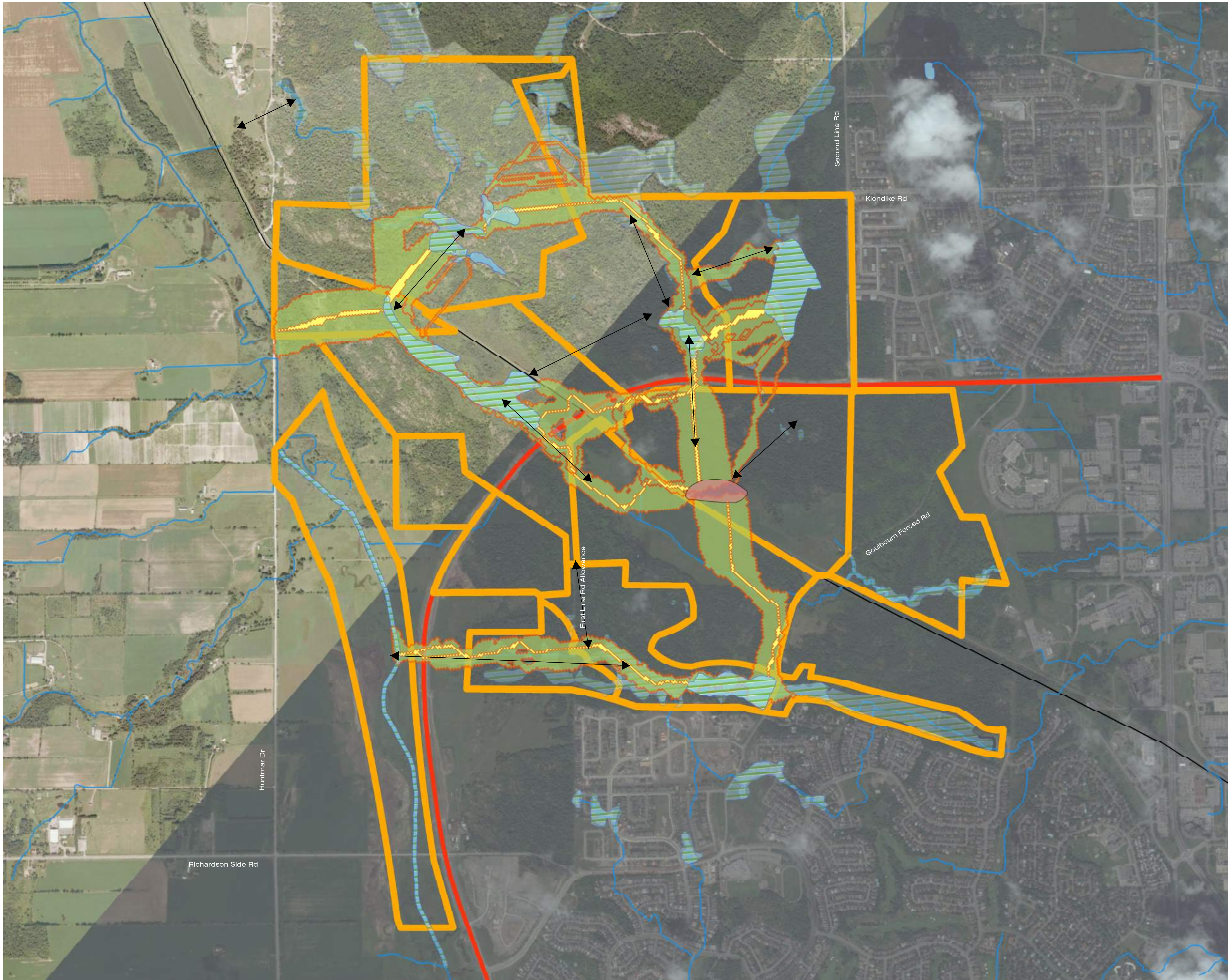
A number of core habitat functions have been identified within the study area during the population study (**Figures 5** and **12**). These include providing spaces for nesting, feeding, mate-searching, overwintering, year-round residence and activity centers. Functionally, many of these habitats are independent from one another generally requiring the females to travel outside of the core habitats to complete some of their life processes. The range study findings (Dillon 2011b) confirm the presence of turtles in habitats of lower quality/suitability, suggesting the turtles are moving between the core areas.

Given the development pressures on the SMH Blanding's turtle population, the identification of the potential corridors that link core habitats would provide a valuable management tool to maintain a viable population within the area. To identify these potential movement corridors a GIS model was created to link the core habitats together using the 2012 HSI_{BT} mapping, described above, to calculate the 'least cost' method of linking two or more core habitats. The basic premise to this GIS model assumes the turtles will follow the most direct route that expends the least amount of energy, while moving between suitable habitats, as they move from core area to core area. The corridor model does not identify all the possible corridors that may exist on the landscape, but rather identifies the pathway of a conceptual corridor, as identified in the model design. As an output, the corridor model also illustrates the functionality of the wildlife culverts installed during construction of the Terry Fox Drive extension as a 'gateway' within each corridor. The GIS model was run twice: once assuming movement through KNL Phase 7 and 8 lands as existing (**Figure 13A**), and again assuming no movement through the lands under a post-development scenario (**Figure 13B**).

The results of both corridor analyses identify potential ecological corridors linking core habitats (**Figure 13A** and **13B**). The results outline the best modeled corridor solution and a more general corridor solution. The best modeled corridor solution is based on the best 0.1% solution linking core features while the general corridor represents the best 2% solution. These modeled movement corridors generally link the core habitats through the most efficient route of suitable habitats, generally using highly suitable areas where possible.

The model output mapping differs because of the assumption of obstructed movement through KNL Phases 7 and 8. Particularly, the existing model where movement is allowed to occur over the KNL lands clearly shows the influence of the nesting site (**Figure 12**) identified during the distribution and range portions of the field studies (Dillon 2012a). Under existing (pre-development) conditions (**Figure 13A**), there are five potential corridors that connect the nesting area to the rest of the core habitats in the SMH and Kizell Wetland. Under the scenario that the KNL lands will be inaccessible to turtles (**Figure 13B**), the aforementioned corridors are no longer predicted and the Kizell Wetland becomes isolated from the rest of the SMH turtle population. The model predicts no pathway connecting it to the rest of the SMH, other than west to the Carp River system which is weakly connected to the SMH - Central population due to a major ridge lying between the Carp River and the West Shirley's Brook wetlands of Zone 2. Both in 2011 (Dillon 2011b) and 2012 (Dillon 2012b) there was only one movement each year of the same old-age, non-gravid female (Female #1-11) along the First Line road allowance, so we conclude that this potential linkage is not currently an important link between the Kizell Drain and Shirley's Brook basins for Blanding's turtle.

If the Kizell Drain wetland sub-population of Blanding's turtle are to be sustained, it is therefore imperative that the conservation management strategies include provision for enhancing the habitat availability, nesting sites and corridor linkages along the Carp River system, and as a second priority to maintain and utilize the retained forest lands along the First Line road allowance as a connection to the Shirley's Brook wetlands. It is also important to note that "under utilized corridors may still be important in maintaining long-term population connectivity" (Pers Comm, Dr. Gabriel Blouin-Demers).



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South March Highlands Blanding's Turtle Conservation Needs Assessment

Blanding's Turtle Corridor Analysis

Figure 13A

- Zone Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway
- Potential Blanding's Turtle Nesting Site
- Best Modeled Corridor Solution
- General Modeled Corridor Solution
- Radio Telemetry Determined Movement Corridors

0 75 150 300 450 600
Meters

SCALE 1:17,500

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

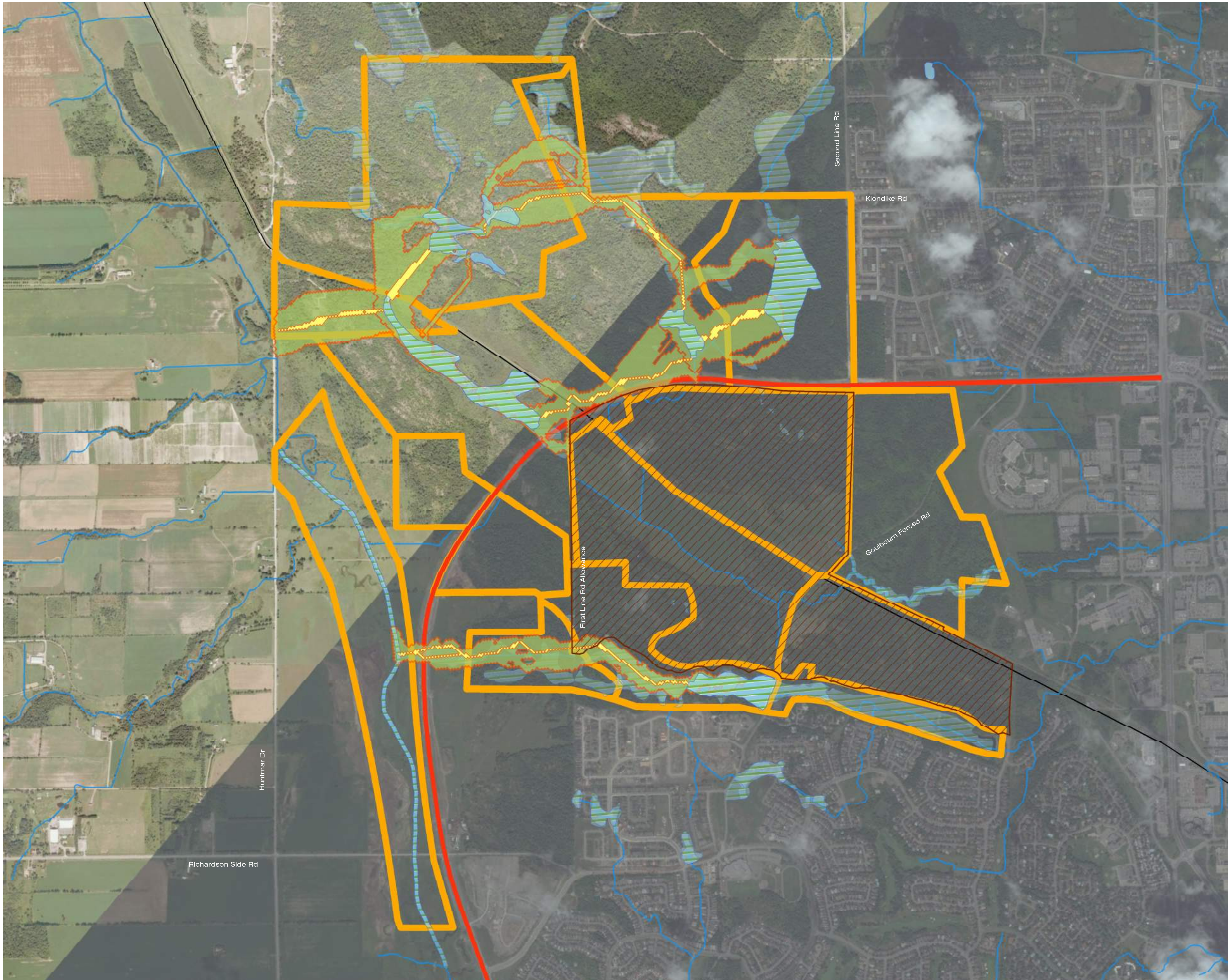
FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\13A-CoridorModel.MXD

DILLON CONSULTING

PROJECT: 12-6019

STATUS: FINAL

DATE: 12/4/12



Ottawa

City of Ottawa

South March Highlands Blanding's Turtle Conservation Needs Assessment

Blanding's Turtle Corridor Analysis with Proposed Development

Figure 13B

- Zone Boundary
- Terry Fox Drive
- Wetlands
- Watercourse
- Railway
- Potential Blanding's Turtle Nesting Site
- Best Modeled Corridor Solution
- General Modeled Corridor Solution
- Proposed Development Area

0 75 150 300 450 600
Meters

SCALE 1:17,500

MAP DRAWING INFORMATION:
DATA PROVIDED BY MNR, the City of Ottawa, and Dillon Consulting Limited

MAP CREATED BY: AJZ
MAP CHECKED BY: CTH
MAP PROJECTION: NAD 1983 UTM Zone 18N

FILE LOCATION: \\DILLON.CA\DILLON_DFS\OTTAWA\OTTAWA CAD\2012\126019 34\Design_GIS\MXDs\Report Maps\13B-CoridorModel.MXD

DILLON CONSULTING

PROJECT: 12-6019
STATUS: FINAL
DATE: 12/4/12

5.0 Management Recommendations

5.1 Conservation of the Blanding's Turtle Population in South March Highlands

The following recommendations are based on the above sections and have been developed from Dillon's experience with the previous Blanding's turtle and Wildlife Guide System research, the National Recovery Plan written for the Nova Scotia population, the experiences of the technical steering committee, expert advice from our peer reviewers and further research of management options undertaken by similar plans. Individuals involved with this needs assessment have been gaining Blanding's turtle conservation knowledge since they were confirmed to be residing in the South March Highlands in 2009. The planners, engineers, councilors and other employees that are responsible for management of the City's growth now consider Blanding's turtle, as well as other species-at-risk, in planning approvals, policy development, traffic management, and municipal boundary expansion. Likewise, awareness has been heightened within public, community organizations and the education system, which ultimately should be to the benefit of the species.

Realizing a 'Net Benefit to the Species' is a key guiding principle of the provisions of the Ontario Endangered Species Act as administered by the Ontario Ministry of Natural Resources (MNR). The test required by the MNR is that the activities or programs intended to offset the harmful impacts of disturbance, destruction of habitat or loss of individuals through mortality must have as a result, a net benefit to the recovery of the global Blanding's turtle population. Practically, the management strategies proposed herein focuses on the South March Highlands population, which is currently at risk, and threatened by urban development usurping their habitat. The particular threats to the population vary with respect to temporal impacts, but also relate to the species biology, habitat needs and the impact of anthropogenic processes.

Several key objectives are identified to help sustain the SMH Blanding's turtle population. Also listed are several examples of how the objectives can be met to support this population, however, the management tools should be generic enough to be applicable throughout the Ottawa Region and to other turtle populations elsewhere as needed. We have attempted to focus on immediate strategies that could be implemented to deal with current SMH issues, but some of the broader techniques are also applicable to the larger areas as the surrounding communities are developed in the future or are brought within the boundaries of the City of Ottawa. In addition to the specific objectives, we make detailed recommendations related to current development issues in the SMH.

5.2 Specific Objectives for Conservation of SMH Blanding's Turtle

Below we outline four aspects of SMH Blanding's turtle conservation (**Table 1**). The aspects focus around the species, their habitat, awareness, education and research. Within each aspect, specific objectives designed to achieve the conservation of the SMH Blanding's turtle are outlined, with generic actions, priority levels, time scale, stakeholders and targets identified. In addition to the objectives outlined in **Table 1**, specific examples of tasks that could be undertaken to meet the targets of the objectives are provided.

Table 1. Action, Priority, Time Scale, Organization Needed and Targets

Action	Priority Level	Time-Scale	Stakeholders / Organization	Targets to meet Objectives
Species Aspects				
Objective 1- Reduce direct and indirect causes of mortalities.				
1.1 Reduce the road mortality of Blanding's turtles to the greatest extent possible	High	Ongoing	Relevant government agencies, intergovernmental and non-governmental organizations (GINGO), universities, research institutions, scientists, researchers, local stakeholders and Ontario Road Ecology Group.	Road mortality in the SMH and surrounding area is minimized.
1.2 Reduce the amount of Blanding's turtles removed by illegal take	High	Ongoing	Ministry of Natural Resources, Peace Officers and Conservation Officers.	Illegal take of Blanding's turtle is minimized.
1.3 Reduce the amount of Blanding's turtle mortality associated with other anthropogenic sources to the greatest extent possible	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, and other stakeholders	Mortality from other anthropogenic sources should be minimized
1.4 Reduce the amount of nest/hatchling mortality to the greatest extent practical	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, and other stakeholders	Identify and protect as many Blanding's turtle nests as practical.
Objective 2- Continue to improve local knowledge of Blanding's turtles through research and monitoring				
2.1 Continue to determine the distribution and abundance of SMH Blanding's turtle	High	Immediate	GINGO, scientist and researchers	Understanding the number and whereabouts of the SMH Blanding's turtle population
2.2 Conduct new research and monitoring of the Blanding's turtle SMH Population	High	Ongoing	GINGO, universities and research institutions, scientists and researchers	Research and monitoring to assists with conservation and local knowledge is conducted
2.3 Collect and analyze data in order to determine root causes of mortality, especially as it relates to adult and	High	Ongoing	GINGO.	Data collected and published in the peer-reviewed literature and technical reports to support turtle

Action	Priority Level	Time-Scale	Stakeholders / Organization	Targets to meet Objectives
Species Aspects				
hatchling mortality				conservation.
Habitat Aspects				
Objective 3- Protect, conserve and manage Blanding's turtle habitat				
3.1 Identify core habitats of the SMH population (and neighbouring populations)	High	Immediate	GINGO, universities, research institutions, scientists and researchers	Complete map of core habitats in the SMH / Carp Ridge and surrounding North Kanata ridges / lowlands
3.2 Establish broad habitat protection measures	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, and local stakeholders	Determination of 'best practices' associated with protection of Blanding's turtle habitat
3.3 Understand mechanisms causing habitat degradation; develop mitigation measures to reduce development effect	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, and local stakeholders	Understanding of how anthropogenic and natural factors influence habitat degradation and 'best practices' for mitigating effects
3.4 Conserve areas of high Blanding's turtle density	High	Ongoing	GINGO, universities, research institutions, scientists, researchers, and local stakeholders	Areas of known Activity Centers are conserved
3.5 Rehabilitate degraded habitats where appropriate	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, and local stakeholders	Degraded habitat rehabilitated to promote use by Blanding's turtle
3.6 Create new habitats close to identified core habitats; establish suitable compensation ratio of Loss to Replacement.	Low	Short Term	Land development community, builders organizations, professional services	Allow for offsetting compensation where unavoidable impacts may occur.
Research Aspects				
Objective 4- Improve understanding of Blanding's turtle and habitats through research				
4.1 Conduct new research that supports management interventions	Medium	Long Term	Relevant government agencies, universities, research institutions, students, scientists and researchers	Research conducted and published in peer-reviewed literature and technical reports
4.2 Fund bursaries, scholarships, post-graduate fellowships and primary research	Medium	Long Term	University graduate students, research scientists	Promote Ottawa institutions as centers of excellence in species at risk research

Action	Priority Level	Time-Scale	Stakeholders / Organization	Targets to meet Objectives
Species Aspects				
Awareness and Education				
Objective 5- Raise awareness of Blanding's turtle and conservation				
5.1 Establish education, awareness and information programs	High	Ongoing	GINGO, universities, research institutions, scientists, researchers	Implement programs and conservation needs are known by stakeholders
5.2 Work with local communities and groups to gain participation in conservation efforts	High	Ongoing	GINGO, universities, research institutions, local stakeholders and Ontario Road Ecology Group	Local communities are actively involved in Blanding's turtle conservation
Collaborative Aspects				
Objective 6- Enhance cooperation between local, provincial, federal, and international agencies and organizations				
6.1 Develop and implement mechanisms for effective exchange of information with respect to Blanding's turtle biology and habitat needs	Medium	Ongoing	GINGO, universities, research institutions, scientists, researchers, community organizations, Municipal environment committees and clubs	Ongoing dialogue and communication between Blanding's turtle stakeholders.
Legislative Aspects				
Objective 7- Promote lawful protection of Blanding's turtle				
7.1 Encourage environmental protection laws design to promote Blanding's turtle conservation	Medium	Ongoing	Non-governmental organizations, universities and research institutions, scientists and researchers, and local community	Laws passed design to protect Blanding's turtle and promote conservation
7.2 Support those in power to ensure the objectives of the conservation needs assessment are met.	High	Ongoing	Non-governmental organizations, universities and research institutions, scientists and researchers, and local community	Implementation of the objectives and recommendations of the conservation needs assessment

5.3 Management Actions

From the objectives and targets identified above, a number of specific actions could be implemented by the various stakeholders. Preferably, those of high priority would be addressed first, with the medium and lower priority actions addressed in time as needed. The first set of activities is intended to support the individual animals that constitute the population, versus habitat aspects which are addressed later.

5.3.1 Species Aspects

Objective 1- Reduce direct and indirect causes of Blanding's turtle mortality

1.1 Reduce the road mortality of Blanding's turtles to the greatest extent possible

Examples of specific actions that could be implemented:

a) Extend the Wildlife Guide System along arterial roads. Fencing could be considered on the habitat side (rather than the urban side) of Terry Fox Drive towards Richardson Side Road, along Second Line Road towards Old Carp Road, and along Old Carp Road between Second Line Road and Huntmar Drive. Future improvements to the above roads or new arterial road improvements in Ottawa near Blanding's turtle habitat should consider the construction of wildlife culverts to facilitate dispersion between habitats and reduce the impacts of the road as barriers to movement corridors and the use of the granular shoulders as nesting sites.

b) Reduce speed limits on selected roadways during sensitive periods when turtles are expected to be moving widely (nest searching). Install overhead signage and amber flashing lights to increase awareness.

c) Implement a reduced Wildlife Guide System along Goulbourn Forced Road and other Collector roads adjacent to Blanding's turtle habitat including limited fencing and wildlife culverts.

d) Increase "turtle" crossing signage and reduce speed limits along sensitive areas during prone periods of May-June and September. Ensure the signs are tamper proof and cannot be stolen.

e) Re-visit the TFD Wildlife Guide System to identify usefulness for preventing the movement of hatchlings and juvenile Blanding's turtles.

f) Re-examine the fencing fabric used, the height, configuration and general makeup of the fencing to see if it can be improved upon.

g) Work with community groups to identify safe ways of moving turtles off roads and develop a public protocol for dealing with turtles crossing roads.

h) Identify locations where alive, yet hurt, turtles can be taken for recovery (ie. Kawaratha Turtle Trauma Centre). An interested community group may wish to establish a similar centre in Kanata and could be the coordinating group for other efforts, such as a head start program.

1.2 Reduce the amount of Blanding's turtles removed by illegal take

Examples of specific actions that could be implemented:

a) Increase public awareness of the crime and penalties of poaching species at risk. This could be done using signage or public announcements in the media.

b) Monitor sensitive areas for illegal activities (e.g., set nets). Public action groups may be interested in forming watch parties during the prone periods. Trail cameras may be a useful tool to remotely monitor sites and identify intruders.

c) Approach the MNR/Provincial Conservation Officers to conduct random inspections of vehicles leaving sensitive Blanding's turtle areas during prone periods. Establish a Turtle Tips hot line to local police.

d) Lobby law-makers to increase the fines and penalties associated with poaching Blanding's turtle and other species at risk.

1.3 Reduce the amount of Blanding's mortality associated with other anthropogenic sources to the greatest extent possible

Examples of specific actions that could be implemented:

a) Limit access to sensitive areas to reduce mortality and nest predation caused by pets. Nesting sites and areas with a high density of basking (or exposed) Blanding's turtles should be avoided by pets, as pets may cause harm (and/or harassment) to the turtles.

b) Add signage to bike trails to inform riders of potential Blanding's turtle encounters and to enhance awareness of what to do if encountered.

c) Monitor threats to Blanding's turtles. This may include monitoring fluctuations in water levels, predator abundance and movement, and seasonal temperature. As well, monitoring agricultural, forestry, and residential development disturbance could be completed. Once threats are identified to exist, contingency plans should be developed.

1.4 Reduce the amount of nest/hatchling mortality to the greatest extent practical

Examples of specific actions that could be implemented:

a) Empower public groups to alert researchers/local governments to the whereabouts of Blanding's turtle nests. This could involve an annual public awareness campaign where the pubic is encouraged to send nesting locations to a maintained database. A volunteer nest monitoring program occurs in Nova Scotia and provides valuable data including nest success, clutch size, and nest site fidelity. This information is lacking for the SMH population.

b) Initiate and manage a nest protection program to reduce predation by raccoons and fox. Grouped with solution 'a'; a nest protection program consists of locating nests and protecting them for four months by installing wire nest covers (e.g., http://turtle_tails.tripod.com/backyardturtles/byttour4.htm).

c) Fund and manage a 'head-start' program whereby eggs would be collected, incubated, the hatchlings reared in captivity and released once large enough to be invulnerable to predation. See below for further details. Funding for such a program could be provided by activities having direct, long term impacts on Blanding's turtle.

Objective 2- Continue to improve local knowledge of Blanding's turtles through research and monitoring.

2.1 Continue to determine the distribution and abundance of SMH Blanding's turtle.

Examples of specific actions that could be implemented:

a) Extend the mark: recapture population estimate field work beyond the current 2013 end point. By doing so, population-specific vital rates (such as adult and juvenile survivorship, reproductive success, transitioning rates, etc.) could be calculated; abundances and projections could be determined with a higher level of confidence. This work is labour intensive and must be done at specific times of the year, yet could be done by funding a volunteer group(s) or transitioning the current program to a research based institution (e.g., Carleton University, University of Ottawa, and Algonquin College) or organization (e.g., Wildlife Conservation Society- Canada, Ontario Nature). Regular sampling of the SMH population is essential for understanding the long-term demographics, survival rates, hatching success and age structure.

b) Collect and identify road kill mortalities by their PIT tags, to adjust the population statistics and maintain an inventory of the population as it matures.

c) Develop a turtle watch program whereby community users can contact a 'hotline' and report turtle sightings or poaching activities.

d) Continue to identify habitats where juveniles are present and refine the methods for juvenile capture.

e) Ensure that data collected is standardized and that marking and handling procedures are refined as technologies change.

f) Further refine the population structure by understanding movement patterns. A long-term monitoring project using radio telemetry (or other similar devices) to continuously track individuals could be funded, however this activity should be done or supervised by trained professionals.

2.2 Conduct new research and monitoring into Blanding's turtle and the SMH and neighbouring populations

Examples of specific actions that could be implemented:

a) Conduct a landscape-scale study to assess potential movement corridors of Blanding's turtles between the major habitats where a few Blanding's turtles have already been observed. This could involve habitat suitability GIS analysis across the region, and/or road mortality studies to determine 'hot-spots' of animal mortality. This information could be used to identify other Arterial Roads in need of Wildlife Guide Systems. This work could be undertaken by the scientific or research community and be published in peer-reviewed literature and/or technical reports

b) Fund research to understand the biological basis for Blanding's turtle local movements and motivations. Genetic research into the larger Ottawa Population could be done to understand the genetic variability between the sub-populations. This should be undertaken by the local scientific community and be published in peer-reviewed literature to the benefit of the species. This may include genetic-based studies to understand the relationship between the local Blanding's turtle populations, and it may aid with understanding movement corridors between sub-populations. Understanding paternity in clutches is another possible project, as it would help to determine the degree of inbreeding that occurs in the SMH population.

c) Maintain a current Blanding's turtle database for the SHM population. This should be held at a long-lived institution such as a university or college as the turtles often outlive the researchers studying them. Kejimkujik National Park in Nova Scotia offer a great example, as they include general observations, trapping data, radio tracking locations, imagery, nesting monitoring data, hatchling statistics, morphological measurements, and more in a database. Data from researchers, volunteers, public sightings, university-based research and museums are included in the database.

2.3 Collect and analyze data in order to determine root causes of mortality, especially as it relates to adult and hatchling mortality

Examples of specific actions that could be implemented:

a) Fund research into Blanding's turtle mortality associated with other anthropogenic sources (e.g., bioaccumulation, invasive species, etc.). Understanding the causes of mortality will potentially allow researchers to develop mechanisms to reduce mortality caused by anthropogenic sources. This should be undertaken by the scientific community and be published in peer-reviewed literature.

b) Investigate the impact of global climate change on local wetlands. Changes in water chemistry, levels and the surrounding environment could potentially degrade Blanding's turtle habitat and reduce the amount of critical habitat (i.e., overwintering areas). This should be undertaken by the scientific and research community and be published in peer-reviewed literature and/or technical reports.

c) Fund research to understand Blanding's turtle nest predation and parasites. Understanding nest mortality will allow for long-term and sustainable solutions to be developed. This should be undertaken by the scientific and research community and be published in peer-reviewed literature and/or technical reports.

5.3.2 Habitat Aspects

Objective 3- Protect, conserve and manage Blanding's turtle habitat

3.1 Identify core habitats used in the SMH and by Neighbouring Populations

Examples of specific actions that could be implemented:

a) Based on the Blanding's turtle habitat quality analysis completed for this study, develop a city-wide GIS application using readily available Remote sensing topographical, wetted perimeter and vegetation data to identify potential core habitats of Blanding's turtle.

b) Ground truth a number of areas identified through remote sensing to confirm the presence or absence of Blanding's turtle in these potential habitats. See PhD Dissertation (In Progress) – Amy Mui, University of Toronto.

c) Create a Population-wide Conservation Management/Protection Plan. This plan should consider all populations and habitats (i.e., core habitats, resident wetlands, activity centers, and not presently occupied wetlands) in the region for Blanding's turtle and suggest protection measures to ensure population longevity. This plan would need to consider future land development, education and stewardship initiatives for private landowners.

3.2 Establish broad protection measures for Blanding's turtle core habitat

Examples of specific actions that could be implemented:

a) Research techniques and develop guidelines for planners and practitioners to aid with rapidly defining and identifying core habitats and 'best practices' for protection.

b) Identify known locations to property speculators so they may be acknowledged during the due diligence phases of their property enquiries, avoiding planning conflicts which may arise later during development applications.

c) Exchange information with other groups focused on Blanding's turtle protection.

d) Publicly promote Blanding's turtle protection measures to aid in community involvement.

e) Reduce threats by protecting in perpetuity core habitats.

3.3 Understand mechanisms causing habitat degradation and develop mitigation measures to reduce risk effects

Examples of specific actions that could be implemented:

a) Research should be conducted to assess habitat degradation caused by urbanization and its impact on Blanding's turtle.

b) Experiment with different buffer widths, enhanced planting strategies, fencing alternatives and habitat creation in close proximity to residential areas to test the limits of the species tolerance towards interaction with human activities.

c) Develop mitigation measures which bring ecological processes into the urban fabric (reconfigured creek valleys, stormwater management alternatives, Low Impact Development [LID] strategies, infiltration technologies), which are also designed to prevent urbanization from negatively impacting Blanding's turtle habitat.

3.4 Conserve areas of high Blanding's turtle density

Examples of specific actions that could be implemented:

a) Review the proposed realignment of Gholbourn Forced Road to ensure it does not impact core habitats important to the conservation of Blanding's turtle.

b) Purchase lands or undergo land swaps with Owners where known, high concentrations of Blanding's turtle or their core habitat exist on private land.

c) Integrate park systems, trails, wildlife corridors and Natural Environment zoning to ensure habitat connectivity between core habitats.

d) Work with land owners to plan Blanding's turtle solutions when encountered on their properties. This could serve as a "how to" guide for owners dealing with Blanding's turtles and other species-at-risk throughput the Province.

e) Foster the idea that turtles and humans can "Share the Space". Turtles only move about for part of the year, living in wetlands most of the time. They only need to utilize these corridors for a short period and can share the space with some human recreational activities.

3.5 Rehabilitate degraded habitat where appropriate

Examples of specific actions that could be implemented:

a) Tile drain fields were once wet, sometimes wetlands or sloughs. Reinstating the hydraulic conditions by removing or blocking the tile drainage will almost always revert the land to wetland conditions in time. Excavating basins adjacent to existing or degraded habitats and allowing natural encroachment to revegetate the area is a cost-effective method of rehabilitation. Tree roots, boulders and other naturally occurring objects are the only other ingredients necessary to reestablish the once-present wetlands.

b) Identify degraded habitat and implement 'best practices' for restoration. This potentially could be done by means of a literature review combined with a field assessment of candidate areas. If technology gaps are present, a series of case studies could be used to determine protocols. Cost efficiency should be understood as well. Funding for rehabilitation could be raised from developers/constructors/governments that have degraded Blanding's turtle habitat or seek to offset the impacts of land development.

c) Mitigation Banking is a concept where entities requiring impact offsets may purchase units of created or protected habitats created for this purpose, which are then permanently enshrined in the planning framework to ensure sustainable, long term protection of the habitat without the threat of further infrastructure or land development.

3.6 Create new wetlands close to core habitats; Establish suitable compensation ratio of Loss to Replacement

Examples of specific actions that could be implemented:

a) Allow for compensation wetland or nest construction where avoidance of the impacts to existing turtle habitat is not practical or possible. Restoring the Carp River north from Richardson sideroad, reinstating the broad meandering channel originally there, may be an appropriate location for large scale compensation efforts.

b) Establish a standardized ratio of loss to replacement (i.e., 3:1 to 10:1) on an area-basis (ha or m²) to ensure fair and equitable treatment of proponents, but with the aim of ensuring a net benefit accrues to the species, core habitats and related flora and fauna species.

c) Focus efforts on nesting areas of at least ½ ha in size each, with multiple locations to reduce the density of nests and the likelihood of egg predation. Provide ongoing surveillance and maintenance to avoid aggressive or exotic invasion of vegetation (ie. Autumn Olive shrubs, *Phragmites australis*) that blocks nesting or shades the nests from solar radiation.

d) Include a large component of roots, stumps, log piles, boulders, aquatic macrophytes and standing trees under permanently flooded conditions.

5.3.3 Research Aspects

Objective 4 – Improve understanding of Blanding's turtle and habitats through research

4.1 Conduct new research that supports management interventions

Examples of specific actions that could be implemented:

a) Research biophysical characteristics of key Blanding's turtle habitats (e.g., overwintering sites, nesting sites).

b) Refine habitat suitability models to further define Blanding's turtle habitat in the SMH.

c) Conduct a large scale corridor study to assess the connections of the SMH Blanding's turtle population to other populations.

d) Further understand habitat-use by Blanding's turtle.

e) Identify all key habitats for Blanding's turtle in the SMH.

4.2 Fund bursaries, scholarships, post-graduate fellowships and primary research

Examples of specific actions that could be implemented:

a) Partner with academic research councils to research programs (e.g., Natural Sciences and Engineering Research Council).

b) Fund local research programs at Carleton University, University of Ottawa, and other local schools that are conducting Blanding's turtle and/or conservation biology research.

c) Facilitate partnerships between stakeholders and academic institutions to fund monitoring and research.

5.3.4 Awareness and Education

Objective 5- Raise awareness of Blanding's turtle and conservation

5.1 Establish Education, awareness and information programs

Examples of specific actions that could be implemented:

a) Introduce a school program designed to teach local children about Blanding's turtle and conservation. Parks Canada has a Teacher Resource Centre designed to aid teachers with educating students about species-at-risk, however the individual species aids are lacking (http://www.pc.gc.ca/apprendre-learn/prof/sub/theme/spec_e.asp).

b) Implement a youth-in-environment summer work program, engaging high school and college-age students on restoration of local streams, wetlands and promoting the importance of protecting natural areas within the City. Similar to SHaRP (Salmon Habitat Restoration Program) or SNAP (Surrey's Natural Areas Partnership) in Surrey BC.

(http://www.surrey.ca/city-services/1997.aspx;

http://www.surrey.ca/culture-recreation/2013.aspx)

c) Partner with a charitable foundation or local major corporation (RIM, CAE) willing to promote and take action on Blanding's turtle conservation. The Rick Hanson Foundation founded the Fraser River Sturgeon Conservation Society to promote sturgeon populations at the grassroots level (http://www.rickhansen.com/language/en-CA/Who-We-Are/About-Rick-Hansen/Ricks-Life-Passions/Fraser-River-Sturgeon-Conservation-Society.aspx).

5.2 Work with local communities and groups to gain participation in conservation efforts

Examples of specific actions that could be implemented:

a) Work with local community advocacy groups, the City Environmental Alliance Committee and Green Space Committee and the City's Parks and Recreation Department to produce awareness signage for local forests, wetlands and creek valleys.

b) Promote and develop stewardship. Fostering an ethic of local stewardship will support success of Blanding's turtle conservation. This can be completed by enhancing landowner contact (often landowners are unaware that Blanding's turtle exist on their lands), and collaborating with private and corporate landowners, which will encourage habitat protection and reduce disruptive activities.

c) Support local education efforts. The Kejimkujik Area Stewardship program for Blanding's turtle offers an appropriate template for how such a program would function (http://www.speciesatrisk.ca/stewardship/BlandingsTurtle.html)

5.3.5 Collaboration Aspects

Objective 6 - Enhance cooperation between local, provincial, federal, and international agencies and organizations

6.1 Develop and implement mechanisms for effective exchange of information with respect to Blanding's turtle biology and habitat needs

Examples of specific actions that could be implemented:

a) Form a stakeholders group designed specifically to deal with Blanding's turtle conservation in the City of Ottawa (and particularly the SMH and surrounding area). Stakeholders may include the City of Ottawa, National Capital Commission, Ministry of Natural Resources, Parks Canada, Professors from University of Ottawa and/or Carleton University, Representatives from local conservation-oriented groups, Nature Conservancy of Canada, Wildlife Society of Canada, Ontario Road Ecology Group, etc.

b) Host a symposium on Blanding's turtle conservation and invite local, provincial, federal, and other agencies and organizations to attend. Presenters could be researchers, policy makers, managers, etc.

5.3.6 Legislative Aspects

Objective 7- Promote lawful protection of Blanding's turtle

7.1 Encourage environmental protection laws designed to promote Blanding's turtle conservation.

Examples of specific actions that could be implemented:

a) Lobby all levels of government to strengthen environmental protection laws designed to promote Blanding's turtle conservation.

b) Advocate for evidenced-based Blanding's turtle conservation policies and laws.

c) Support local action with respect to Blanding's turtle conservation policies and laws.

7.2 Support those in power to ensure the objectives of the conservation needs assessment are met.

Examples of specific actions that could be implemented:

a) Secure long-term funding for Blanding's turtle conservation in the SMH by associating with a likeminded foundation, conservation oriented society or major corporation with local connections to the community (i.e., RIM, CAE)

b) Ensure that the conservation needs assessment is implemented and a working group is created.

c) Formalize conservation agreements with relevant stakeholders.

5.4 Information to Support Specific Actions

5.4.1 Expansion and Improvement of Existing Wildlife Guide System

To improve the efficacy of the existing Wildlife Guide System we suggest the following:

- The culverts with larger rocks should be smoothed out and where feasible covered with a more 'turtle friendly' substrate such as coarse gravel, sand, and woody debris. Some of the culverts currently have turtle-friendly substrates and should be used as a template.

- Expand fencing beyond the current limits. We suggest extending the fence on the west side of Second Line Road to Klondike Road and on Terry Fox Drive to Richardson Side Road (or the limit of current development activities).

- Fencing should be tested to ensure that hatchlings cannot move through the current fence fabric. If they can, a finer gauge fence material should be installed along the bottom.

- Consider reducing speeds on Terry Fox Drive during the Blanding's turtle prone periods (i.e., nesting period (early June to early July) and hatching period (mid-September to early October).

5.4.2 Offsite Habitat Creation / Protection Zones /Ecological Restoration

Offsite habitat creation may be considered a practical, cost effective method of offsetting habitat losses or population impacts elsewhere. Advances in ecological restoration over the past 20 years have resulted in fairly significant changes to the science of recreating habitats. With time, usually on the order of 10 years or more, many common habitat types can be created. Once a habitat is built, many wildlife species will opportunistically move in and establish territories within weeks or months. On the Terry Fox Drive project, three wetlands were constructed over an 8.0 ha area in 2010. By the spring of 2012, at least one male Midland Painted Turtle had used one of the wetlands (Personal Observation, Shawn Taylor, Dillon biologist).

5.4.3 Ensuring Connectivity- Linkage Planning

Connectivity between populations is important for maintaining genetic diversity and access to habitats. Development in the vicinity of the SMH has reduced access to other Blanding's turtle populations and habitats. By buying lands, creating protection area, or reducing barriers, connectivity can be restored and populations can disperse to ensure genetic diversity and access to quality habitat.

<u>Existing Linkages Identification</u>

The SMH population is located at the southern edge of the Carp Hills/SMH ridge, with the Kizell Wetland. There are approximately 57 km^2 of suitable wetlands and forest woodlots that are relatively contiguous and undeveloped north of the SMH in the Carp Hills. Currently, road and residential development is a barrier for movement between the two areas. To increase connectivity between the SMH and Carp Hills, residential development should be limited to the current type (i.e., estate lots) and a Wildlife Guide System should be created below Old Carp Road and March Road.

Other connections lie to the west along Huntmar Drive and along the Carp River. The majority of the adjoining area are clay-based floodplains, developed for agricultural uses and do not provide suitable habitat for Blanding's turtle. The Carp River has been deepened and straightened to provide improved drainage to support agricultural uses; however, the area regularly floods in the spring. Today, Blanding's turtle may occasionally use the Carp River as a corridor to the Cork Highlands, but it is open with little overhead cover and given the intervening road network and distance involved, this may be a risky movement for a Blanding's turtle. As the Carp River restoration project proceeds, constructing wetlands habitat suitable for Blanding's turtle along the way, as was done near Richardson's Sideroad, would be appropriate to try and re-establish the Carp River linkage and reduce the risk of movements between habitats. As the urban area expands and land-uses change, restoring the original, meandering form of the Carp River, with wide, forested buffers suitable to Blanding's turtle should be a goal.

Buying Land

Parcels of the land could be purchased by the City (or donated) as part of the conservation strategy to offset habitat losses elsewhere. Land that is existing habitat for turtles is most desirable, although land that is near water and can be converted into Blanding's turtle habitat is also acceptable. The parcel at the southwest corner of Second Line and Old Carp Road, owned by Metcalf Realty would be a good candidate, as Blanding's turtles were found using radio telemetry to be using a large wetland there. Other tracks of land located in the flood plain of the Carp River would allow for a large habitat restoration project to be undertaken.

Integrating Parklands

Land development proposals in Ottawa are required to dedicate 5% of the land holdings to the City for dedicated parklands. In most cases, these are developed for soccer fields, parks or baseball diamonds, often filling in the marginal lands unusable for homes. In close proximity to naturally wet areas, the parks sometimes become the only available nesting areas for turtles (2011 case of snapping turtles in Britannia Park, Ottawa[1]). The First Line Road Allowance corridor, running north of Kizell Drain to Terry Fox Drive, has been zoned Natural Environment and planned for future recreational use, but other than having a width of 25-30 m and a planned walkway, the park area is unplanned. We recommend maintaining the First Line Road Allowance corridor as it is today ensuring a sustained linkage between the Kizell Wetland and the West Shirley's Brook watercourse.

Planned parkland parcels within existing Blanding's turtle habitat should be created keeping habitat intact without any land re-grading, no hard infrastructure and limited hazard tree removals. Narrow pathways could be built with hard (i.e., paved) surfaces, but lighting should be managed in away to not interfere with Blanding's turtle (i.e., lighting may disrupt nesting as it occurs later in the day and into the evening). There should be no playground equipment or turf grass in the parklands to encourage people to stay in the area. As much as possible, parkland areas with known Blanding's turtle habitat should be left natural and undeveloped. Fencing around the perimeter, to limit turtle and wildlife movements into developed areas would reduce threats.

5.4.4 Programs to Support Egg & Hatchling Survivability

Increasing the survivability of eggs and hatchlings is a secondary priority in maintaining the SMH population (relative to the protection of adults). It is known that natural predation of the eggs in Blanding's turtle nest is the largest cause of egg loss and hatchling mortality, and so if nests can be protected, or managed to reduce losses, then the overall population will benefit. Egg and hatchling programs can also provide important data for PVAs. It should be noted that egg protection and hatchling rearing is a time intensive action and can be expensive.

1[1] http://www2.canada.com/ottawacitizen/news/city/story.html?id=c919a060-0b4c-4d09-945d-0dc425c0ea4b

Nest Protection

A long term stewardship program has been operating at Kejimkujik National Park in Nova Scotia to help sustain their population of about 300 adults, based largely on local volunteer participation through the Kejimkujik Stewardship Program[2]. During nesting season of mid-May to mid-June, known nesting areas are monitored nightly to identify when females are nesting and if they have laid eggs. The known nesting sites may be protected with stout wire mesh coverings, staked or anchored to the ground, that prohibit wildlife from depredating the nests after being laid (**Plate 3**). Eggs incubate in sandy or gravel soils for 60-90 days, depending on the mean ambient temperature and exposure to sunlight. The nests would need protection throughout this period, and then in September and October, the nests are monitored daily for emerged hatchlings, which are trapped under the cages. Alternatively, the screens are removed just prior to hatching for free release, or the young hatchlings are taken into captivity for artificial rearing (Head Start as below).

Plate 3 Volunteers at Kejimkujik National Park placing a nest protection box. Photo: J. McKinnon, Parks Canada with permission.

Artificial Turtle Nests

Creating nesting areas for Blanding's turtle may induce females to lay eggs in preferential areas rather than in sites close to threats. Sunny openings in the SMH where the substrate is suitable for nesting could be increased in size to promote nesting. Artificial nesting beds may be created by simply layering a sand-gravel mixture covering large areas (> 1 acre; ½ ha), over a well-drained site with minimal vegetation cover;

[2] http://www.speciesatrisk.ca/stewardship/BlandingsTurtle.html

however, the specific biophysical factors of nesting sites are unknown (Pers Comm, Dr. Justin Congdon). Blanding's turtles may find the sites randomly and hopefully use the sites for nesting.

Head Start Program

Head start programs aim to harvest Blanding's turtle eggs and rear them to a predetermined age (often over periods greater than one year). A successful Blanding's turtle head start program has been undertaken in Kejimkujik National Park in Nova Scotia. Eggs or newborn hatchlings are collected and reared in captivity to help sustain the local population. Eggs can either be collected by digging up recently laid nests or by collecting gravid females and encouraging egg deposition using oxytocin. Eggs are incubated underground naturally or in artificial incubation chambers (Plate 4) where the temperature can be controlled and varied as needed. When the eggs hatch (Plate 5), the hatchlings are kept in captivity and fed a formulated diet.

Plate 4. Eggs in incubation beginning to hatch.

Plate 5. Recently hatched Blanding's turtles.

Photos with permission of Southwest Nova Biosphere Reserve.

Under controlled conditions hatchlings can feed on algae, plankton, crustaceans, insects, worms, small fish and other food resources while remaining protected from predators. The young are raised for about two years and released to the wild. A head start program in the SMH would require a dedicated staff biologist, a group of knowledgeable volunteers, and a small facility to undertake the work. Alternatively, eggs could be collected in the SMH, raised elsewhere in an existing facility and released back into the SMH. Any such facility or operation would require permitting and technical oversight by the Ontario Ministry of Natural Resources. Should a head start program be considered, best practices should be researched more thoroughly, and a cost-effective analysis be done to ensure that the program meets its goals. It is clear that a head start program would be expensive and be a long-term investment, so partnerships and funding sources should be identified early in the process.

6.0 Blanding's Turtle and Planning Urban Development in the SMH

Urban development is a reality for the lands adjacent to the SMH Conservation Forest. Within the curve of Terry Fox Drive, it is expected that residential communities will be developed over the next several years. The proposed changes will have direct impacts on Blanding's turtle core habitat in the South March Highlands. Below we briefly review the four main changes that will affect the SMH Blanding's population the most; 1) The conversion of turtle habitat to residential developments, 2) The proposed use of the Kizell Wetland as a storm water management facility, 3) The realignment of West Shirley's Brook, and 4) The realignment of Goulbourn Forced Road.

6.1 Residential Development in Turtle Habitat

The Blanding's Turtle study area Zones 9A and 9B (Dillon 2011a) overlay the locations of Phases 7 & 8 of the KNL (Kanata Lakes) approved draft plan of subdivisions. They are separated by the Arnprior Nepean Railway Line that bisects the South March Highlands, with the new Terry Fox Drive extension defining the northern limit. Phase 7 lies south of the rail line, Phase 8 to the north. **Figure 14** provides a schematic of the approved draft plan as proposed by the Urbandale Development Corporation in 2004, with the turtle study zones superimposed overtop. This version of the draft plan of subdivision is currently outdated and is currently undergoing revision by the KNL land development group. KNL currently maintains ownership of Trillium Woods, east of the Second Line road allowance south of Terry Fox Drive, an area of hardwood forest that has been promised to the City of Ottawa as part of the Natural Area dedication. A 40% dedication of green space was determined through a 1983 hearing of the Ontario Municipal Board (OMB, 1983) and reconfirmed in 2006 during the appeal process, as part of the Official Plan review by the City (OMB, 2006). Four other blocks of land listed below were specifically mentioned in the OMB decision (OMB, 1983; OMB 2006):

- Beaver Pond and associated Black Cherry trees - Zone 7B above
- Kizell Pond (Kizell Drain wetland) – southern portion of Zone 7A
- West Block (hardwood beech forest) – northern lobe of Zone 7A and Zone 6A
- Trillium Woods – Zone 5

For the purposes of the Population Viability Analysis modeling and subsequent scenario sensitivity testing, the assumption was made that all habitats (watercourses, wetlands, vernal pools, forests and grasslands) would be converted to residential uses. It will therefore be the responsibility of the proponent(s) to offset the impacts on Blanding's turtle as described herein, by implementing a number of the conservation management recommendations made in the preceding section, under a duly approved application under the Endangered Species Act of 2007. Habitats of this nature will become regulated by the Province on July 1, 2013, under the existing legislation.

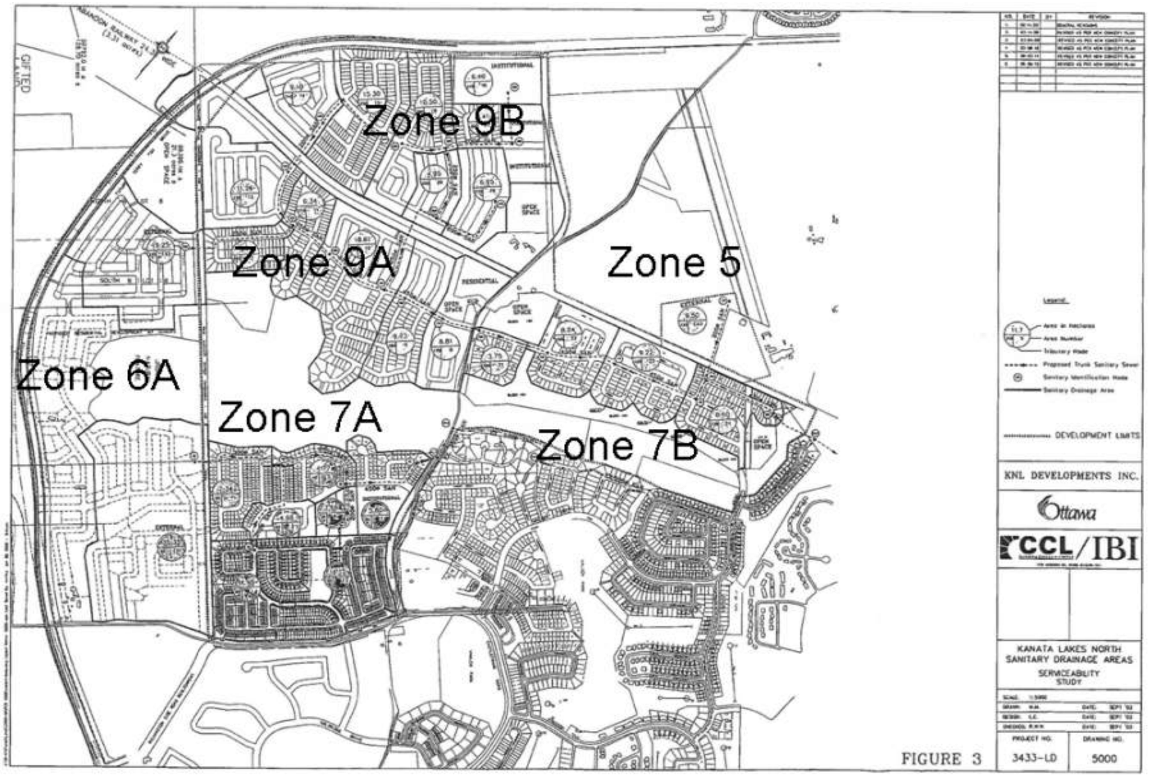


Figure 14. Planned urban development by Kanata Lakes (KNL) near the South March Highlands. Note that the plan shown is not current and is being revised by KNL.

* The Blanding's Turtle Population Distribution Study Zones have been superimposed on the map for clarity purposes.

During the three years of study on Blanding's turtle in the South March highlands, this species has only been found twice in Trillium Woods, but repeatedly in the Kizell Drain wetland. They have been observed once in the Beaver Pond east of Goulbourn Forced Road and have traversed through the West Block along the First Line road allowance, and west to the Carp River, occasionally. Several Blanding's have been caught in Shirley's Brook in Zone 9A and as noted earlier, Zone 9B is a known Blanding's turtle overwintering and nesting area.

The current, draft-approved KNL land development proposal is expected to impact habitats important for the Blanding's turtle SMH population. Proceeding as proposed, the land development will impact movement corridors (Shirley's Brook, First Line), impact a confirmed core nesting site, impact overwintering sites, clear mixed woodlots used occasionally by Blanding's turtles and remove the vernal pool cascade, which provides year-round core habitat for at least 7 adults. Of the four areas identified by the OMB as part of the 40% dedication of green space, only the Kizell Wetland has a significant population of Blanding's turtle and is considered to be core habitat. The Kizell Wetland is planned to receive most of the stormwater runoff from both Phases 7 and 8 in the current KNL plan. The other three areas identified by the OMB, zoned Natural Environment and planned to be preserved as Open Space, appear to be valuable habitats for other terrestrial flora and fauna, but not for Blanding's turtles.

6.2 Kanata Lakes Stormwater Management Plan

The current Draft Approved Plan prepared by IBI Consultants for the KNL property proposes a diversion of storm water runoff from 150 ha of land (KNL Phases 7 and 8), which currently drains into the Shirley's Brook system, into Watt's Creek *via* the Kizell Wetland and Kizell Drain. The Kizell Wetland-Beaver Pond system is an approved stormwater management facility. This combined facility has already exceeded its approved capacity (AECOM, 2011). At the time of preparation of this report, the City understands that KNL is revising its stormwater management plan in response to capacity constraints and potential biological impacts on the Kizell Wetland.

Any alterations to the Kizell Wetland for increased stormwater management will need to consider the characteristics in the wetland that make it high quality core habitat for Blanding's turtle. Permanent increases in water level could change the vegetation community and the habitat structure from a complex, diverse system to a simple system dominated by broad-leave cattail or exotic invaders. If eggs were successfully laid by adult females in close proximity to the shoreline, then temporary water level changes in response to storm events could drown them. Dredging and construction inside the wetland to increase its stormwater capacity could remove habitat, including critical overwintering habitat. During construction, all life stages would be prone to disturbance, damage or mortality, and finding a construction window that does not conflict with the life stages of Blanding's turtle or other regulated species could be difficult. These potential impacts could result in turtle emigration, reproductive failure, injury or death. Preventing or mitigating them will be a significant challenge.

6.3 Destruction or Isolation of Phase 8 Nesting Area

Development of Phases 7 and 8 would destroy or isolate the Blanding's turtle nesting area in Phase 8. The exact nest locations are not known, but radio telemetry suggests that nesting occurs along the north tree line of the field immediately north of the rail line, and/or possibly on the embankment of the rail line. In either case, the proposed development would either eliminate the nesting sites, or block turtle access to them.

6.4 Planned West Shirley's Brook Realignment

Within the study area, Shirley's Brook occurs as two tributaries that come together to form the main stem within Phase 7 of the KNL development lands. On the KNL lands, both the east and west tributaries have been previously ditched to improve drainage for agriculture, as has the main stem. The east Shirley's Brook tributary drains Provincially Significant Wetlands (PSW) north of Terry Fox Drive, through Zones 3 and 4, and flows for a short distance north of the rail line, before passing beneath and then flowing diagonally southeast toward the main stem confluence. A 250 m reach of the east tributary was realigned by the City of Ottawa, on its own property, in 2010 as part of the Terry Fox Drive construction. Approximately 350 m of the east tributary remains on KNL lands immediately south of Terry Fox Drive. The City is unaware of any proposal to relocate or enclose this reach.

The 2004 draft plan of subdivision would re-align a portion of the west tributary and the main stem of Shirley's Brook north, to run parallel and adjacent to the rail line. This would alter one of the movement corridors to/from the Phase 8 nesting area, and to/from further east along Shirley's Brook. In the overall context of development of Phases 7 and 8, which would include loss of the nesting area, this additional impact on Blanding's turtles would be relatively minor. However, the realignment might offer some opportunity for habitat compensation, if measures could be implemented to prevent the area from becoming an "ecological trap". An "ecological trap" is an area with apparently suitable habitat attractive to animals, but with an increased exposure to hazards, causing it to become a population sink (negative population growth).

6.5 Goulbourn Forced Road Realignment

A Class Environmental Assessment (EA) conducted in 2005 by the City of Ottawa (Dillon Consulting Limited, 2005) recommended a preferred alignment and service improvement of Goulbourn Forced Road. In 2007, the Goulbourn Forced Road Environmental Study Report identified the preferred alignment for GFR to the west of Trillium Woods. The existing roadway is a two-lane hard surface road, in rural cross section, considered to be substandard and prone to flooding from the Kizell Wetland. Temporary remedial works to prevent flooding were completed in 2012, primarily to stop beavers from damming the single large bore (900 mm) culvert. The 2005 Class EA recommended a straighter roadway, separated from Trillium Woods, intersecting with Terry Fox Drive, approximately 400 m west of Second Line. At the time, although Blanding's turtle were recognized as being in the area, the 2005 Class EA predated the 2007 *Endangered Species Act*, so the occurrence of Blanding's turtle was not considered significant, nor was the location of their core habitats known. The proposed realignment passes through or very close to a series of six cascading vernal pools, identified as potential overwintering Blanding's turtle core habitat in the 2011/12 mark and recapture and radio telemetry programs (Dillon 2011b, 2012b).

We recommend reviewing the preferred alignment and amending the Class Environmental Assessment of Goulbourn Forced Road in at least two locations; the realignment near the Second Line Road intersection and the level crossing of the Kizell Wetland.

- Realignment of the roadway should be considered to avoid the vernal pool core habitats in Zone 9B, providing a natural vegetation buffer of sufficient width to avoid impacts to the groundwater table elevations, flow direction and volume. The location should aim to minimize or avoid stormwater runoff flows towards the vernal pools and should avoid disturbing any overwintering habitat.
    - If the vernal pools are approved for removal for development under an Endangered Species Act application procedure however, no realignment of GFR at this location would be necessary given that the core habitats will no longer exist.
- At the level crossing of the Kizell Wetland, provide the roadway improvements by removing the fill to the pre-development organic layer and undertaking remediation of the impacted soils. We suggest improving the crossing by constructing a flat causeway structure on piers, allowing for the free flow of water, nutrients, animals and resources below the structure while eliminating the risk of flooding during major events.
- Considering that Goulbourn Forced Road will be improved to a collector-level road, it is suggested that a limited Wildlife Guide System be constructed between the vernal pools in Zone 9B and Trillium Woods in Zone 5.

7 Conclusions

Blanding's turtles inhabit the SMH Conservation Forest and surrounding lands. Due to a variety of historic, current and future stressors, the SMH population is at high risk of decline and eventual extirpation. Planned urban development will exacerbate this risk. Conservation of the population will require sustained financial support for the management options recommended herein. Several specific actions, such as measures to reduce adult mortality, increase hatchling success, and to limit urban development in the most sensitive core habitats, may significantly curtail the predictable population decline.

Excess, suitable core habitat is present in the area, and improved linkages to other habitats and sub-populations should be investigated to support the SMH population. Blanding's turtle conservation and management in the SMH should remain a long term priority of the City of Ottawa and other stakeholders to help preserve this threatened, unique species. Should the objectives, targets and recommendations of the Conservation Needs Assessment not be implemented, the Blanding's turtle in the SMH will continue to face threats to their core habitats and population abundance. Approaches to implement the Conservation Needs Assessment successfully, must consider the recommended strategies to beneficially support Blanding's turtles through activities focused on the species, core habitats, research, education, awareness, collaboration and legislative aspects. The objective is to seek a sustainable, net global benefit to this species at risk while at the same time allowing for economic growth and prosperity for the residents of Ottawa.

In addition, the recommendations made to curtail further habitat loss, degradation and other threats to the SMH Blanding's turtle should be explored prior to any further urban development outside of the Terry Fox Drive planning area. The conservation and protection of this species at risk requires collaboration, sustainable funding, innovation and enforcement by government, landowners, researchers, non-governmental organizations and the public.

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http://nature.ca/rideau/b/b9b-e.html#Crayfish

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http://www.torontozoo.com/Adoptapond/turtlenests.asp?opx=2

http://www.cayolargo.net/sea-turtles.html

http://www.conserveturtles.org/costarica.php

http://www.marineconservationkohtao.com/

http://www.speciesatrisk.ca/SARGuide/download/Blanding's%20Turtle.pdf

https://www.dial4light.de/dial4light/static/en/home.htm

APPENDIX A

CURRICULUM VITAE OF PEER REVIEWERS

CURRICULUM VITAE

Justin D. Congdon, Ph.D.

Savannah River Ecology Laboratory
Drawer E
Aiken, South Carolina 29802
Phone (803) 725-5341
congdon@vtc.net

Birth Date: 5 January 1941

MILITARY
United States Navy, 1959-1962.
Honorable Discharge

EDUCATION

A.A. Victor Valley College, Victorville, California, 1966
B.S. California State Polytechnic University, San Luis Obispo, California, 1969
M.S. California State Polytechnic University, San Luis Obispo, California, 1971
Ph.D. Arizona State University, Tempe, Arizona, 1977
Post-doctoral Scholar. Museum of Zoology, University of Michigan, 1977-1980.
Advisor, Dr. Donald W. Tinkle.
Post-doctoral Scholar. Savannah River Ecology Laboratory, 1980-1984.
Advisor, Dr. J. Whitfield Gibbons.

POSITIONS

Professor Emeritus, University of Georgia, Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina, 2002 - present.
Senior Research Ecologist, Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina, 1990 - 2002.
Associate Research Ecologist, Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina, 1985-1990.
Adjunct Professor, Zoology Department, Arizona State University, Tempe, AZ, 1999 - present.
Adjunct Senior Research Ecologist, Institute of Ecology, University of Georgia, Athens, Georgia, 1985 - present.
Adjunct Research Investigator, Museum of Zoology, University of Michigan, Ann Arbor, Michigan, 1981 - 2007.
Adjunct Professor, Zoology Department, University of Guelph, Guelph, Ontario, Canada, 1998 - 2006.
Adjunct Professor, Department of Biological Sciences, University of South Carolina, Columbia, SC, 1998 - 2004.
Adjunct Senior Research Ecologist, Zoology Department, University of Tennessee, Knoxville, Tennessee. 1984-1990.
Adjunct Professor, Department of Aquaculture, Fisheries and Wildlife, Clemson University, Clemson, South Carolina, 1982-1988.

GRANTS

NSF Predoctoral Grant for Field Research, 1972. $3,700.
NSF Grant, Life History Characteristics of Reptiles: Ecological and Evolutionary Perspectives of Long-Lived Species 1979-1983. $146,395.
American Philosophical Society Grant, Analysis of long-term lizard life history studies made by Dr. Donald W. Tinkle, 1981. $760.
NSF Grant, Life History Characteristics and Ecology of Turtles: Evolutionary Perspectives on Long-lived Organisms. 1984-1987. $121,000.
NSF Grant, Evolution of Delayed Sexual Maturity in Turtles. 1991-1994. $136,000.
EPA Grant, Global Change Research Program. 1993-1995. Comparative Risk Assessment of Climate Change and Other Anthropogenic Stresses: Habitat and Biological Diversity on the Savannah River Site, South Carolina, With Dr. Ronald Pullman PI, $578,818.
DOE- Environmental Management Science Program. 1996-1999. Determining Significant Endpoints for Ecological Risk Analyses, with Dr. Thomas Hinton (Savannah River Ecology Laboratory), Dr. Chris Rowe (Savannah River Ecology Laboraotyr), Mr. David Scott (Savannah River Ecology Laboratory), and Dr. Ward Wicker (Colorado State University), and Dr. Joel Bedford (Colorado State University). $897,666
NSF Dissertation Improvement Grant 1997-1998. Experimental Tests of the Parental Investment in Care Hypothesis. With Rebecca Yeomans (University of Georgia). $11,000
EPA Star Grant. 1999-2000, Coal Combustion Waste: New Perspectives on an Old Problem. $67,000, with Dr. Christopher Rowe (University of Maryland, Chesapeake Bay Laboratory) and Dr. William Hopkins (Savannah River Ecology Laboratory).
USFWS. 2002. Demographic characteristics of turtles in relation to harvest. $70,000, with Dr. Robert Reed and Dr. Whit Gibbons (Savannah River Ecology Laboratory).

HONORS AND AWARDS

1965. Outstanding Scholarship Award, Kiwanis Club, Victor Valley College.
1972. Summer Fellowships for Outstanding Teaching Assistants.
1973. Summer Fellowships for Outstanding Teaching Assistants.
1974. Graduate Fellowship, Arizona State University.
1993. Alumni Hall of Fame, Victor Valley College.
1994. Education Medal of Honor, Student Alumni, San Bernardino County Community College.
1994. Distinguished Alumni, California Community Colleges.
2001. Longevity Award, Foundation IPSEN, France ($15,000).

TEACHING EXPERIENCE

Undergraduate Classes: General Biology, General Zoology, General Physiology
Graduate Classes: Evolution of Life Histories, Evolutionary Ecology

STUDENTS

Committee Chair or Co-Chair: MS

Julie Wallin	1990	University of Georgia, Athens
Mark Komoroski	1996	University of Georgia, Athens
Roy Nagle	1997	University of South Carolina, Columbia
Owen Kinney	1999	University of Georgia, Athens
Brandon Staub	2000	University of Georgia, Athens
Willy Hollett	2002	University of Guelph, Guelph, Ontario, Canada

Committee Member: MS

Hal Avery	1986	State University of New York, Buffalo
Anita Caudle	1988	University of Georgia, Athens
Matthew Osentoski	1993	East Carolina University, Greenville, NC
Rebecca Yeomans	1993	University of Georgia, Athens
John Lee	1996	University of Georgia, Athens
Jason Samson	2003	University of Guelph, Guelph, Ontario, Canada
Melissa Cameron	2005	University of Guelph, Guelph, Ontario, Canada

Committee Chair or Co-Chair: Ph.D.

Christopher Beck	1998	University of Georgia, Athens
Rebecca Yeomans	1999	University of Georgia, Athens
Miriam Benabib	1990	University of Georgia, Athens
William Hopkins	2001	University of South Carolina, Columbia

Committee Member: Ph.D.

Mary Mendonca	1986	University of California, Berkeley
Scott Eckert	1989	University of Georgia, Athens
Edward Michaud	1989	University of Tennessee, Knoxville
David Galbraith	1989	Queens University, Kingston, Canada
Jeffrey Lovich	1990	University of Georgia, Athens
Mark Belk	1992	University of Georgia, Athens
Peter Niewiarowski	1992	University of Pennsylvania, Philadelphia
Steven Beaupre	1993	University of Pennsylvania, Philadelphia
Robert Fischer	1995	University of South Carolina, Columbia
Vincent Burke	1995	University of Georgia, Athens
John Krenz	1995	University of Georgia, Athens
Willem Roosenburg	1995	University of Pennsylvania, Philadelphia
Michael Angeletta	1998	University of Pennsylvania, Philadelphia
Kurt Buhlmann	1998	University of Georgia, Athens
Christopher Tatara	1999	University of Georgia, Athens
Matthew Osentoski	2001	Florida International University, Miami, FL
Michael Sears	2001	University of Pennsylvania, Philadelphia, PA

Mark Mills	2002	University of Georgia, Athens
Kim Orell	2002	Virginia State Polytechnic University, Blacksburg
William Hopkins	2002	University of South Carolina, Columbia
Jacquline Litzgus	2003	University of South Carolina, Columbia
James Novak	2003	University of Georgia, Athens
Tracey Tuberville	2006	University of Georgia, Athens
Jeanette McGuire	2011	Michigan State University, East Lansing

Post-doctoral Researchers supervised

Roger Anderson	1989-1991	Michael Dorcas	1995-1997
David Schultz	1990-1992	Christopher Rowe	1995-1997
Peter Niewiarowski	1993-1995		

RESEARCH INTERESTS

My research interests and activities encompass the major areas of : 1) physiology, population biology and evolutionary ecology, and 2) toxicology of heavy metals associated with coal combustion waste products. I am interested in theoretical and conceptual aspects of physiological and ecological processes that combine to shape reproductive, demographic, and life history strategies in natural and contaminated environments. I have conducted field and laboratory investigations of bio-energetics, growth, demography, reproductive biology, and aging of vertebrates.

RESEARCH EXPERIENCE

Principal Investigator, University of Michigan's E. S. George Reserve study of turtle life histories. 1975 - 2007.

Co-Principal Investigator with Michael Pappas on a study of orientation of eight species hatchlings dispersing from nests in the Weaver Dunes area of Minnesota. 2001 - present.

Co-Principal Investigator with Richard van Loben Sels on a study of life history and demography of the Sonoran mud turtle. 1990 - present.

Senior Research Ecologist, Savannah River Ecology Laboratory, Aiken, South Carolina. Physiological Ecology and Toxicology of Coal Ash Basins. 1990- present.

Associate Research Ecologist, Savannah River Ecology Laboratory, Aiken, South Carolina. Thermal biology of vertebrates. 1985-1990.

Post-doctoral Scholar, Savannah River Ecology Laboratory, Aiken, South Carolina. 1980-1984.

Post-doctoral Scholar, Museum of Zoology, University of Michigan, 1976-1979.

Research Assistant, Museum of Zoology, University of Michigan, 1972-1973.

Research Contract, California Fish and Game Department, Endangered Species Status, 1971.

Research Assistant, California Polytechnic University, 1970.

ADMINISTRATIVE EXPERIENCE

Administration of Physiological Ecology Group, Savannah River Ecology Laboratory. (one research coordinator, two full-time and two part-time research assistants, and one post-doc). 1985-2002.

Administration of NSF Grants, (two full-time and four part-time research assistants). 1980-1984, 1984-1986, 1991-1995.

PROFESSIONAL SOCIETIES

AAZPA, Freshwater Turtle Advisory Panel
Chelonian Conservation and Biology Society (**Life Member**)
Herpetologists' League (**Life member**)
IUCN/SSC Tortoise and Freshwater Turtle Specialist Group
Malpai Borderlands Group Science Advisory Board
Sky Island Alliance Science Advisory Board
Society of the Study of Amphibians and Reptiles (**Life Member**)
Society of Sigma Xi
Tucson Herpetological Society (**Life Member**)
Turtle Survival Alliance

APPOINTMENTS IN PROFESSIONAL ORGANIZATIONS

AAZPA, Freshwater Turtle Advisory Panel
Society for the Study of Amphibians and Amphibians, Journal of Herpetology Editorial Board, 1987- 2002
Chelonian Conservation and Biology, Editorial Board

Reviewer- Grants: DOE, EPA, NSF, Research Council of Canada
Reviewer- papers: American Midland Naturalist, American Naturalist, Animal Conservation, Canadian Journal of Zoology, Canadian Field Naturalist, Chelonian Conservation and Biology, Conservation Biology, Copeia, Ecology, Ecology Letters, Evolution, Functional Ecology, Herpetologica, Herpetological Conservation and Biology, Journal of Herpetology, Journal of Mammalogy, Journal of Toxicology and Chemistry, Oecologia

OAK RIDGE TRAVELING LECTURES

Berry College, Rome, GA
Ohio State University, OH
Purdue University, IN
Southwest Texas University, TX
University of Texas at Arlington, TX
Eastern Carolina University, NC
Oklahoma State University, OK
Randolph Macon College, VA
University of Eastern Tennessee, TN
Washington-Lee University, VA

INVITED SEMINARS

1st Donald W. Tinkle Memorial Lecture, University of Michigan, Ann Arbor, MI
1st World Congress of Herpetology, Canterbury, England (3)
2nd World Congress of Herpetology, Adelaide, Australia
3rd Donald W. Tinkle Memorial Lecture, University of Michigan, Ann Arbor, MI
All Florida Herpetology Conference, Gainesville, FL
Arizona State University, Tempe, AZ (3)
Auburn University, Auburn, AL
Bowling Green University, Ohio
California State Polytechnic University, San Luis Obispo, CA
Clemson University, Clemson, SC
Desert Tortoise Council Meetings (4)
Duke University, NC
Eastern Illinois University, Charleston, IL
Georgia Southern University, Statesboro, GA
Malpai Borderlands Science Meeting, Douglas AZ (2)
Michigan State University, E. Lansing, MI
Midwest PARC Meeting, Lorado Taft Field Campus of Northern Illinois University
North Carolina State University, Raleigh, NC
North Western PARC, 2010 keynote address
Pennsylvania State University, College Park, PA
Powdermill Freshwater Turtle Meetings I, II, III, IV, VI
Queen's University, Kingston, Canada
Sea Turtle Meetings (2)
Sky Island Conference (2)
Savannah River Ecology Laboratory, Aiken, SC
Southwestern Louisiana University
Tennessee State University, Memphis, TN
Texas Tech University, Lubbock, TX
Toronto Zoo Turtle Conservation Workshop (4)
Tucson Herpetological Society (2)
Universidad Nacional Autonoma de Mexico, Mexico City (2)
University of Arizona, Tucson, AZ (2)
University of Florida, Gainesville, FL (3)
University of Georgia, Athens, GA (7)
University of Guelph, Guelph, Canada
University of Kentucky, Lexington, KY
University of Michigan, Ann Arbor, MI (3)
University of Michigan, Dearborn, MI
University of Nebraska, Lincoln, NE
University of North Carolina, Greensboro, NC
University of Ohio, Miami, OH
University of Ohio, Athens, OH
University of Oklahoma, Norman, OK

University of South Florida, Tampa, FL
University of Tennessee, Knoxville, TN (3)
University of Texas at Arlington, Arlington, TX (2)
University of Toledo, Toledo, OH
Utah State University, Provo, UT (2)
Victor Valley College, Victorville, CA
Virginia Polytechnical Institute and State University, Blacksburg, VA (3)
Wilkes College, Wilkes Barre, PA

SYMPOSIA ORGANIZED

1989. Nutrition and Energetics in Desert Tortoises. Desert Tortoise Council Meeting, Mesquite NV. Presentation: "*Why desert tortoises eat dirt*"
1989. Evolution of Life Histories of Turtles,. First World Congress of Herpetology, Canterbury, England. Presentation: "*Life history evolution in turtles*"
1991. Chaired the Third Meeting of the Freshwater Turtle Research Group, Powdermill III. Savannah River Ecology Laboratory. Presentation "*Reproduction and Nesting Ecology of Painted Turtles*"
1997 Resource Allocation Processes: the Connection Between Individual and Population Levels of Biological Organization:. Savannah River Ecology Laboratory Symposia Series IV. Presentation: "*Allocation to growth by juveniles: evolution of delayed sexual maturity in painted turtles*"
2006 Co-chaired with Dr. Dawn Wilson. Powdermill VI Freshwater Turtle Ecology, Southwestern Research Station, Portal, Arizona. Presentation: *Demographics of age and Aging in long-lived vertebrates (i.e., turtles).*
2011. Co-chaired with Dr. Richard Vogt and Michael Pappas. Upper Mississippi River Symposium Honoring Dr. John Legler. Joint Meeting of SSAR and Herpetologists League, Minneapolis, Minnesota. Presentation: "*Perceptions of Indeterminate growth and its importance in the evolution of turtle life histories and longevity".*

SYMPOSIA PARTICIPATION

1982. *Reproductive energetics of painted turtles*." Reproduction in Reptiles. **Joint meeting of the Society for the Study of Amphibians and Reptiles and the Herpetologists' League. Memphis, TN.**
1987. "*Proximate and evolutionary constraints on energy relations of reptiles*" Bioenergetics of Organisms in Extreme Environments. **American Society of Zoologists Meeting**, **San Antonio, TX.**
1989. "*Pre-ovulatory parental investment in care by reptiles*" **Egg Tricks. First World Congress of Herpetology. Canterbury, England.**
1989. "*A long-term study of turtles on the E. S. George Reserve in southeastern Michigan*" Long-Term Studies: First World Congress of Herpetology. Canterbury, England.
1989. "*Life history evolution in turtles*" **Evolution of Turtle Life Histories. First World Congress of Herpetology. Canterbury, England.**

1989. "*Demographics of common snapping turtles (Chelydra serpentina): implications for conservation and management of long-lived organisms*" **Long-Term Studies and Conservation biology. American Society of Zoologists Meeting. Vancouver, Canada.**

1992. "*Senescence in turtles: evidence from three decades of study on the E. S. George Reserve*" **Senescence in Organisms in Natural Populations:. American Association of Gerontologists. Washington, DC.**

1993. "*Parental investment strategies in reptiles*" **Parental Investment in Reptiles. Second World Congress of Herpetology. Adelaide, Australia.**

1994. "*Consequences of variation in age at sexual maturity to the demographics of painted turtles (Chrysemys picta)*" **Interfaces Between Individuals and Populations: Joint Annual Meeting of the Herpetologists' League and the Society for the Study of Amphibians and Reptiles. Athens, GA.**

1997. "*Applying the concept of 'feasible demography' to conservation and management of endangered species Endangered Species of Michigan*. **Michigan Academy of Arts and Sciences. Grand Rapids, MI.**

1997. "*Applying the concept of 'feasible demography' to conservation and management of long-lived organisms*" **Life Histories of Turtles. Joint annual meeting of the Herpetologists League and the Society for the Study of Amphibians and Reptiles. Seattle, WA.**

1997. "*Juvenile and adult survivorship rates of turtles: life history trait values that limit harvest*" **Sustainable Yield and the Conservation of Long-Lived Vertebrates. Joint annual meeting of the Herpetologists League and the Society for the Study of Amphibians and Reptiles. Seattle, WA,**

1997. "*Oviductal Sperm Storage as a Reproductive Tactic of Turtles*" **Reproductive Biology. World Congress of Morphology, London, England..**

1998. "*Evidence for actuarial senescence in turtles*" Workshop on Organisms with Negligible Senescence II. **Ethel Percy Andrus Gerontology Center, University of Southern California.**

1999. "*Evidence for reproductive senescence in turtles*" **Workshop on Organisms with Negligible Senescence III. Ethel Percy Andrus Gerontology Center, University of Souther California.**

1999. "*Resource-allocation based life histories: A conceptual basis for studies of ecological toxicology"* **Bioenergetics and Toxicology. SETAC Meetings, Philadelphia.**

1999. "*Hypotheses of Aging in a Long-lived Vertebrate (Blanding's turtle, Emydoidea blandingii)*" **Symposium on Slowly Aging Organisms. Ethel Percy Andrus Gerontology Center, University of Southern California.**

2000. "*Resource Allocation Based Life-Histories of Reptiles: Concepts for Studies of Sub-Lethal Effects of Contaminants Toxicology of Reptiles*". **Reptile Toxicology, Society of Environmental Toxicologists and Chemists Meetings, Nashville, TN.**

2000. Living With Uncertainty: Life-History and Demographics of Sonoran Mud Turtles (*Kinosternon sonoriense*). **Malpai Borderlands Science Meetings, Douglas, AZ.**

2001. "*Old Blanding's Turtles Never Die, nor do they Fade Away*". **Foundation IPSEN Symposium on Longevity, World Congress of Gerontology, Vancouver, Canada.**

2002. *"A Review of Demography, Longevity and Aging in Blanding's Turtle"*. **The Brain and Longevity, Foundation IPSEN, Paris, France.**

2002. *Feasible Demography Approach to the Study of Desert Tortoises*" **Desert Tortoise Research on Ft. Irwin, California, Desert Tortiose Council Meeting, Plam Springs, CA**

2002. *Life history and demographic aspects of aging in a long-lived turtle (Emydoidea blandingii).* **The Oldest Old. Thirteenth Annual Southeastern Regional Student Convention in Gerontology and Geriatrics. University of Georgia, Athens.**

2004. *The History of Life Histories of Long-Lived Organisms*. Symposium Honoring the Career and Life of Dr. Eric Pianka. **Joint meeting of the Society for the Study of Amphibians and Reptiles and the Herpetologists' League. Norman, OK.**

2004. *Life Histories and Aging in Long-Lived Organisms*. **Demography of Aging in Turtles. Max Plank Institute of Demography, Rostock, Germany**

2008. *The currency of life-history evolution: why older turtles are valuable, and how they got that way*. Is Management of Sustainable Commercial Harvest of Long-Lived Organisms Possible. **Joint Meeting of SSAR and Herpetologists League, Montreal, Canada.**

2011. Upper Mississippi River Symposium Honoring Dr. John Legler. Presentation: "*Perceptions of Indeterminate growth and its importance in the evolution of turtle life histories and longevity"*. **Joint Meeting of SSAR and Herpetologists League, Minneapolis, Minnesota.**

TECHNICAL REPORTS

1971. Congdon, J.D. Population estimate and distribution of the Morro Bay kangaroo rat. **California Department of Fish and Game Wildlife Management. Br. Admin. Rpt. No. 71-11, mimeographed. 16 pp.**

1987. Congdon, J.D., M.V. Plummer, M.E. Seidel, and L.R. Swingland. An assessment of the sufficiency and accuracy of available data regarding the status of the Flattened Musk Turtle (*Sternotherus depressus*). **Report to the director of the U.S. Fish and Wildlife Service, U.S. Department of the Interior. Washington, DC 20240.**

1995. van Loben Sels, R.C., J.D. Congdon and J.T. Austin. Aspects of the life history and ecology of the Sonoran mud turtle (*Kinosternon sonoriense*). p. 262-266. In: **Proceedings of the Biology of the Madrean Archipelago: The Sky Island of Southwestern United States and Mexico. General Technical Report RM-GTR-264. Rocky Mountain Research Station, USDA Forest Service. Tucson, AZ.**

1995. Congdon, J.D., A.E. Dunham and R.C. van Loben Sels. Life histories and demographics of long-lived organisms: implications for management and conservation. p. 624-630. In: **Proceedings of the Biology of the Madrean Archipelago: The Sky Island of Southwestern United States and Mexico. General Technical Report RM-GTR-264. Rocky Mountain Research Station, USDA Forest Service. Tucson, AZ.**

2001. Pappas, M.J., J.D. Congdon, A. Pappas. Weaver Bottoms 2001 Turtle Survey: Management and Conservation Concerns. **Report to the Minnesota Department of Natural Resources and the United States Fish and Wildlife Service.**

2002. Congdon, J. D. and M. J. Pappas. Status of Blanding's Turtles in Exner Marsh in Lake of the Hills, Illinois. **Report to the Plote Construction Company and Lake of the Hills Community Planning Committee.**

2002. Reed, R.N., J.D. Congdon, and J.W. Gibbons. The Alligator Snapping Turtle [*Macrochelys (Macroclemys*) *temminckii*]: a review of ecology, life history, and conservation, with demographic analyses of the sustainability of take from wild populations. **Division of Scientific Authority, United States Fish and Wildlife Service**

2003. Pappas, M.J., and J.D. Congdon,. Weaver Bottoms 2002 Turtle Survey: Management and Conservation Concerns. **Report to the Minnesota Department of Natural Resources and the United States Fish and Wildlife Service**

2003. Pappas, M.J., and J.D. Congdon, Removal of sand from Island #42 on the Mississippi River: impact on nesting turtles. **Report to the Minnesota Department of Natural Resources and the United States Fish and Wildlife Service.**

PUBLICATIONS (PUBLISHED PAPERS)

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2006. Congdon, J.D. and D.A. Keinath. (2006, July 20). Blanding's Turtle (*Emydoidea blandingii*): a technical conservation assessment. [Online]. **USDA Forest Service, Rocky Mountain Region. Available:** http://www.fs.fed.us/r2/projects/scp/assessments/blandingsturtle.pdf [date of access].

2007. Gist D.H., J.D. Congdon, R.A. Ness. Estrogen response system in the reproductive tract of the turtle: an imuno-cytochemical study. **General and Comparative Endocrinology.**

2007 Gist, D. E., S. Bradshaw, C. M. K. Morrow, J. D. Congdon and R. A. Hess.. Estrogen response system in the reproductive tract of the male turtle: An immunocytochemical study. **General and Comparative Endocrinology** 151(1): 27-33.

2008 Congdon, J.D., Graham, T.E., Herman, T.B., Lang, J.W., Pappas, M.J., and Brecke, B.J. 2008. *Emydoidea blandingii* (Holbroook 1838) – Blanding's turtle. In: Rhodin, A.GJ., Pritchard, P.C.H., van Dijk, P.P. Saumure, R.A Buhlmann, K.A., and Iverson, J.B. (Eds.) Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs No. 5, pp. 015.1-015.12, doi:10.3854/crm.5.015.blandingii.v1.2008,http://www.iucn-tftsg.org/cbftt/.

2009. Buhlamnn, K.A., J.D. Congdon, J. Whitfield Gibbons, and J.L. Greene. Ecology of chicken turtles (Deirochelys reticularia) in a seasonal wetland ecosystem: exploiting resource and refuge environments. Herpetologica 65:39-53.

2009. Pappas, M.J., J.D. Congdon, B.J. Brecke, and J.D. Capps. Orientation and dispersal of hatchling Blanding's turtles (*Emydoidea blandingii*) for experimental nests. 2009. **Canadian Journal of Zoology** 87:755-766.

2011. Congdon, J.D., M.J. Pappas, and B.J. Brecke. Conservation Implications of Initial Orientation of Naıve Hatchling Snapping Turtles (Chelydra serpentina) and Painted Turtles (Chrysemys picta belli) Dispersing From Experimental Nests, **Chelonian Conservation and Biology** 10:42-53.

2011. McGuire, J.M., J.D. Congdon, K.T. Scribner, and J.D. Capps. Variation in Female Reproductive Quality and Reproductive Success of Male Painted Turtles (*Chrysemys picta marginata*). **Canadian Journal Zoology** 89:1136-1145.

2011. Congdon, J.D., O.M. Kinney, and R.D. Nagle. Spatial Ecology and Core Area Protection of Blanding's Turtle (*Emydoidea blandingii*). **Canadian Journal Zoology**, 89:1098-1106.

2012. Steen, D.A., Gibbs, J.P., Buhlmann, K.A., Carr, J.L., Compton, B.W., Congdon, J.D., Doody, J.S., Godwin, J.C., Holcomb, K.L., Jackson, D.R., Janzen, F.J., Johnson, G., Jones, M.T., Lamer, J. T., Langen, T.A., Plummer, M.V., Rowe, J.W., Saumure, R.A., Tucker, J.K., and Wilson D.S. Use of Terrestrial Habitat by Nesting Freshwater Turtles. **Biological Conservation 150**: 121-128.

2012. Congdon, J.D., Gibbons, J.W., Brooks, R.J., Rollinson, Njal, and Tsaliagos, R.N. Indeterminate Growth in Long-lived Freshwater Turtles as a Component of Individual Fitness. **Evolutionary Ecology 26**: available on line (page numbers upon publication).

2013. Pappas, M.J., Congdon, J.D., Brecke, B.J., and Freedberg, S. Orientation of Hatchling Blanding's (*Emydoidea blandingii*) and Snapping Turtles (*Chelydra serpentina*) Dispersing from Experimental Nests in Agricultural Fields. **Herpetological Conservation and Biology**, in press.

PUBLICATIONS (SUBMITTED PAPERS)

McGuire, J.M, K.T. Scribner, and J.D. Congdon. Individual movements, mating patterns, and nest distributions influence gene flow among population subunits of Blanding turtles (*Emydoidea blandingii*).

PUBLICATIONS (IN PREPARATION)

McGuire, J.M, J.D. Congdon, and K.T. Scribner. Female reproductive qualities affect male Painted turtle (*Chrysemys picta marginata*) reproductive success.

Buhlmann, K.A., J.D. Congdon, J.L. Greene, and J.W. Gibbons. Life-history of the short-lived Chicken Turtles (*Deirochelys reticularia*), with comparisons to longer-lived Eastern Mud Turtles, *Kinosternon subrubrum* and Blanding's turtle, *Emydoidea blandingii*).

Congdon, J.D. The influence of growth on life-histories of Painted Turtles (*Chyrsemys picta*), Blanding's turtle (*Emydoidea blandingii*), and Snapping Turtles (*Chelydra serpentina*).

Congdon, J.D., Nagle, R.D., Kinney, O.M., Quinter, T., McGuire, J.M., and K.T. Scribner. The influence of growth on life-histories of Painted Turtles (*Chyrsemys picta*), Blanding's turtle (*Emydoidea blandingii*), and Snapping Turtles (*Chelydra serpentina*).

PUBLICATIONS (BOOK CHAPTERS)

1976. Congdon, J.D. Effects of habitat quality on the distribution of three sympatric species of desert rodents. p.358. In: *Selected Reading in Mammalogy*. J.K. Knox, S. Anderson, and R.S. Hoffman (eds.). Univ. Kansas Press, Lawrence, KS.

1982. Congdon, J.D., A.E. Dunham and D.W. Tinkle. Energy budgets and life histories of reptiles. p. 233-271. In: *Biology of the Reptilia*. Vol. 13. C. Gans and H. Pough (eds.). Academic Press, London.

1990. Congdon, J.D. and J.W. Gibbons. Turtle eggs: their ecology and evolution. p. 109-123. In: *Life History and Ecology of the Slider Turtle*. J.W. Gibbons (ed.), Smithsonian Institution Press, Washington, D.C.

1990. Congdon, J.D. and J.W. Gibbons. The evolution of turtle life histories. p. 45-54. In: *Life History and Ecology of the Slider Turtle*. J.W. Gibbons (ed.), Smithsonian Institution Press, Washington, D.C.

1990. Gibbons, J.W., J.L. Greene and J.D. Congdon. Temporal and spatial movement patterns of sliders and other turtles. p. 201-215. In: *Life History and Ecology of the Slider Turtle*. J.W. Gibbons (ed.), Smithsonian Institution Press, Washington, D.C.

1993. Congdon, J.D. and A.E. Dunham. Contribution of long-term life history studies to conservation biology. p. 181-182. In: *Principles of Conservation Biology*. G. Meffe and R. Carroll (eds.). Sinauer Associates. New York.

1995. Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. Delayed sexual maturity and demographics of Blanding's turtles: implications for conservation and management of long-lived organisms. p. 104-111. In: *Readings from Conservation Biology: Genes, Populations and Species*.D. Ehrenfeld (ed.).

1995. Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. Delayed sexual maturity and demographics of Blanding's turtles: implications for conservation and management of long-lived organisms. p. 187-194. In: *Readings from Conservation Biology: To Preserve Biodiversity - An Overview*. D. Ehrenfeld (ed.).

1996. Congdon, J.D. and J.W. Gibbons. Structure and dynamics of a turtle community over two decades. pp. 137-159. In: *Long-Term Studies of Vertebrate Communities*. Eds. Martin C. Cody and Jeffrey Smallwood. Academic Press, Inc.

1999. Congdon, J.D., and Dunham, A.E. Defining the beginning: the importance of research design. In: Research and Management Techniques for the Conservation of Sea Turtles. K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 1999

2002. Life history and demographic aspects of aging in a long-lived turtle (*Emydoidea blandingii*). Congdon, J. D., R. D. Nagle, M. O. Osentoski, O. M. Kinney, and R. C. van Loben Sels. In C. E. Finch, J-M Robine, and Y Christen (Eds.). *The Brain and Longevity*, Springer Verlag, Paris, 15-31.

2008. Congdon, J. D., Graham, T. E., Herman, T. B., Lang, J. W., Pappas, M.J., and Brecke, B.J. 2008. *Emydoidea blandingii* (Holbrook 1838) – Blanding's turtle. In: Rhodin, A.G.J., Pritchard, P.C.H., van Dijk, P.P., Saumure, R.A., Buhlmann, K.A., and Iverson, J.B. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs No. 5, pp. 015.1-015.12, doi:10.3854/crm.5.015.blandingii.v1.2008,http://www.iucn-tftsg.org/cbftt/.

2008. Congdon, J.D., Greene, J. L. and Brooks, R.J. 2008. Reproductive and nesting ecology of female snapping turtles. In: Biology of the Snapping Turtle (*Chelydra serpentina*). A. C. Steyermark, Finkler, M. S., and Brooks, R. J. (Eds.). Johns Hopkins University Press, Baltimore. pp. 123-134.

REFERENCES

Dr. J. Whitfield Gibbons
Savannah River Ecology Laboratory
Drawer E
Aiken, SC 29802
(803) 725-2472

Dr. Arthur Dunham
Biology Department
University of Pennsylvania
Philadelphia, PA 19104
(215) 898-4117

Dr. Laurie Vitt
Oklahoma Museum of Natural History
University of Oklahoma
Norman, OK 73019
(405) 325-5002

INFORMATIONS PERSONNELLES - PERSONAL DATA

Gabriel Blouin-Demers, PhD
Département de Biologie - Department of Biology
Université d'Ottawa - University of Ottawa
30 Marie-Curie
Ottawa (Ontario) K1N 6N5

T: (613) 562-5800 6749
F: (613) 562-5486
C: (819) 329-4080
gblouin@uottawa.ca
www.science.uottawa.ca/gblouin

Citoyenneté - Citizenship: Canada
Né - Born: 16/08/1974, Québec, Canada
Statut - Status: Marié, deux enfants - Married, two children
Langues - Languages: Français, English, Español

TITRES UNIVERSITAIRES - ACADEMIC TITLES

1996 – 2001	PhD Biology – Carleton University. Thesis: Thermoregulation and habitat use by black rat snakes (*Elaphe obsoleta obsoleta*) at the northern extreme of their distribution. Supervisor: PJ Weatherhead
1993 – 1996	BSc Environmental Biology – McGill University. Thesis: Evaluation of a community-oriented wildlife management marsh. Supervisor: JR Bider

EXPÉRIENCE PROFESSIONNELLE - PROFESSIONAL EXPERIENCE

2011 – ...	Full Professor, Department of Biology, University of Ottawa
2006 – 2011	Associate Professor, Department of Biology, University of Ottawa
2002 – 2006	Assistant Professor, Department of Biology, University of Ottawa
2002 – ...	Member, Faculty of Graduate and Postdoctoral Studies, University of Ottawa
2004 – 2008	Special Member, Faculty of Graduate Studies, University of Guelph
2004 – ...	Research Associate, Arizona-Sonora Desert Museum
2001 – 2002	Postdoctoral Fellow, Department of EEOB, The Ohio State University
2000 – 2001	Sessional Lecturer, Department of Biology, Carleton University

DISTINCTIONS - AWARDS

2012	Nominé de la Faculté des Sciences pour le prix d'excellence en enseignement de l'Université d'Ottawa - Faculty of Science nominee for the University of Ottawa Award for Excellence in Teaching
2010	Prix d'excellence en éducation de l'Université d'Ottawa - University of Ottawa Prize for Excellence in Education ($10,000)
2008	Prix de la Faculté des Sciences pour l'excellence en enseignement - Faculty of Science Award for Excellence in Teaching ($1000)
2002 – 2003	Natural Sciences and Engineering Research Council of Canada, Postdoctoral Fellowship ($70,000)
2001 – 2002	The Ohio State University, University Postdoctoral Fellowship ($US24,000)
1998 – 2000	Natural Sciences and Engineering Research Council of Canada, Postgraduate Scholarship B ($39,000)
1998	Fonds pour la Formation de Chercheurs et l'Aide à la Recherche, Postgraduate Scholarship B2 ($35,000 declined)
1996 – 1998	Natural Sciences and Engineering Research Council of Canada, Postgraduate Scholarship A ($39,000)
1996 – 2001	Carleton Scholarship, Carleton University ($30,000)
1996	Fonds pour la Formation de Chercheurs et l'Aide à la Recherche, Postgraduate Scholarship B1 ($35,000 declined)
1995	Stewart Brown Scholarship, McGill University ($1,500)
1994	McConnell Award, McGill University ($1,500)
1993 – 1996	Dean's Honour List, McGill University ($3,000)
1993 – 1996	Eliza M. Jones Scholarship, McGill University ($5,000)

SERVICE UNIVERSITAIRE - ACADEMIC SERVICE

2012 – ...	Associate Editor for Amphibia-Reptilia
2011 – ...	Elected member of the Faculty of Science Teaching Personnel Committee
2011	Chair, hiring committee for 2 regular faculty positions, Department of Biology, University of Ottawa
2009 – ...	Director, Environmental Science program, Faculty of Science, University of Ottawa
2009 – ...	Elected member of the Amphibians and Reptiles subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)

2008	Member, hiring committee for 2 regular faculty positions, Department of Biology, University of Ottawa
2008 – 2010	Faculty of Science representative on the University Animal Care Committee and member of the ACC Protocol Review Committee
2008 – 2010	Évaluateur pour les concours de bourses B1/B2 du comité 02C (Biologie Animale et Médecine vétérinaire) du Fonds Québécois de la Recherche sur la Nature et les Technologies
2006 – 2009	Assistant Director, Environmental Science program, Faculty of Science, University of Ottawa
2006 – 2008	Member of the Committee on Academic Standing, Faculty of Science, University of Ottawa
2005 – 2008	Member, Animal Care and Veterinary Services Advisory Committee, University of Ottawa
2005 – ...	Associate Editor for Ecoscience - Rédacteur adjoint pour Écoscience
2005	Member, hiring committee for 4 regular faculty positions, Department of Biology, University of Ottawa
2004 – 2010	Chair, University of Ottawa Day Committee, Department of Biology, University of Ottawa
2003 – 2005	Member, Graduate Studies Committee, Department of Biology, University of Ottawa
2003 – ...	Member, Faculty of Science Council, University of Ottawa
2003 – 2008	Member, Committee for the Administration of NSERC Funds for the Indirect Costs of Research, Department of Biology, University of Ottawa
2002 – 2005	Executive Member, Snake and Lizard Advisory Group, Ontario Ministry of Natural Resources
1999 – 2005	Secretary, Black Ratsnake Recovery Team, COSEWIC

1999 – ... Referee for peer-reviewed journals: American Midland Naturalist, American Naturalist, Behavioral Ecology and Sociobiology, Biological Conservation, Biological Journal of the Linnean Society, Biology Letters, Canadian Field-Naturalist, Canadian Journal of Zoology, Conservation Biology, Conservation Ecology, Copeia, Ecography, Ecology, Écoscience, Ethology, Evolutionary Ecology, Herpetologica, Herpetological Review, Integrative and Comparative Biology, Journal of Applied Ecology, Journal of Animal Ecology, Journal of Avian Biology, Journal of Evolutionary Biology, Journal of Experimental Biology, Journal of Herpetology, Journal of Tropical Ecology, Landscape Ecology, Molecular Ecology, Oecologia, Oikos, Physiological and Biochemical Zoology, Southwestern Naturalist

Referee for funding agencies: NSERC, NSF

External thesis examiner: Brock University (MSc 2007), Carleton University (MSc 2005), Carleton University (PhD 2008), University of Otago (PhD 2009), University of Sydney (PhD 2010), Université Laval (PhD 2010), Nelson Mandela National University (PhD 2010)

Graduate program review: Laurentian University (MSc 2010)

Tenure & promotion evaluation: Université du Québec à Montréal (promotion 2011), Ohio University (promotion 2011)

ÉTUDIANTS EN SPÉCIALISATION ET DIPLÔMÉS - HONOURS AND GRADUATE STUDENTS

2012 – ... Halliday W. BSc (Lakehead), MSc (Lakehead). PhD working title: fitness consequences of habitat selection.

2012 – ... Slevan-Tremblay. BSc (Ottawa). BSc working title: Parasitism and mercury load in turtles.

2011 – 2012 Lacroix M. BSc (Ottawa). BSc: Do Blanding's turtles in poor quality habitats experience reduced immunocompetence and increased parasitaemia?

2011 – 2012 Proulx C. BSc (Ottawa). BSc: Are roads a barrier to movement in Blanding's turtles (*Emydoidea blandingii*)?

2011 – ... Cairns N. BSc (Brandon). MSc working title: Population effects of fisheries bycatch on freshwater turtles. (co-supervised by S Cooke, Carleton). Scholarship holder.

2011 – ... Stoot L. BSc (Lakehead). MSc working title: Individual effects of fisheries bycatch on freshwater turtles. (co-supervised by S Cooke, Carleton).

2011 – ... Châteauvert J. BSc (McGill). MSc working title: Mercury accumulation in freshwater turtles.

2010 – 2011	Hanna D. BSc (Ottawa). BSc: Singing higher to be heard: the effect of anthropogenic noise on red-winged blackbird song. Scholarship holder.
2010 – 2012	Thomasson V. BSc (McGill). MSc: Habitat suitability modelling for the eastern hog-nosed snake, *Heterodon platirhinos*, in Ontario.
2010 – 2012	Fortin G. BSc (Laval). MSc: Can landscape composition predict movement patterns and site occupancy by Blanding's turtles? A multiple scale study in Québec, Canada. Scholarship holder.
2010 – 2012	El Balaa R. BSc (Ottawa). MSc: Effect of predator diet on predator-induced changes in life history and performance of anuran larvae. Scholarship holder.
2010 – 2012	Banger N. BSc (Queen's). MSc: Consequences of multiple paternity for female fitness in an Ontario population of northern map turtles, *Graptemys geographica*. (co-supervised by S Lougheed, Queen's). Scholarship holder.
2009 – 2011	Larocque S. BSc (Guelph). MSc: Occurrence and mitigation of freshwater turtle bycatch and mortality associated with inland commercial hoop net fisheries. (co-supervised by S Cooke, Carleton). Scholarship holder.
2009 – 2011	Robson L. BSc (Western). MSc: The spatial ecology of eastern hognose snakes (*Heterodon platirhinos*): habitat selection, home range size, and the effects of roads on movement patterns.
2009 – 2010	Peet-Paré C. BSc (Ottawa). BSc: Nest-site selection in eastern hognose snakes (*Heterodon platirhinos*). Scholarship holder.
2009 – 2010	Reilly S. BSc (Ottawa). BSc: Painted turltes (*Chrysemys picta*) may not flee earlier when chronically stressed.
2009 – 2010	Graham J. BSc (Ottawa). BSc: Thermal ecology of Blanding's Turtles (*Emydoidea blandingii*) on Grenadier Island: the influence of thermal quality of the environment on habitat selection.
2009 – 2010	Campeau-Devlin J. BSc (Ottawa). BSc: Le comportement d'alimentation des chauves-souris n'est pas sensible au risque de prédation.
2009 – 2010	Ceillier I. BSc (Ottawa). BSc: Is emergence after hibernation of the black ratsnake (*Elaphe obsoleta*) triggered by a thermal gradient reversal?.
2008 – 2009	El Balaa R. BSc (Ottawa). BSc: Anti-predatory behaviour of wild vs. captive freshwater angelfish, *Pterophyllum scalare*. Scholarship holder.
2008 – 2009	Reshke N. BSc (Ottawa). BSc: Factors affecting leech parasitism on four turtle species in St. Lawrence Islands National Park.
2008 – 2009	Marcil Ferland D. BSc (Ottawa). BSc: Geometric morphometrics offer insight on the intersexual differences in allometric coefficients of bite force in the northern map turtle (*Graptemys geographica*).
2008 – …	Juneau V. BSc (Ottawa). PhD working title: Effect of stress on condition and parasitism in painted turtles. Scholarship holder.

2008 – 2010 Millar C. BSc (Ottawa). MSc: Spatial ecology and movement patterns of Blanding's turtles in St. Lawrence Islands National Park. Scholarship holder.

2007 – 2008 Picard G. BSc (Ottawa). BSc: Does thermal quality of the environment affect habitat selection by musk turtles (*Sternotherus odoratus*)?

2007 – 2011 Row JR. BSc (Queen's). MSc (Ottawa). PhD: Origins of genetic variation and population structure of foxsnakes across spatial and temporal scales. (co-supervised by S Lougheed, Queen's). Scholarship holder.

2006 – 2010 Lelièvre H. Master et DÉS (Paris 6). PhD: Stratégies de thermorégulation chez deux colubridés sympatriques: la couleuvre verte et jaune *Hierophis viridiflavus* et la couleuvre d'esculape *Zamenis longissimus*; une approche intégrée de la physiologie à la démographie. (co-dirigé par O Lourdais, CNRS CÉBC).

2006 – 2009 Plummer A. BSc (Queen's). MSc: Thermal preference and the effects of food availability on components of fitness in the bearded dragon, *Pogona vitticeps*.

2006 – 2007 Elgee KE. BSc (Ottawa). BSc: Sexual size dimorphism in garter snakes (*Thamnophis sirtalis*), water snakes (*Nerodia sipedon*), and black ratsnakes (*Elaphe obsoleta*).

2006 – 2007 Patterson LD. BSc (Ottawa). BSc: The effect of constant vs. fluctuating incubation temperatures on the phenotype and fitness of black rat snake (*Elaphe obsoleta*) hatchlings. Scholarship holder.

2005 – 2006 Verly C. BSc (Ottawa). BSc: Does multiple paternity increase with female body size in the common map turtle (*Graptemys geographica*)?

2005 – 2006 Ben-Ezra E. BSc (Ottawa). BSc: A test of the thermal coadaptation hypothesis in the common map turtle (*Graptemys geographica*). Scholarship holder.

2005 – 2006 Gravel MA. BSc (Ottawa). BSc: Sexual size dimorphism and diet specialization in the common map turtle (*Graptemys geographica*).

2005 – 2008 Belleau P. BSc (Sherbrooke). MSc: Habitat selection, movement patterns, and demography of common musk turtles (*Sternotherus odoratus*) in southwestern Québec. (co-supervised by R Titman, McGill).

2005 – 2007 Carrière MA. BSc (Guelph). MSc: Movement patterns and habitat selection of common map turtles (*Graptemys geographica*) in St. Lawrence Islands National Park, Ontario, Canada.

2004 – 2009 Bulté G. BSc (UQTR). PhD: Sexual dimorphism in northern map turtles (*Graptemys geographica*): Ecological causes and consequences. Scholarship holder.

2003 – 2005 Bjorgan L. BSc (McMaster). MSc: Habitat use and movements of juvenile black ratsnakes (*Elaphe obsoleta*) and their conservation implications.

2003 – 2005 Row JR. BSc (Queen's). MSc: Thermal quality influences thermoregulation, behaviour, and habitat selection at multiple spatial scales in eastern milksnakes (*Lampropeltis triangulum*).

2003 – 2005 Edwards A. BSc (McGill). MSc: Using painted turtles (*Chrysemys picta*) to test the cost-benefit model of thermoregulation.

2003 – 2004	Nadeau P. BSc (Ottawa). BSc: The cost-benefit model of thermoregulation does not predict the thermoregulatory behaviour of lizards.

COURS SUPÉRIEURS - GRADUATE COURSES

Recent Advances in Biology
Advanced Field Behavioural Ecology

COURS DE BACCALAURÉAT - UNDERGRADUATE COURSES

Ecology of Amphibians and Reptiles
Applied Wildlife Ecology
Introduction to Tropical Ecosystems
Animaux: formes et fonctions
Biologie de la conservation des espèces
Comportement animal
Animal Behaviour
EVS seminar
University of Ottawa Coordinator, Ontario Universities Program in Field Biology

SUBVENTIONS DE RECHERCHE - RESEARCH GRANTS

2012	6 500 $	**Canadian Wildlife Federation:** Sub-lethal consequences of freshwater turtle interactions with commercial fishing gear. Co-PI: S Cooke (Carleton)
2011 – 2013	65,000 $	**Parks Canada Species at Risk:** Fate of mercury in the Rideau Canal and its uptake by turtles. Co-PIs: L Campbell (Queen's) and G Bulté (Carleton)
2011 – 2013	50,000 $	**Ontario Ministry of Natural Resources Species at Risk:** Reducing bycatch of at risk turtles in freshwater commercial fisheries. Co-PI: S Cooke (Carleton)
2011	23,000 $	**Canadian Wildlife Federation:** Reducing bycatch of at risk turtles in freshwater commercial fisheries. Co-PI: S Cooke (Carleton)
2010	2000 $	**Community Fisheries and Wildlife Involvement Program:** Construction of basking traps for monitoring threatened turtles in Lake Opinicon.
2010	29,500 $	**NSERC Research Tools and Instruments:** Field vehicle
2010	16,000 $	**Canadian Wildlife Federation:** Habitat selection in hognose snakes.

2010	14,000 $	**Canadian Wildlife Federation:** Reducing bycatch of at risk turtles in freshwater commercial fisheries. Co-PI: S Cooke (Carleton)
2009	21,200 $	**Habitat Stewardship Program:** A model approach to habitat restoration and protection: Essex County & Chatham-Kent foxsnakes. Co-PIs: S Lougheed & J Row (Queen's)
2009	2700 $	**Community Fisheries and Wildlife Involvement Program:** Construction of basking traps for monitoring threatened turtles in Lake Opinicon.
2009	30,000 $	**WWF Species at Risk Research Fund for Ontario:** Evaluation of at risk turtle bycatch associated with inland commercial fisheries in eastern Ontario. Co-PI: S Cooke (Carleton)
2009	26,000 $	**WWF Species at Risk Research Fund for Ontario:** Habitat suitability, critical habitat, and demography of eastern Hog-nosed Snakes (*Heterodon platirhinos*) in Ontario.
2009 – 2012	65,000 $	**Parks Canada Species at Risk:** Habitat suitability, critical habitat, and demography of eastern Hog-nosed Snakes (*Heterodon platirhinos*) in Ontario.
2008 – 2012	147,750 $	**NSERC Discovery Grant:** Behavioural and physiological ecology of reptiles.
2007 – 2009	195,000 €	**Agence Nationale de la Recherche (France):** Impact of climate change on terrestrial ectotherms. Co-PI: O Lourdais (CNRS)
2006 – 2008	284,400 $	**NSERC Major Facilities Access Grant:** Queen's University Biological Station. PI: B Tuft (Queen's)
2006 – 2007	12,000 $	**Ontario Ministry of Natural Resources Species at Risk:** Movement patterns and habitat use in stinkpot and map turtles.
2005	17,000 $	**Habitat Stewardship Program:** Cottage lot securement for the protection of a black ratsnake hibernaculum.
2005 – 2006	36,000 $	**WWF Endangered Species Recovery Fund:** Repatriation of massasaugas in the Ojibway Prairie Provincial Nature Reserve. (declined)
2005	1,600 $	**Canadian Wildlife Federation:** Quantification of predation on zebra mussels by map turtles with stable isotopes.
2004	350,383 $	**Canada Foundation for Innovation / Ontario Innovation Trust:** Thermal ecology field and laboratory facility.
2004 – 2005	41,000 $	**Interdepartmental Recovery Fund:** Eastern ratsnake demographic modelling and critical habitat identification.
2004 – 2007	181,000 $	**Parks Canada Species at Risk:** Stinkpot and map turtle critical habitat idendification.
2003 – 2005	242,100 $	**NSERC Major Facilities Access Grant:** Queen's University Biological Station. PI: R Robertson (Queen's)

2003 – 2007	125,000 $	**NSERC Discovery Grant:** Thermal ecology of reptiles.
2003 – 2007	14,300 $	**Community Fisheries and Wildlife Involvement Program:** Construction of permieter fences around communal hibernacula for population monitoring of the threatened black ratsnake.
2002	80,000 $	**University of Ottawa:** Start-up Funds
2002 – 2003	32,000 $	**WWF Endangered Species Recovery Fund:** Artificial nests designed to enhance nesting success of black rat snakes. Co-PI: P Weatherhead (Illinois)
2001 – 2007	62,500 $	**Parks Canada Species at Risk:** Long-term monitoring of black rat snakes.
2001 – 2005	29,500 $	**Ontario Ministry of Natural Resources Species at Risk:** Long-term monitoring of black rat snakes.
1998	5,000 $	**Canadian Wildlife Federation:** Movement patterns and habitat use in black rat snakes.

ARTICLES - PUBLICATIONS

1. Colotelo AH, Raby GD, Hasler CT, Haxton TJ, Smokorowski KE, **Blouin-Demers G** & Cooke SJ. 2013. Northern pike bycatch in an inland commercial hoop net fishery: effects of water temperature and net tending frequency on injury, physiology, and survival. Fisheries Research, in press.
2. Robson LE & **Blouin-Demers G**. 2013. Does the eastern hognose snake (*Heterodon platirhinos*) avoid crossing roads? Copeia, in press.
3. Bulté G, Germain RR, O'Connor CM & **Blouin-Demers G**. 2013. Sexual dichromatism in the northern map turtle. Chelonian Conservation and Biology, in press.
4. LeDain MRK, Larocque SM, Stoot L, Cairns N, **Blouin-Demers G** & Cooke SJ. 2013. An assessment of strategies for facilitating recovery of freshwater turtles exhausted from submergence in fishing nets using blood physiology and reflex impairment. Chelonian Conservation and Biology, in press.
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ARTICLES PRÉSENTÉS - PAPERS PRESENTED

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2. Cairns N, **Blouin-Demers G** & Cooke SJ. 2012. Reduction of turtle bycatch by means of gear modification in a small-scale inland commercial fishery. World Congress of Herpetology, University of British Columbia.
3. Stoot L, **Blouin-Demers G** & Cooke SJ. 2012. Consequences of incidental capture of freshwater turtles in commercial fisheries. World Congress of Herpetology, University of British Columbia.
4. Juneau V & **Blouin-Demers G**. Cocoa butter injections, but not silastic implants, of corticosterone can be used to mimic chronic stress in a free- living ectotherm, the painted turtle. World Congress of Herpetology, University of British Columbia.
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57. Prior KA, **Blouin-Demers G** & Weatherhead PJ. 1999. Sampling biases in black rat snake populations. Canadian Amphibian and Reptile Conservation Network Conference, Canadian Wildlife Service.
58. **Blouin-Demers G**, Prior KA & Weatherhead PJ. 1999. Démographie comparée de la couleuvre obscure. Congrès de la Société Québécoise pour l'Étude Biologique du Comportement, Université Laval.

59. **Blouin-Demers G**, Prior KA & Weatherhead PJ. 1998. Variation et patrons d'émergence chez la couleuvre obscure. Congrès de la Société Québécoise pour l'Étude Biologique du Comportement, Concordia University.
60. **Blouin-Demers G**, Prior KA & Weatherhead PJ. 1998. Variation in spring emergence by black rat snakes. Joint Meeting of Ichtyologists and Herpetologists, University of Guelph.
61. **Blouin-Demers G**. 1997. Patterns of habitat use and movement in relation to thermoregulatory requirements in the black rat snake (*Elaphe obsoleta*). Snake Ecology Group Conference, University of Texas at Tyler.

CONFÉRENCES INVITÉES - INVITED SEMINARS

1. **Blouin-Demers G**. 2012. Going beyond descriptive habitat selection studies: making the link with fitness is paramount in a conservation context. Invited symposium presentation for the World Congress of Herpetology, University of British Columbia.
2. **Blouin-Demers G**. 2010. Thermorégulation, utilisation de l'habitat et conservation chez les reptiles. Conférences de Biologie, Université Laval.
3. **Blouin-Demers G**. 2009. Conserving freshwater turtles in the St. Lawrence ecosystem. Seminar Series, St. Lawrence River Institute of Environmental Sciences.
4. **Blouin-Demers G**. 2009. Fitness consequences of habitat selection in reptiles and their implications for conservation. Biology Seminar Series, State University of New York at Potsdam.
5. **Blouin-Demers G**. 2008. Habitat use is linked to components of fitness through the temperature-dependence of performance in reptiles. Head Office Seminar Series, Parks Canada.
6. **Blouin-Demers G**. 2008. Écologie fonctionnelle et dimorphisme sexuel. Centre National de la Recherche Scientifique, Centre d'Études Biologiques de Chizé, France.
7. **Blouin-Demers G**. 2008. Habitat use is linked to components of fitness through the temperature-dependence of performance in ratsnakes and map turtles. Invited symposium presentation for the Joint Meeting of Ichtyologists and Herpetologists, McGill University.
8. **Blouin-Demers G**. 2008. Physiological ecology of reptiles. Biology Seminar Series, Western Kentucky University.
9. **Blouin-Demers G**. 2006. Les reptiles démystifiés / The fascinating world of reptiles. Holiday Lecture Series, Faculty of Science, University of Ottawa.
10. **Blouin-Demers G**. 2006. The sexual serpent and other scaly things. Pub talk for the Ottawa-Carleton Institute of Biology Research Days, University of Ottawa.
11. **Blouin-Demers G**. 2005. Thermorégulation, utilisation de l'habitat et aptitude chez les reptiles. Conférences de Biologie, Université de Sherbrooke.
12. **Blouin-Demers G**. 2005. Écologie thermique des reptiles. Conférences de Biologie, Université du Québec à Montréal.
13. **Blouin-Demers G**. 2005. Thermoregulation, habitat use, and fitness in reptiles. Plenary address for the Canadian Amphibian and Reptile Conservation Network Conference, Canadian Wildlife Service Ottawa.
14. **Blouin-Demers G** & Weatherhead PJ. 2005. From thermoregulation-driven habitat selection to fitness in black ratsnakes. Invited symposium presentation for the Wildlife Society Conference, University of Wisconsin.
15. **Blouin-Demers G**. 2004. Nest selection and sexual selection in ratsnakes. Biology Seminar Series, Carleton University.
16. **Blouin-Demers G**. 2004. Nest selection and sexual selection in ratsnakes. Biology Seminar Series, Laurentian University.
17. **Blouin-Demers G**. 2003. Reproductive ecology of the black ratsnake. Ecology, Evolution, and Behaviour Seminar Series, Queen's University.

18. **Blouin-Demers G**. 2003. Écologie de la reproduction chez la couleuvre obscure. Conférences de Biologie, Université du Québec à Trois-Rivières.
19. **Blouin-Demers G** & Weatherhead PJ. 2003. Insights from 25 years of research on black ratsnakes in eastern Ontario. Invited symposium presentation for the Snake Ecology Group Conference, University of Southern Illinois.
20. **Blouin-Demers G**. 2003. Écologie de la reproduction chez la couleuvre obscure. Conférences de Biologie, Université de Sherbrooke.
21. **Blouin-Demers G**. 2002. Living on the edge is hot: thermoregulation and habitat use by snakes. Biology Seminar Series, University of Indiana – Purdue University.
22. **Blouin-Demers G**. 2001. Habitat use and its links to thermoregulation in black ratsnakes. Biology Seminar Series, University of Toronto at Scarborough.
23. **Blouin-Demers G**. 2001. Sélection d'habitat et ses liens à la thermorégulation chez la couleuvre obscure. Conférences de Biologie, Université du Québec à Montréal.
24. **Blouin-Demers G**. 2001. Habitat use and its links to thermoregulation in snakes. Keynote address for the Meeting of the St. Lawrence Valley Natural History Society, McGill University.
25. **Blouin-Demers G**. 2001. Habitat use and thermal ecology of black rat snakes at the northern extreme of their distribution. Biology Seminar Series, McMaster University.
26. **Blouin-Demers G**. 2001. Living on the edge is hot: thermoregulation and habitat use by black rat snakes. Program in Ecology & Evolutionary Biology Seminar Series, University of Illinois.
27. **Blouin-Demers G**. 2001. Population biology of black rat snakes: sampling biases, comparative demography, population trends & synchrony. Eco-Lunch Seminar Series, University of Illinois.
28. **Blouin-Demers G**. 2000. Habitat use and thermal ecology of black rat snakes in a thermally challenging environment. Biology Seminar Series, Carleton University.
29. **Blouin-Demers G**. 2000. Population biology of black rat snakes. Ecology, Evolution, and Behaviour Seminar Series, Queen's University.
30. **Blouin-Demers G**. 1997. Thermal ecology of the black rat snake in eastern Ontario: a test of the co-adaptation hypothesis. Ecology, Evolution, and Behaviour Seminar Series, Queen's University.

QUALIFICATIONS PARTICULIÈRES - SPECIAL QUALIFICATIONS

- Certification de plongeur élémentaire de la fédération québécoise des activités subaquatiques (1993)
- Permis de conduire pour minibus de 24 passagers (SAAQ classe 4B) / 24-passenger mini-bus driver's license (1995)
- Permis d'armes à feu possession et acquisition / Firearms Licence Possession and Acquisition (1995, 2000, 2007)
- Second Degree Black Belt from the International Taekwon-Do Federation (1997)
- Ontario Professional Chainsaw Operator (2001)
- Carte de conducteur d'embarcation de plaisance / Pleasure Craft Operator Card (2003)
- Cours de sécurité de base des petits bâtiments autres que les embarcations de plaisance (FUM A3) / Small Non-Pleasure Vessel Basic Safety course (MED A3) (2004)
- Secourisme avancé en régions isolées Sirius / Sirius Advanced Wilderness First-Aid (2006, 2008, 2010)
- Introduction pour entraîneur de sport communautaire par le Programme national de certification des entraîneurs pour le ski de fond / Introduction to Community Coaching by the National Coaching Certification Program for cross-country skiing (2009)
- Entraîneur de sport communautaire par le Programme national de certification des entraîneurs pour le ski de fond / Community Coaching by the National Coaching Certification Program for cross-country skiing (2010 #1199310)
- Introduction pour entraîneur de compétition (terrain sec & neige) par le Programme national de certification des entraîneurs pour le ski de fond / Introduction to Competition Coaching (dryland and on-snow) by the National Coaching Certification Program for cross-country skiing (2012)

AUTRES ACTIVITÉS - OTHER ACTIVITIES

Mountaineering, ice and rock climbing, mountain and road biking, cross-country skiing, trail running, scuba diving, wood working.

MÀJ - Updated: mardi 28 février 2012

APPENDIX B

LETTERS OF PEER REVIEW

The University of Georgia

(803) 725-2472
FTS 239-2472
FAX 803-725-3309

Savannah River Ecology Laboratory

Drawer E
Aiken, SC 29802

Mr. Shawn Taylor
Project Manager
Dillon Consulting Limited
1155 North Service Road West Unit 14
Oakville, Ontario, L6M 3E3

15 January 2013

I was asked by Dillon Consulting Limited to review a previous draft of the "South March Highlands Blanding's Turtle Conservation Needs Assessment" (BTCNA) and provide a letter with comments on the biology and ecology of Blanding's Turtles in relation to the report. I was not asked to comment on the Population Viability Analyses, but I did make some observations on the management scenarios developed from those models. My assessment of the situation at South March Highlands (SMH) was made without the benefit of a site visit.

My expertise was gained primarily from 33 continuous years (1975-2007) of research on three species of turtles (Blanding's Turtles, Painted Turtles and Snapping Turtles) on the University of Michigan's E. S. George Reserve. Areas of study on Blanding's Turtles include: 1) evolution of life-histories, 2) the importance of indeterminate growth to life histories, 3) aging and the expression of actuarial senescence, 4) reproductive and nesting ecology, 5) spatial biology and core area protection, 6) genetic connectivity among population sub-units, and 7) male reproductive success. I have published 13 papers on Blanding's Turtles (including two conservation assessments) and have one on spatial genetics in review, one on male reproductive success in full draft, and one on reproductive frequency in preparation.

I found the recent draft of the BTCNA to be comprehensive in covering the situation at South Marsh Highlands to date and the proposed management scenarios for Blanding's Turtles cover all important issues. The work on the design, construction and monitoring of the 'eco-passages' in the Terry Fox Drive extension was commendable and further monitoring should provide data useful in future designs. The basic data on the population status and spatial biology of the South Marsh Highland area collected over the past few years provides baseline support for the issues and management recommendations discussed in the report.

My comments on the BTCNA are in two major sections, first is a general statement about Blanding's Turtles at South Marsh Highlands and how their life histories and biology relate to overall conservation concerns. Second are general and specific comments organized around the management objectives listed beginning on page 48 of the BTCNA.

General statement of the problems for Blanding's Turtles in the South March Highlands and in many other areas where they are of conservation concern.

Core areas and conservation. - - The concept of core area (the area required for organisms to successfully complete their life cycle) is important for landscape level conservation planning that is needed at the SMH area. The concept is of particular importance for the conservation of semi-aquatic organisms such as Blanding's Turtles that have core areas that include permanent and ephemeral wetlands and surrounding terrestrial areas. Maintaining the physical and ecological integrity of the core areas of Blanding's Turtles requires an appreciation of the importance of ephemeral wetlands and terrestrial areas, and knowledge of their life-histories, spatial biology, and the behaviors that help define the underlying functions and temporal aspects of habitat use.

To successfully maintain Blanding's Turtle populations, four habitats have to be included in a protected area: 1) resident wetlands, 2) ephemeral wetlands, 3) riparian corridors, and 4) an adequate number of terrestrial nesting areas of reasonable size. Blanding's Turtles have been documented to have long-term fidelity (> 40 years) to a single resident wetland and both sexes of adults make relatively long-distance terrestrial movements to visit (e.g., find mates, and exploit seasonal resources) ephemeral wetlands. In addition, females make long-distance movements to nest in well drained soils in open areas that receive sunlight for much of the day (in Michigan, embryos in completely shaded nests always failed to fully develop). In Michigan, females used from 1- 6 nesting areas in different years, some separated by up to 1 km. Loss of nesting areas (such as KNL Phase 8 lands) and previously visited ephemeral wetlands will certainly cause individuals to move to new areas and that will increase risks associated with movements, particularly movements in new areas. Risks associated with the extensive terrestrial movements of Blanding's Turtles are at odds with the high adult survivorships required to maintain stable populations, particularly in areas that overlap with human development and the associated increased roads and traffic that will occur in the SMH area.

The size of protection zones should be determined from documentation of biologically based core areas of semi-aquatic species. A 33 year study of Blanding's Turtle ecology and spatial biology on the E. S. George Reserve in southeastern Michigan documented that a 2.0 km protection zone around the residence wetlands was required to protect all resident females that nested on the 525 ha protected area, and that approximately 50% of resident females nested outside of the protected area in at least one year of the study (Congdon et al. 2011a). Based on those results, the 400 ha protected area at SMH will probably not be sufficient to encompass all movements and nesting areas used by Blanding's Turtle females. Establishment of inadequate protected areas will allow the integrity of actual core areas to degrade while giving the appearance of protecting wetland communities (see Congdon et al. 2011a and citations therein).

Long-term fidelity to residence wetlands suggests that there are substantial costs associated with changing residence (e.g., increased risks of injury or death and reduced efficiencies in finding and harvesting seasonal resources). In small and isolated populations like the one found at SMH, fidelity to residence wetland contributes to spatial variation in allele frequencies that can contribute to the probability of loss of genetic diversity. Because Blandings Turtles have long reproductive lifetimes, fidelity to residence wetlands increases the probability of within generation inbreeding (between siblings) and intergenerational inbreeding (between parents and offspring) that will also contribute to loss of genetic diversity within the population. In addition, fidelity to a single residence wetland substantially reduces the probability of genetic exchange resulting from immigration or emigration of adults, the most often documented mechanism promoting genetic connectivity between sub-units of metapopulations and between populations. At SMH fidelity to residence will also result in increased risks for adults remaining in wetlands impacted by development.

Blanding's Turtle life-history and conservation. - - Compared to shorter-lived organisms, the suite of co-evolved life-history traits of Blanding's Turtles pose additional problems for conservation efforts. The life-history trait values of Blanding's Turtles include: 1) high adult survivorship, 2) potentially long reproductive lifespans, 3) low nest (embryo) survivorship, 4) high average juvenile survivorship, 5) delayed attainment of sexual maturity (14-21 years), 6) and low annual fecundity. Reproductive output of females (clutch size and clutch frequency) and parental investment (i.e., egg and offspring size) primarily increase with age rather than body size and that contributes to older females being valuable for population persistence.

An important conservation issue for Blanding's Turtle is that delayed maturity requires high average juvenile survivorship (from yearling to age at maturity) to result in adequate recruitment of juveniles into the adult population (i.e., replace the adults that die). In most cases the smaller body sizes of juveniles (compared to adults) increases risk of being killed by predators and therefore it very difficult to increase the survivorship of juveniles, particularly if core habitats are degraded or lack all components.

Comments specific to the Management Objectives of the BTCNA.

The BTCNA management objectives address the major issues related to the conservation of Blanding's Turtles at SMH.

Objectives for reducing direct and indirect causes of mortality of Blanding's Turtles. - -

1. A lot of thought went into the "Wildlife Culvert Crossings" and associated fencing and a lot can be learned from efforts to determine culvert characteristics (e.g., lighting and substrates) that will promote use by Blanding's Turtles and other organisms. Because fencing material and its configuration may pose a trap hazard for different sized animals, the areas around culvert opening should be monitored and periodically searched for dead animals.
2. As development within the radius of Terry Fox Drive is completed, I think that site fidelity to residence wetlands will result in continued exposure to increased risks rather than result in adults moving to less impacted wetlands.
3) Poaching for the pet trade will remain a serious and a particularly deleterious problem for Blanding's Turtle populations since experienced poachers can remove a substantial number of adults from the population in a relatively short time. Poaching is particularly detrimental to small populations because removal any number of adults may represent a large proportion of reproductive females and removal is a population equivalent of death. The proposed use of publicity to make poachers aware of risks and penalties for poaching activities will probably reduce risks of loss of turtles.
4) Using metal cages should not be part of protocols to protect nests because metal cages apparently affect magnetic fields around the embryos and hatchlings in nests (Irwin et al. 2004). At present it is not known whether hatchling freshwater turtles use a sun or magnetic compass to maintain headings while dispersing from nests when target habitats are not available (Pappas et al. 2009; Congdon et al. 2011b; Iverson et al. 2011).

Transplantation of adult turtles, nest protection, and head starting. - - On page 28 of the BTCNA three potential management strategies are suggested based on the Population Viability Analyses.

"First, if two adult female turtles every 5 years are removed from the SMH-C sub-population and transplanted in the KW subpopulation, the action prevents decline in the KW sub-population, but causes the SMH-C subpopulation to decline (an undesirable outcome)."

> An underlying assumption is that transplanted adults will remain in a new residence wetland. I have reservations that adult turtles would remain in a new area; however, I know of no data pro or con on translocation of adult Blanding's Turtles.

"Second, the next management strategy modeled was to protect nests found in the area. The outcome of the nest protection scenario suggests a positive outcome, as both the SMH sub-populations grow and the KW sub-population remains unchanged, compared to the Baseline model."

Protecting nests is not difficult (but see above comment about using metal cages) but locating nests requires a substantial effort.

"Third, if a head start program is implemented (eggs hatched and young reared for 2 years in captivity prior to release) both SMH sub-populations increase in size while the KW sub-population also shows positive growth."

Head starting turtles is difficult and expensive, particularly if such an endeavor must continue over many years. Harvesting eggs requires nests to be located, gravid females to be captured and induced to lay eggs with hormones, or gravid females have to be held in enclosures until they lay eggs. I am not sure females will voluntarily lay eggs in captivity (in Michigan, 12 female Painted Turtles were moved to outdoor ponds with adjacent nesting areas after the nesting season, none laid eggs the following year). After eggs are obtained, incubation temperatures and moisture content of egg incubation substrates have to be closely monitored because they influence the sexes and quality of hatchlings. After that, hatchlings reared for 2 years.

Conclusions. - - I fully agree with the summary paragraph on p. 67.

"In addition, the recommendations made to curtail further habitat loss, degradation and other threats to the SMH Blanding's turtle should be explored prior to any further urban development outside of the Terry Fox Drive planning area. The conservation and protection of this species at risk requires collaboration, sustainable funding, innovation and enforcement by government, landowners, researchers, non-governmental organizations and the public."

However, I think that some curtailment to development inside the Terry Fox Drive planning area may also be required to reduce the severity of influence on resident turtles there.

The single and most important issue for South March Highlands (SMH) Blanding's Turtles is the amount of protected land and a commitment to managing all four habitats listed above. The paragraph on page 3 of the BTCNA describing the situation at SMH is not encouraging.

"Overall, the South March Highlands has experienced multiple, cumulative effects of urbanization, including direct loss of habitat, fragmentation, and alteration of drainage patterns. These impacts are projected to continue in the future, resulting in the permanent loss, isolation or degradation of approximately half of the natural landscape. The remaining 400 ha of Conservation Forest will be largely bound by urban development, arterial and collector roads, and estate lot developments. At present, a semi-natural landscape connection exists between the Conservation Forest and the floodplain of the Carp River. However, that connection would be lost if development were to occur in the newly approved urban expansion study area".

Based on the situation at SMH and the results from my three decades of study, I am skeptical that a stable Blanding's Turtle population can be maintained on the remaining 400 ha of the SMH Conservation Forest. Successful conservation programs for Blanding's Turtle and other semi-aquatic organisms require broad-scale protection of wetlands of all sizes and protection of substantial areas of terrestrial habitats. I recognize that further work is necessary to identify critical Blanding's Turtle habitats in the SMH area. Surveys identifying critical nesting areas and their qualities will be important to maintain adequate recruitment into the SMH population. Identifying patterns of use of riparian corridors for movement within and adjacent to protected areas are desperately needed to understand how well existing protected lands are adequate to protect the existing Blanding' Turtle population.

Acquiring key terrestrial areas suitable for nesting, overland access routes to those nesting areas, and additional riparian corridors connecting SMH to other populations or sub-populations will substantially reduce the need for long-term and expensive conservation interventions (e.g., wetland construction, nesting area construction, nest protection, head starting). As stated the BTCNA abstract.

> "Blanding's Turtle conservation and management in the SMH must remain a priority of the City of Ottawa and other stakeholders to help preserve this threatened, unique species. Should the objectives, targets and recommendations of the BTCNA not be implemented, the Blanding's Turtle in the SMH will continue to face threats to their core habitats, survivability and population abundance".

Over time, the cost of acquiring critical additional land areas would be discounted by reductions in intensive conservation management costs. Because interest in maintaining long-term commitments to intensive conservation efforts often wane, acquiring critical habitats for protection will, in my opinion, have the highest probability of long-term success in promoting the persistence of the SMH Blanding' turtle population.

Sincerely,

Justin D. Congdon

Justin D. Congdon, Ph.D.
Professor Emeritus, University of Georgia Savannah River Ecology Laboratory

References

Irwin, W.P., A.J. Homer, K.J. Lohmann. 2004. Magnetic field distortions produced by protective cages around sea turtle nests: unintended consequences for orientation and navigation. Biological Conservation 118:117-120.

Iverson, J.B., R.L. Prosser, and E.N. Dalton. 2009. Orientation in juveniles of a semiaquatic turtle *Kinosternon flavescens*. Herpetologica 65:237–245.

Pappas, M.J., J.D. Congdon, B.J. Brecke, and J.D. Capps. 2009. Orientation and dispersal of hatchling Blanding's turtles (*Emydoidea blandingii*) from experimental nests. Canadian Journal of Zoology 87:755–766.

Congdon, J.D., O.M. Kinney, and R.D. Nagle. 2011a. Spatial Ecology and Core Area Protection of Blanding's Turtle (*Emydoidea blandingii*). Canadian Journal Zoology, 89:1098-1106

Congdon, J.D., M.J. Pappas, B.J. Brecke, and J.D. Capps. 2011b. Conservation implications of initial orientation of naïve hatchling Snapping Turtles (*Chelydra serpentina*) and Painted turtles (*Chrysemys picta belli*) dispersing from experimental nests. Chelonian Conservation and Biology 10:42–53.

11 January 2013

Review of the *South March Highlands Blanding's Turtle Conservation Needs Assessment* by Dillon Consulting

Preface

Blanding's turtles (*Emydoidea Blandingii*) are semi-aquatic turtles that are found in the eastern half of North America at a latitudinal range corresponding roughly to that of the Great Lakes. In Canada, they are found primarily in Ontario and Québec, but a disjunct population also occurs in Nova Scotia. The designatable unit of the St. Lawrence/Great Lakes that occurs in Ontario and Québec is considered Threatened by the Committee on the Status of Endangered Wildlife in Canada as per the last species assessment conducted in May 2005. As such, this designatable unit is listed on Schedule 1 of the Canadian Species at Risk Act.

Blanding's turtles occur within the Ottawa city limits. Ongoing development in the city puts several populations in jeopardy. One such population occurs in the South March Highlands. In an effort to preserve this population of Blanding's turtles, the City of Ottawa has asked Dillon Consulting to prepare an assessment of its conservation needs. In the present document, I offer my review of this assessment entitled «*South March Highlands Blanding's Turtle Conservation Needs Assessment*». In March 2012, I have also provided a review of the document entitled «*Professional Services Proposal: Blanding's Turtle Conservation Management Plan*» by Dillon Consulting that served as the planning document for the current assessment.

Brief Qualifications

I have been conducting research on reptiles since 1995. My research areas are Evolutionary Ecology and Conservation Biology. Since 2000, I have published over 75 articles in peer-reviewed journals on the ecology of reptiles. Specifically in the context of this review, my graduate students and I have conducted two radio-telemetry studies of Blanding's turtles: one is St. Lawrence National Park, and one in Gatineau Park and adjacent lands. Thus far, these two studies have led to the following publications:

✤ Millar C. 2010. The spatial ecology of Blanding's turtles (*Emydoidea blandingii*): from local movement patterns, home ranges and microhabitat selection to Ontario-wide habitat suitability modeling. MSc Thesis, Department of Biology, University of Ottawa.

- Millar CS & Blouin-Demers G. 2011. Spatial ecology and seasonal activity of Blanding's turtles (*Emydoidea blandingii*) in Ontario, Canada. Journal of Herpetology 45: 370-378.
- Millar CS & Blouin-Demers G. 2012. Habitat suitability modelling for species at risk is sensitive to algorithm and scale: a case study of Blanding's turtle, *Emydoidea blandingii*, in Ontario, Canada. Journal for Nature Conservation 20: 18-29.
- Millar CS, Graham JP & Blouin-Demers G. 2012. The effects of sex and season on patterns of thermoregulation in Blanding's turtles (*Emydoidea blandingii*) in Ontario, Canada. Chelonian Conservation and Biology 11: 24-32.
- Fortin G, Blouin-Demers G & Dubois Y. 2012. Landscape composition weakly affects home range size in Blanding's turtles (*Emydoidea blandingii*). Écoscience 19: 191-197.
- Fortin G. 2012. Can landscape composition predict movement patterns and site occupancy by Blanding's turtles? A multiple scale study in Québec, Canada. MSc Thesis, Department of Biology, University of Ottawa.

Finally, I am a Full Professor in the Department of Biology at the University of Ottawa, and an elected member of the Amphibians, Reptiles & Turtles sub-committee of the Committee on the Status of Endangered Wildlife in Canada.

General Comments

In general, I found the assessment thorough and comprehensive. It was mostly easy to read, although several sentences were awkwardly written. I do have several suggestions for improvement, however. I detail these suggestions below.

I think population isolation needs to be addressed in more depth in the report. A strong case can be made that the long-term likelihood of survival of the South March Highlands Blanding's turlte population is near zero if it is completely isolated. This point is somewhat made on Page 11 and on Page 58, but a stronger case can and should be made early in the report. With an effective population size (i.e., reproductive individuals) probably around 100, the South March Highlands populations falls very short of being self-sustainable. The minimum effective population size that is necessary to avoid extinction has been estimated to range from about 500 to 5000 individuals.

- Lande R. 1995. Mutation and conservation. Conservation Biology 9: 782-791.
- Franklin IR & Frankham R. 1998. How large must populations be to retain evolutionary potential? Animal Conservation 1: 69-73.

Another point that I think should be addressed more thoroughly and early in the report is what we should consider to be the proper baseline. We have no information on what this population of Blanding's turtles was like before the City of Ottawa was created. What are the impacts that have occurred prior to the development of the area? Surely, the original population has been reduced as a result of habitat loss and habitat fragmentation. Data gathering only started a few years ago, a very long time after development started affecting this population. This issue is alluded to on the top of Page 11, but this is a very important point that deserves further discussion. In conservation, there is a realization that the baseline is shifting with each passing generation. If this trend continues, there is a real danger that we may consider the baseline to be much degraded ecosystems.

- Pauly D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10: 430.
- Papworth SK, Rist J, Coad L & Milner-Gulland EJ. 2009. Evidence for shifting baseline syndrome in conservation. Conservation Letters 2: 93-100.

Specific Comments

Page iii: The statement «The field research reported herein, however, is the first in-depth study conducted on an individual population in this region» is inaccurate if you consider Gatineau Park to be part of the Ottawa-Gatineau region. We have conducted an extensive radio-telemetry study as well as a population survey from 2008 to 2011 in the western section of Gatineau Park and adjacent lands. Two documents have already been published from this work.

- Fortin G, Blouin-Demers G & Dubois Y. 2012. Landscape composition weakly affects home range size in Blanding's turtles (*Emydoidea blandingii*). Écoscience 19: 191-197.
- Fortin G. 2012. Can landscape composition predict movement patterns and site occupancy by Blanding's turtles? A multiple scale study in Québec, Canada. MSc Thesis, Department of Biology, University of Ottawa.

Page iv: I agree that Objective 1 should be the top priority, and that part of Objective 2 (population monitoring) should be the next priority. Objectives 2 and 4 are partly redundant. I think Objective 2 should be about continued population monitoring, while Objective 4 should be about filling knowledge gaps both in terms of life history and habitat needs. I would keep Objective 3 about habitat protection. Objectives 5 and 6 are fine. Objective 7 should be clarified. The Species at Risk Act already affords legal protection of the species. In terms of critical habitat, this applies to federal lands only. The 'safety net' that is built into the Act, however, could theoretically be invoked to afford protection to the South March Highlands population of Blanding's turtles. In addition, as is explained on Page 3, the Endangered Species Act of Ontario also affords protection to the species and its habitats.

Page 3: The statement «... Old Carp Road. The latter road bisects the northern half of the South March Highlands, but because it is narrow and heavily forested on both sides it may not be a significant barrier to movement of Blanding's turtle» is unsubstantiated. The barrier effect of roads can occur in two ways: 1) animals avoid crossing the roads, or 2) animals attempt to cross the roads, but get hit by vehicles and die. In both cases, the effective dispersal is much reduced. In the second case, not only is effective dispersal reduced, but mortality augmented. Thus, the negative population effects of small forested roads that animals attempt to cross can sometimes be worse than those of large roads that animals do not attempt to cross. In the absence of strong data on both the propensity to cross various types of roads and on the risk of mortality while crossing these roads, it is premature to speculate that a small forested road is not a significant barrier.

Page 8: The Canadian range of the Blanding's turtle extends into Québec. This is actually mentioned at the bottom of Page 10. The range extent should be made clear here, as the connectivity of the South March Highlands population is most likely to be achieved through connections with the populations living on both sides of the Ottawa River to the north of the South March Highlands. In addition, while the studies by Congdon and colleagues do provide very valuable information on patterns of habitat selection and life history characteristics, additional studies have been conducted locally by our research group (see references above) and that of Jacqueline Litzgus at Laurentian University:

- Edge CB, Steinberg BD, Brooks RJ & Litzgus JD. 2010. Habitat selection by Blanding's Turtles (*Emydoidea blandingii*) in a relatively pristine landscape. Écoscience 17: 90-99.
- Paterson JE, Steinberg BD & Litzgus JD. 2012. Revealing a cryptic life-history stage: differences in habitat selection and survivorship between hatchlings of two turtle species at risk (*Glyptemys insculpta* and *Emydoidea blandingii*). Wildlife Research 39: 408-418.
- Edge CB, Steinberg BD, Brooks RJ & Litzgus JD. 2009. Temperature and site selection by Blanding's Turtles (*Emydoidea blandingii*) during hibernation near the species' northern range limit. Canadian Journal of Zoology 87: 825-834.

This body of work even includes the elusive juvenile life stages. The patterns of habitat selection documented in these local studies are likely to be more applicable to the South March Highlands population than those found by Congdon and colleagues in Michigan. I am very surprised that more references are not made to this body of work in this section.

Page 15: One cannot really expect to document evidence of effective dispersal (animals moving between distinct populations and successfully reproducing in their new population) via a radio-telemetry study. The rule of thumb in population genetics is that 1 to 10 effective migrants per generation is sufficient to maintain gene flow.

- Mills LS & Allendorf FW. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology 10: 1509-1518.

✤ Wang J. 2004. Application of the one-migrant-per-generation rule to conservation and management. Conservation Biology 18: 332-343.

Given that the generation time for Blanding's turtles is probably 15 to 20 years, it would still be unlikely to detect an effective migrant in a two-year mark-recapture and radio-telemetry study even if radio-transmitters were attached to all adults. Genetic tools are probably more appropriate than telemetry data to assess the current and past levels of genetic connectivity with neighbouring populations.

Page 20: Inbreeding would be reduced by maintaining connectivity with neighbouring populations. Again, I think this is a very important point.

Page 21: I am surprised that reference is made only to organic toxins in the first paragraph of the section on bioaccumulation. I would think mercury, which is inorganic, may be a prime candidate for bioaccumulation in turtles.

Page 22: I am surprised that habitat loss is not mentioned as a factor of endangerment in the first paragraph.

Page 22: In section 4.1 on Population Viability Analysis, I think it must be made crystal clear that making absolute predictions about extinction risk is a very shaky enterprise. As I indicated in my review of the initial proposal, PVA can be effectively used to compare various conservation scenarios, for instance:

✤ Row JR, Blouin-Demers G & Weatherhead PJ. 2007. Demographic effects of road mortality in black ratsnakes (*Elaphe obsoleta*). Biological Conservation 137: 117-124.
✤ Bulté G, Carrière MA & Blouin-Demers G. 2010. Impact of recreational power boating on two populations of northern map turtles (*Graptemys geographica*). Aquatic Conservation 20: 31-38.

Its use to make absolute predictions is, however, rightly critiqued. PVA is very sensitive to variation in input parameters. In addition, PVA requires input parameters that are unknown for most species, for instance age-specific survivorship from birth to adulthood. This is why many authors recommend that PVA be used to evaluate relative rather than absolute extinction risk.

✤ Ellner SP, Fieberg J, Ludwig D & Wilcox C. 2002. Precision of population viability analysis. Conservation Biology 16: 258-261.

I could not agree more with these authors: using PVA to make absolute predictions about the risk of extinction is a shot in the dark. My experience with PVA is that slight variation of some key input parameters (e.g., juvenile survival) within the range of our estimated values has a dramatic influence on the probability of persistence. Some allusion is made to this limitation is sections 4.1.1 and 4.1.5, but I think this information should figure prominently in section 4.1.

Page 23: The reality is that we have no idea whether the number of males present affects the population growth rate. Even if males are polygynous, they could be sperm limited. Although sperm are less costly to produce than eggs, they are not free. In the absence of a sufficient number of males, it is possible that some females are not inseminated. This is an entirely untested assumption. This comment also applies to Page 77.

Page 26: Translocation (a better word than transplantation) of adult reptiles has been shown to be a very poor conservation strategy. Adult reptiles frequently do not survive translocation events. I am thus unsure adult translocation should be envisioned.

- Reinert HK & Rupert RR. 1999. Impacts of translocation on behavior and survival of timber rattlesnakes, *Crotalus horridus*. Journal of Herpetology 33: 45-61.
- Sullivan BK, Kwiatkowski MA & Schuett GW. 2004. Translocation of urban Gila monsters: a problematic conservation tool. Biological Conservation 117: 235-242.

Page 36: It would be useful to describe briefly how habitat suitability is derived in the body of the report. As it turns out, I do not think this index can really be called habitat suitability (please see my last comment below). Also, it would also be useful to preface this section with a short explanatory paragraph on why this habitat suitability index was derived.

Page 39: The role of COSEWIC is to assign species to risk categories. The identification of critical habitat is actually the responsibility of recovery teams or government agencies.

Page 41: There is real danger in inferring the importance of movement corridors with, relative to the whole population, fairly scant telemetry data. As indicated above, not very much movement is necessary to maintain population connectivity. Thus, existing corridors that appear under utilized may in fact be important in maintaining long-term population connectivity.

Page 46: Please refer to my comments on the objectives presented for Page iv above. These comment apply equally here. In addition, I am unsure of the distinction between 2.1 and 2.2. They seem largely overlapping. I am unsure 4.2 is really relevant in the context of this assessment. What laws does 7.1 refer to? There are already a provincial law and a federal law that can both be used to protect Blanding's turtles and their habitat. The tools are in place, they need to be used.

Page 58: Given the limited dispersal ability of Blanding's turtles, and their propensity to use the same areas year after year, re-creating habitats in areas where there are no Blanding's turtles, or in areas inaccessible to Blanding's turtles, seems unlikely to yield conservation benefits for this species.

Page 63: An ecological trap is actually an area where a given species is attracted, but where the population growth rate is negative. The population is only sustained because of immigration. The negative growth rate can, but is not necessarily due, to genetic isolation. The negative growth rate is actually often attributed to poor local reproduction.

Page 77: I am surprised that a greater dispersing ability is inferred for adults than for juveniles. Adults tend to be very faithful to their home ranges year after year. I would expect that most dispersal occurs at the juvenile stage, not at the adult stage.

Page 88: Again, I am surprised that only organic pollutants are considered in the first sentence. Given the life habits of turtles, I suspect they accumulate several metals, notably mercury.

Pages 91-93: This habitat suitability index is a bit misleading. It considers several variables, but the suitability values are then defined by the researcher based on experience. Therefore, the suitability values are largely arbitrary. In addition, the contributing variables are weighed differently, with no rationale given for the selection of the various weights. Therefore, although in the body of the report the index looks more formal than a simple assignment by the researcher, it really boils down to the researchers's best guess based on relatively scant telemetry and capture data. This aspect deserves acknowledgement in the body of the report. In addition, habitat suitability is probably an inappropriate name for this index. I would call it a 'subjective habitat quality index'. Habitat suitability models are a class of models that employ a series of predictor variables (often habitat variables) to predict correctly the presences and absences of a species. For example, see:

- Millar CS & Blouin-Demers G. 2012. Habitat suitability modelling for species at risk is sensitive to algorithm and scale: a case study of Blanding's turtle, *Emydoidea blandingii*, in Ontario, Canada. Journal for Nature Conservation 20: 18-29.

Gabriel Blouin-Demers

Gabriel Blouin-Demers, PhD, Full Professor
Department of Biology, University of Ottawa
30 Marie-Curie, Ottawa, On K1N 6N5
gblouin@uottawa.ca
www.science.uottawa.ca/gblouin

Dr. Blouin-Demers' Comment	Location in Text	Response/Action
1)General comments	Forward	RESPONSE. Dr. Stow has addressed these comments in his forward of the Conservation Needs Assessment.
2) Inaccuracy with respect to the statement that the study is the first in the region.	End of first paragraph of Executive Summary	REVISED. The field research reported herein represents one of the first in-depth studies conducted on an individual population in the urbanized area of the Ottawa and Gatineau region.
3) Comment about objectives	Page iv	NOTED.
4) Comment about Old Carp Road and threat to Blanding's turtles	Page 3	NOTED. We acknowledge the statement is speculative and have written it as such.
5) Range extent	Page 8	REVISED. Blanding's turtles range from central Nebraska and Minnesota to southern Ontario/southwestern Quebec and northern New York.
6) Studies by Litzgus	Page 8	NOTED.
7) Comment on effective dispersal	Page 15	NOTED.
8) Inbreeding	Page 20	NOTED.
9) Bioaccumulation in turtles	Page 21, first paragraph	REVISED. Removed "organic" from the sentence
10) Comment about the omission of habitat loss as a threat	Page 22, first paragraph	REVISED. Added habitat loss to the last sentence.
11) Comment about the interpretation of PVA data in general	Page 22	NOTED.
12) Male presence and sperm limitation	Page 23	NOTED.
13) Comment on Translocation	Page 26	NOTED.
14) Comments on Habitat suitability	Page 36 and Appendix E	REVISED. Now reads: A subjective Blanding's Turtle Habitat Quality Index (HQI_{BT}) was created to reduce biases in the one used in previous Dillon reports. The new approach uses a Geographic Information System (GIS) to model Habitat Quality based on weighted environmental variables based on researcher experiences.

		REVISED. Replaced Habitat Suitability with Habitat Quality throughout.
15) Comment on COSEWIC and Critical Habitat	Page 39	NO CHANGE NEEDED
16)Comments on Conservation Objectives	Page 46	NOTED.
17) Creating habitat in new areas	Page 58	NOTED.
18) Ecological Trap Definition	Page 62	REVISED.
19) Dispersal Ability	Page 77 (Appendix C)	NOTED. Dispersal in the model relates to distance travelled over the year. We acknowledge that there is little evidence to support whether adults or juveniles disperse further.
20) Organic Pollutants	Page 88	See response to comment 9)
21) Habitat suitability	Appendix E	See response to comment 14)

APPENDIX C

POPULATION VIABILITY ANALYSIS - SUPPLEMENTARY

Detailed Methods

All population growth models and PVA used herein were created and completed using the RAMAS® Metapop software (Applied Biomathematics, Setauket, New York). The software allows for the viability analysis of stage-structured metapopulations over user-defined time periods and can be replicated to account for probabilistic demographic and environmental stochasticity. Essentially, stage-classified probability matrices which represent vital rates (i.e., survival, fecundity, and transition rates; Lefhobitch, 1965[3]) are used to model population growth. Other data required by the model includes: initial abundances, standard deviations, metapopulation location, relative vital rates, dispersal rates, and density-dependence effects. Using known information from our studies, or data published in the scientific literature, the model parameters were inputted to estimate the population growth models for the three SMH sub-populations.

The following explains the baseline model used and model inputs that take into account different assumptions of the sub-populations and different scenarios that may occur in the South March Highlands.

To complete a PVA that would adequately model the South March Highlands Blanding's turtle population, a number of assumptions have been made:

- The South March Highlands Blanding's turtle population is spatially-explicit and individuals of the three sub-populations are capable of dispersal between each sub-populations (by definition the SMH is Blanding's turtle population is a 'metapopulation'; we will continue to refer to the grouping as the SMH Blanding's turtle population for simplicity). Six activity centres have been identified through the population and radio telemetry study (Dillon Consulting Limited, 2011b), however the frequency of cross-zone movements indicates that the central wetlands along Shirley's Brook tributaries are really one large subpopulation, separate from the Kizell Wetland and Zone 1, which seems to be a separate environment and used less frequently by Blanding's turtle. For the analysis we have defined three subpopulations:
    - The Kizell Wetland (Zone 7A in the Population Estimate Study)
    - The South March Highlands- Central (Zones 2, 3, 4, 5, 8, and 9).
    - The South March Highlands- Upland (Zone 1)
- The Blanding's turtle have three life stages: (1) Eggs/Hatchlings; (2) Juveniles; and, (3) Adults. Any particular stage is affected by stage-specific vital rates (i.e., survival rates are different between stages, but all individuals of each stage are affected similarly).

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[3] Full citations for all references used can be found in the Report.

- Furthermore, we adjusted the model to assume that eggs/hatchlings have no potential for dispersing between sub-populations, juveniles have a low potential for dispersing, and adults have a moderate potential for dispersing (Congdon *et al.,* 2008). Although there are studies that suggest hatchlings disperse, we are uncertain if this happens in the SMH given that we know of few nesting sites and no hatchling-specific habitat. The model has also been adjusted to reflect that it is more likely for an adult turtle to move between the two South March Highlands sub-populations than between the Kizell Wetland sub-population and either of the South March Highland sub-populations.

- To model the population viability, accurate estimates of survivorship, fecundity, and the ratio of individuals successfully reaching the next stage are needed. The current population study being completed in the South March Highlands has not spanned a long enough time period to accurately determine population-specific vital rates. Thus, vital rates determined from demographic data collected over a span of 37 years have been used (Congdon *et al.,* 1993). The Congdon and colleagues (1993) study followed a population of Blanding's turtles on the University of Michigan's E.S. George Reserve for 27 of 37 years (1953-1991). Survival rate estimates were determined using data collected from all adults sampled over the entire period of study, and fecundity data were collected from data collected after 1976. The reserve is approximately 900 km to the southwest of the South March Highlands (45^{o} 20' N latitude) and located to the west of Ann Arbor Michigan (42^{o} 16' N Latitude). Carrying Capacity (K) was also calculated based on the Michigan population (7.5 turtles per hectare). It should be noted that the calculated K value is a conservative estimate and other populations have been found to have over 50 individuals per hectare in Nebraska (Congdon *et al.,* 2008).

- To "populate" the initial abundances, the number of adult Blanding's turtles observed in each sub-population during the 2010-2012 population study was used, along with literature information from Congdon and colleagues (1993) to estimate the number of eggs laid (based on clutch size) in a year and the number of juveniles (based on expected hatchling success, juvenile survivorship, and age to sexual maturity). To calculate the number of juveniles we assumed that the SMH population is currently at stable state (i.e., $\lambda = 1.0$; Enneson and Litzgus, 2008). The stable-state assumption allowed us to determine the initial survivorship for juveniles and the number of juveniles transferring to the adulthood stage based on formulas published in Enneson and Litzgus (2008).

- Only the number of females was modeled. Blanding's turtle exhibit a polygamous mating system which means that females are the limiting sex (i.e., many potential males can sire a clutch of eggs, however the number of eggs laid is dependent on the number of females). The average number of eggs laid was halved to account for an equal sex ratio. Though findings from the Terry Fox Drive extension work indicate that the SMH Blanding's turtle population has more females than males, sex ratios at the hatchling and juvenile stages are unknown. Also, given that the Terry Fox Drive work has only occurred for two annual mark/recapture periods, it would be unwise to oppose other studies which have indicated that Blanding's turtle populations have a 1:1 sex ratio. Life history and demographic models are based on females since they produce offspring (Congdon *et al.,* 1993; Enneson and Litzgus, 2008).

- Density-dependent effects influence all vital rates (i.e., survival and fecundity). A ceiling approach was used because the impact of density-dependence likely occurs only when the population reaches a specific threshold (i.e., carrying capacity). Carrying capacity was based on a density of 7.5 turtles per ha (Congdon *et al.,* 1993) and the total area (combined wetland and upland habitat) of each sub-population.

The following parameters were used in the baseline model:

- The model spans a 500 year period and is replicated 1000 times (the replications are based on stochastic changes to the model parameters based on the standard deviation matrix).
- Density dependence affects all vital rates, but only for the juvenile and adult life stages. The density dependence type was "Ceiling". Hatchlings were excluded from density dependence effects because of high mortality rates due to nest predation and lack of resource competition.
- The population has three life stages: 1) egg/hatchlings; 2) juvenile (1-14 years of age); and, 3) adult (15+ years of age). Reproduction can only occur in the adult life stage and relative dispersal is quartered for juveniles and nil for egg/hatchlings. Hatchlings may however disperse *via* the adult dispersing. Age of sexual maturity (14) was chosen based on the lower estimate by Congdon and colleagues (1993).
- The following is an example of a stage-classified matrix (*A*) and represents the matrix used in the models:

$$A = \begin{bmatrix} 0 & 0 & F_3 \\ P_{21} & P_{22} & 0 \\ 0 & P_{32} & P_{33} \end{bmatrix}$$

Where P_{21} is egg/hatching survivorship (i.e., the percentage of eggs that successfully hatch and become juvenile turtles); P_{22} is juvenile survivorship minus the percentage of juveniles which have transferred into adults; P_{32} is the percentage of juveniles which have transfer into adults each year; P_{33} is adult survivorship; and F_3 is adult fecundity (i.e., number of eggs laid in a year destined to be female).

The following stage-classified matrix was adapted from Congdon and colleagues (1993) and used in the model:

$$Stage\ Matrix = \begin{bmatrix} 0.0 & 0.0 & 5.0 \\ 0.261 & 0.775 & 0.0 \\ 0.0 & 0.007 & 0.960 \end{bmatrix}$$

To explain the matrix, approximately 26 % of eggs laid become juveniles; less than 1 % of eggs which become juveniles subsequently become adults; 4 % of adults die each year; and 5 female eggs are laid per female turtle each year.

- The following standard deviation matrix was calculated using a 10 % standard deviation in vital rates and applied to the stage matrix during modeling. The standard deviation matrix represents demographic and environmental stochasticity (randomness) which describes the temporal variation in vital rates. Standard deviations in vital rates is not well discussed in the scientific literature, thus a standard deviation value of 10 % was used to avoid truncation and overestimating extinction risks. The number also represents a biologically-relevant standard deviation, though as stated above, scientific discussion on the topic is limited for turtle populations:

$$Standard\ Deviation\ Matrix = \begin{bmatrix} 0.0 & 0.0 & 0.5 \\ 0.026 & 0.0225 & 0.0 \\ 0.0 & 0.0007 & 0.004 \end{bmatrix}$$

- The following characteristics were applied to the subpopulations:
  - Kizell Wetland:
    Centre point: 427037 m E, 5019794 m N (UTM +18)
    Relative fecundity, survival, and dispersal were set to 1 for the baseline model.
    The carrying capacity of the Kizell Wetland habitat is 61 turtles based on 6.3 ha
  - SMH-Central:
    Centre point: 425647 m E, 5020492 m N (UTM +18)
    Relative fecundity, survival, and dispersal were set to 1 for the baseline model.
    The carrying capacity of the SMH-Central habitat is 1639 turtles based on 437.0 ha.
  - SMH-Upland:
    Centre point: 424485 m E, 5020566 m N (UTM +18)
    Relative fecundity, survival, and dispersal were set to 1 for the baseline model.
    The carrying capacity of the SMH-Upland habitat is 415 turtles based on 110.7 ha.

- Initial abundances for the three sub-populations were calculated using the number of adult females found in the sub-populations during the *Population Estimate and Range Study* (Dillon Consulting Limited, 2011a; Unpublished Data; one more year of recapture will be undertaken, but current estimates suggest that there are more adult females than what is represented here, thus our initial abundances are a minimum). The number of eggs and juveniles were calculated using the vital rates presented in Congdon and colleagues (1993) and formulas described in (Enneson and Litzgus, 2008). Specifically, the matrices used were as follows:

$$Initial\ Abundance_{Population} = \begin{bmatrix} Eggs \\ Juveniles \\ Adults \end{bmatrix}$$

$$Initial\ Abundance_{KW} = \begin{bmatrix} 30 \\ 27 \\ 6 \end{bmatrix}$$

$$Initial\ Abundance_{SMH-Central} = \begin{bmatrix} 215 \\ 193 \\ 43 \end{bmatrix}$$

$$Initial\ Abundance_{SMH-Upland} = \begin{bmatrix} 15 \\ 13 \\ 3 \end{bmatrix}$$

- Two catastrophes were added to the model to account for randomly occurring events that may cause negative effects on the populations. One catastrophe halved adult abundances in each population and is analogous to a large poaching event or a fatal disease outbreak. The second catastrophe halved each vital rate and was regional, meaning each metapopulation was affected equally. A rate impacting catastrophe is analogous to a more systemic event, such as climate change, which may alter survivorship, fecundity, and development over a large area. Catastrophes were set to occur once in one hundred years.
- Dispersal was incorporated into the model to account for turtle movements between the sub-populations. Dispersion between the sub-populations was calculated using the following formula:

$\rho_{ij} = a \bullet \exp\left(\frac{-D_{ij}^{c}}{b}\right)$, a, b & c are known as the function parameters where D_{ij} is the distance between the two population centers and a, b, and c are constants (no definition provided by Applied Biomathematics, the software developer).

The function parameters were estimated using information collected during the *Population Estimate and Range Study* (Dillon, 2011a and 2012 Unpublished Data) and Blanding's turtle biology (Congdon *et al.*, 2008). The resulting relationship is depicted below and shows the declining rate of dispersal as distance (m) between sub-population increases:

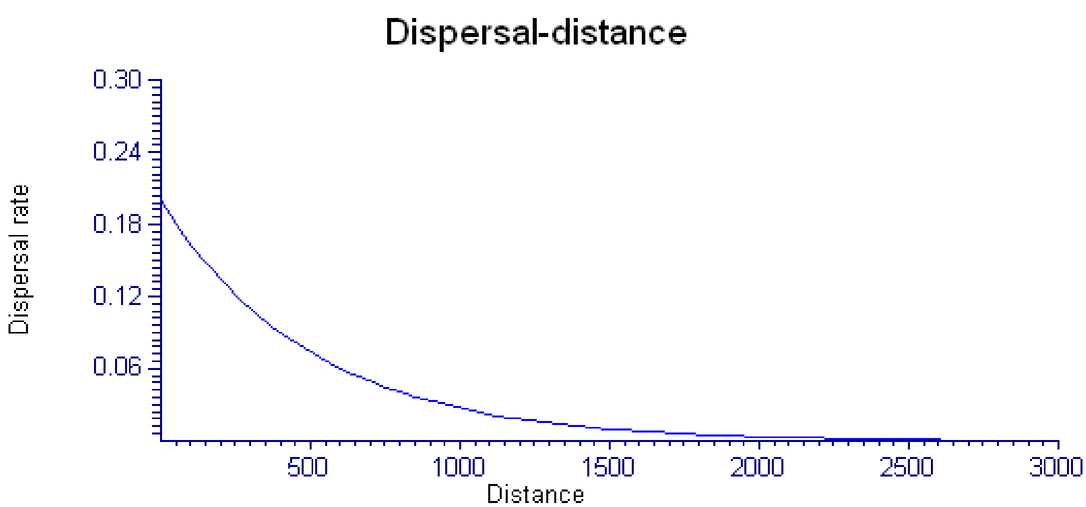

Figure C1. The relationship of disperal likelihood and distance used in the PVA.

Figure C1 shows that the turtles will disperse at a rate of 0.2 which decreases as distance (m) increases. The following Dispersal Matrix was calculated using the depicted function (KD, SMH-CEN, SMH-UP):

$$Dispersal\ Matrix = \begin{bmatrix} & 0.009 & 0.0001 \\ 0.009 & & 0.02 \\ 0.0001 & 0.02 & \end{bmatrix}$$

Results not presented in the Report

The mean population growth rate (λ) of females in the baseline scenario was 1.005 which indicates that based on the initial abundances and the assumed vital rates from the Congdon and colleagues (1993) study, the population is essentially stable (**Table C1**). However, over the course of the model, the SMH population did become extirpated, likely due to the catastrophes (**Table C1**). The baseline scenario considers all three sub-populations equal, with respect to dispersal and survival rates, and is an objective estimation of the population demographics of the SMH Blanding's turtle population. The result of a slight increase to 1.005 is not surprising, considering that model inputs have assumed λ = 1.0, in order to calculate juvenile transition and survival rates based on the Congdon and colleagues (1993) paper. The baseline scenario should not be misinterpreted as being the present day situation and the scenario with the highest likelihood of being fulfilled because the model uses Blanding's turtle specific vital rates measured from a long-term studied population (Congdon *et al.*, 1993) and the SMH-specific initial abundances and spatial locations. As well the model does not take into consideration population-specific differences in vital rates and/or other considerations such as dispersal rates. The model does however serve as a common-ground model for which comparisons may be made. The alternatives to the baseline model will be explored below in the sensitivity analysis, as separate and combined scenarios.

In general, the demographic data in the baseline scenario allows for the calculation of 1) Reproductive value, 2) Stable stage abundance and 3) Resident time. Reproductive value indicates the contribution of an individual to future generations. Stable stage abundance is the population breakdown with respect to stages between age classes. Resident time is the length of time that an individual spends in a given stage.

Adults have a high reproductive value, as the following vector of reproductive value (ν) was calculated:

$$\nu = (1 \quad 3.83 \quad 123.48)$$

On average, ν means that juveniles will contribute 3.83 times more to future generations as compared to eggs/hatchlings, and that the average adult will contribute 123.48 times more to future generations as compared to the eggs/hatchlings. Had we assumed the SMH population has a decreasing rate of growth, the reproductive value of adults would be lower, but still greater than the juvenile and egg/hatchling reproductive values. Alternatively, high rate of growth results in an exponential increase in adult reproductive value. High reproductive value for adults is typical for long-lived turtle species and lends support to protection programs and management objectives that promote survivorship among adults (e.g., the Terry Fox Drive Extension Wildlife Guide System, Turtle Crossing signage, community Turtle Watches; See Section 6 below). Below in our management strategy we explain in detail options for protecting adult Blanding's turtles and particularly mobile females that are more vulnerable.

Stable stage distribution indicates the percentage of individuals within each stage that are required for the population to be stable. The following stable stage distribution (ω) was calculated from the baseline stage matrix:

$$\omega = \begin{bmatrix} 0.42 \\ 0.49 \\ 0.09 \end{bmatrix}$$

The values indicate that a stable population of Blanding's turtles would have an abundance distribution of 42% eggs/hatchling, 49% juveniles and 9% adults. If a lower λ been assumed in the model, adults would have made up more of the stable population, and vice versa (17% for $\lambda = 0.5$, 7% for $\lambda = 1.3$). In general, a stable population of Blanding's turtle should have a high abundance of eggs/hatchlings and juveniles. In order for a stable population, few juveniles need to reach adulthood as relatively few adults can sustain a population if the mortality rates of adults remain low and recruitment is high (i.e., nesting sites are available, egg loss is low, and hatchlings are becoming juveniles). Management options which promote increased hatchling success and protection of juvenile habitat are important if nesting sites are rare and nest predation is high. If ample nesting habitat is available and high hatchling success is occurring, then initiatives to promote recruitment should be considered secondarily to the protection of adults (see Report for further discussion on options to increase recruitment).

With respect to the resident time that individuals spend in each stage, juveniles spent on average 4.4 years (note that 4.4 years is an average and 22% of juveniles die each year). Adults spent on average 25 years in the population. Eggs/hatchlings, by design, spend one year in the stage. Resident times remain stable across different assumptions for λ and therefore are influenced by stage-specific survival rates (Enneson and LItzgus, 2008). Adult Blanding's turtles have been known to live in excess of 80 years (Congdon *et al.,* 2008) and thus management options that will increase adult reproductive lifetimes should be considered to prolong the reproductive value of adults. Likewise, management options which can increase survival rates for juveniles would increase the number of juveniles becoming adults. It is likely that habitat protection focused on adults would indirectly increase juvenile survivorship as their habitat needs are similar at a macro-scale (see Section 6 below for management options associated with habitat protection).

Sensitivity and Elasticity

The following sensitivity matrix (*S*) was calculated from the Stage Matrix used in the baseline model. Note that the same stage matrix is used in each model, so each model will have the same sensitivity matrix.

$$S = \begin{bmatrix} 0.0332 & 0.0384 & 0.0066 \\ 0.1271 & 0.1471 & 0.0254 \\ 4.0956 & 4.7396 & 0.8197 \end{bmatrix}$$

Each element in the matrix represents the sensitivity (*S*) of the corresponding element in the stage matrix described above. Meaningful elements are the values with a corresponding number in the Stage Matrix (e.g., F_3, P_{21}, P_{22}, P_{32}, P_{33} from matrix *A*), the other elements are ignored. The meaningful element that is the most sensitive to the model outcome is the rate of transition from juvenile to adult ($P_{32} = 4.7396$). The next most sensitive element is adult survival (P_{33}=0.8197). P_{32} and P_{33} are the two rates most sensitive in turtle population models (e.g., Congdon *et al.,* 1993; Enneson and Litzgus, 2008). As reported above, the juvenile transition rate was calculated using the assumption that $\lambda = 1$. Had a population growth rate below one been used, the transition rate would have been greater and more adults would be present in the stable state and their reproductive value would be lower (as previously mentioned). Had a greater than one population growth rate been assumed, fewer adults would be required for a stable state and adults would have a higher reproductive value.

The following elasticity matrix (*E*) represents the elasticity of the corresponding element in the Stage Matrix:

$$E = \begin{bmatrix} 0.0000 & 0.0000 & 0.0332 \\ 0.0332 & 0.1140 & 0.0000 \\ 0.0000 & 0.0332 & 0.7865 \end{bmatrix}$$

High elasticity means that a small change in the corresponding element of the Stage Matrix will cause larger changes in the population growth rate. Elasticity was highest for the matrix element representing adult survival rate (P_{33}=0.7865%), followed by the probability for a juvenile to survive (P_{21}=0.0332%) and remain a juvenile (P_{32}=0.332%). Again, the above findings are typical for Blanding's turtle population growth models (e.g., Congdon *et al.*, 1993; Enneson and Litzgus, 2008). This finding further supports the conclusions made above that management options promoting adult survivorship will have the largest impact on Blanding's turtle population viability.

Scenario Results

Table C1 outlines the quantitative results of the PVA used in the report. The table is provided below.

Table C1. A comparison of the baseline PVA to each scenario.

Scenario	Sub-Population	Rate of Population Growth (λ)	% change in λ from baseline model	% change in median years to quasi-extinction from baseline model (negative indicates earlier)	% change in maximum number of adults at final stage from baseline model (negative indicates decline)
Baseline	KW	1.0005	-	-	-
	SMH-CEN	1.0005	-		-
	SMH-UP	1.0005	-		-
Baseline- Decreased Survival (1)	KW	0.9521	-5.3 %	-30.2%	-100%
	SMH-CEN	0.9908	-1.41%		-100%
	SMH-UP	1.005	0%		-100%
Baseline- Low Egg Survival (2)	KW	0.9824	-2.3%	-42.2%	-100%
	SMH-CEN	0.9824	-2.3%		-100%
	SMH-UP	0.9824	-2.3%		-100%
Isolation - KW Low Dispersal (3)	KW	1.0005	-	-3.7%	-14.3%
	SMH-CEN	1.0005	-		-11.1%
	SMH-UP	1.0005	-		+166.7%
Urbanization (4)	KW	0.9521	-5.3 %	-29.3%	-100%
	SMH-CEN	0.9908	-1.41%		-100%
	SMH-UP	1.0005	0%		-66.7%
Transplant-Baseline (5A)	KW	1.0005	-	-3.0%	0%
	SMH-CEN	1.0005	-		-22.2%
	SMH-UP	1.0005	-		100%

Scenario	Sub-Population	Rate of Population Growth (λ)	% change in λ from baseline model	% change in median years to quasi-extinction from baseline model (negative indicates earlier)	% change in maximum number of adults at final stage from baseline model (negative indicates decline)
Transplant-Isolation(5B)	KW	1.0005	-	-12.8%	-33.3%
	SMH-CEN	1.0005	-		-100%
	SMH-UP	1.0005	-		-100%
Transplant (5C) – Urbanization	KW	0.9881	-1.68%	-32.5%	-100%
	SMH-CEN	1.0274	-2.23%		-77.8%
	SMH-UP	1.0372	-3.20%		-100%
Increased Hatchling Success from nest protection-Baseline (6A)	KW	1.0169	+1.18%	n/a	0.0%
	SMH-CEN	1.0169	+1.18%		+613.3%
	SMH-UP	1.0169	+1.18%		+217.6%
Increased Hatchling Success from nest protection -Isolation (6B)	KW	1.0169	+1.18%	n/a	0.0%
	SMH-CEN	1.0169	+1.18%		+966.7%
	SMH-UP	1.0169	+1.18%		+211.8%
Increased Hatchling Success (6C) from nest protection - Urbanization	KW	0.9682	-3.66%	+54.6%	-8.3%
	SMH-CEN	1.0072	+0.22%		+226.7%
	SMH-UP	1.0169	+1.18%		+194.1%
Increased Hatchling Success from head start program -Baseline (7A)	KW	1.0418	+3.66%	n/a	+8.3%
	SMH-CEN	1.0418	+3.66%		+860.0%
	SMH-UP	1.0418	+3.66%		+176.5%
Increased Hatchling Success from head start program -Isolation	KW	1.0418	+3.66%	n/a	+16.7%
	SMH-CEN	1.0418	+3.66%		+846.7%

Scenario	Sub-Population	Rate of Population Growth (λ)	% change in λ from baseline model	% change in median years to quasi-extinction from baseline model (negative indicates earlier)	% change in maximum number of adults at final stage from baseline model (negative indicates decline)
(7B)	SMH-UP	1.0418	+3.66%		+176.5%
Increased Hatchling Success from head start program –Urbanization (7C)	KW	0.9927	-1.22%	n/a	+8.3%
	SMH-CEN	1.0320	+2.69%		+786.7%
	SMH-UP	1.0418	+3.66%		+176.5%
No Catastrophe-Baseline (8A)	KW	1.0005	-	n/a	+16.7%
	SMH-CEN	1.0005	-		+166.7%
	SMH-UP	1.0005	-		+188.2%
No Catastrophe-Isolation (8B)	KW	1.0005	-	n/a	+8.3%
	SMH-CEN	1.0005	-		+126.7%
	SMH-UP	1.0005	-		+129.4%
No Catastrophe-Urbanization (8C)	KW	0.9521	-5.3 %	+81.2%	-41.7%
	SMH-CEN	0.9908	-1.41%		+6.7%
	SMH-UP	1.0005	0%		+17.6%
Removal of 60 eggs from SMH-CEN for 30 years starting 5 years from present- Baseline (9A)	KW	1.0005	-	-4.5%	-66.7%
	SMH-CEN	1.0005	-		-60.0%
	SMH-UP	1.0005	-		-58.8%
Removal of 60 eggs from SMH-CEN for 30 years starting 5 years from present- Urbanization (9B)	KW	0.9521	-5.3 %	-34.0%	-100%
	SMH-CEN	0.9908	-1.41%		-100%
	SMH-UP	1.0005	0%		-100%

Scenario	Sub-Population	Rate of Population Growth (λ)	% change in λ from baseline model	% change in median years to quasi-extinction from baseline model (negative indicates earlier)	% change in maximum number of adults at final stage from baseline model (negative indicates decline)
9A and introduction of 60 juveniles each of the 30 years- Baseline (10A)	KW	1.0005	-	+27.6	-41.7%
	SMH-CEN	1.0005	-		-46.7%
	SMH-UP	1.0005	-		-52.9%
9A and introduction of 60 juveniles each of the 30 years- Urbanization (10B)	KW	0.9521	-5.3 %	-8.2%	-91.7%
	SMH-CEN	0.9908	-1.41%		-93.3%
	SMH-UP	1.0005	0%		-88.2%

APPENDIX D

BIOACCUMULATION

A more thorough examination of the literature

Few comparative studies of bioaccumulation of persistent organic pollutants (POPs) have been conducted on Blanding's turtle, however there has been extensive work done on the Common Snapping turtle as a sentinel indicator of pollutants in estuaries and freshwater ecosystems. Snapping turtles share many of the same habitats as Blanding's turtles, have a similar lifespan, and like Blanding's turtles, they sit high in their food chains so tend to magnify the contaminants consumed through predation. In theory, both Blanding's turtles and snapping turtles may be susceptible to negative effects on individual health or reproduction due to bioaccumulation of organic toxins (Golden and Rattner, 2003). This supplementary section reviews the status and threat of bioaccumulation to turtles, focusing primarily on snapping turtles in Ontario, and then brings the discussion back to Blanding's in the South March Highlands. It is important to note that within the Reptilia Class and Testudines Order, the various turtle species have evolved along separate pathways and therefore will reflect different risk profiles with respect to their vulnerability to bioaccumulation of pollutants; so our interspecies comparison should be interpreted with caution.

Common snapping turtles stay in one general area from year to year, often for their whole life span, so are likely to remain exposed to the same chemicals year after year. As in most carnivorous or omnivorous species, persistent contaminants accumulate in the fatty adipose tissues, liver, skeletal muscles and may be passed through to their young in the lipid content of eggs. Studying Common snapping turtles in the Hudson River in New York State, Stone *et al.* (1980) found PCB's, DDE, dieldrin in 70% of the specimens. In tissue samples of one specimen from Lake Ontario, total PCB's were 663 μg/g compared with 3608 μg/g in one specimen from the Hudson River (Olafsson *et al.*, 1983), reflecting the relative pollutant concentrations within each waterbody. Persistent organochlorine contaminants (OCS) were measured in 78 adult snapping turtles collected in 1988-89 from 16 sites in southern Ontario (Hebert *et al.*, 1993). The range of mean contaminant levels in muscle for all sites were as follows (ng/g wet weight): 0.00-655.28 total PCB, 0.00-164.60 total DDT, 0.00-3.95 mirex, and 0.00-1.26 [other] OCS. Significant site differences were found for all four substances. A highly significant relationship was found between contaminants in adult female turtles and their eggs (Hebert *et al.*, 1993), where over 95% of the total toxicity in an egg resides in the yolk (Bryan *et al.*, 1987). No direct exposure data is available on cholinesterase inhibiting pesticides or data on petroleum residues in snapping turtles (USGS, 2012). Overall, the evidence of negative impacts on health or reproduction appears mixed and inconclusive.

A significant body of research exists from Ontario, looking at contaminant levels in the eggs. Organochlorine accumulation and intra-clutch variation was studied in snapping turtles collected from 7 nests in 1986 and 1987 from Cootes Paradise in western Lake Ontario (Bishop *et al.,* 1995). In comparing the first five eggs laid, the last five eggs, and a composite sample of eggs laid after the first five and before the last five, the first five tended to have the highest mean concentrations of chlorinated hydrocarbons on a wet weight basis and on a lipid weight basis (Bishop *et al.,* 1995). The last five eggs tended to have the lowest values, and composite eggs were generally intermediate (Bishop *et al.,* 1995). In studies on tributaries to the St. Lawrence River from 1989-1991, heavy metals have also been found in turtle eggs, commonly mercury (Hg), cadmium (Cd) and lead (Pb) (Bishop *et al.,* 1998; Bonin *et al.,* 1995), with Hg found in all samples. A more recent study suggests no correlation between lead accumulation and ulcerative shell disease in two turtles species in an urban lake (Bishop *et al*., 2007), suggesting that the toxicological effects of metals on turtles is felt to be somewhat inconsequential to their rates of survival.

Even in pristine areas, contaminates can accumulate. Snapping turtles in Algonquin Park were found to have high levels of PCBs, DDE, HCB, dieldrin and mirex, with eggs tending to be the most contaminated (Bishop *et al.,* 1996). PCB's have been strongly associated with deformities and hatching success from eggs collected in Algonquin Park, including deformities of the tail, hind legs, head, eyes, scutes, forelegs, dwarfism, yolk sac enlargement and missing claws (Bishop *et al*., 1998; Bishop *et al*., 1991). The incidence of abnormal development increased significantly with increasing concentrations of PAH's, particularly PCDD and PCDF, yet was not correlated with TEQ's in eggs. The percentage of unhatched, contaminated eggs due to infertility or interrupted embryonic development ranged from 0-10% (Bishop *et al*., 1998).

Historically, the South March Highlands has been relatively undeveloped, save from the railway routed through the wetlands, a single electricity line, farming in the drier areas and further back in time, lumber extraction from the hillsides. The prey species of frogs, toads, salamanders and the three fish species identified in the system (Brook stickleback, Central mudminnow and Northern redbelly dace) are small, omnivorous and short lived, and therefore less likely to accumulate significant loads of OCS and heavy metals.

Although contaminant levels have not been sampled in this area, we hypothesize that it is quite possible that the creosote, PAH's and OCS in the preservatives for the railway ties and hydro poles may have resulted in some low levels of OCS for the existing Blanding's turtle population prior to the development of Terry Fox Drive and the proposed residential developments.

Most of the SMH population occurs in areas upstream of the planned development and therefore most of their reproductive activities, feeding and life cycle processes should remain apart from the residential areas and relatively free of contaminants. The exception to this is the Blanding's turtle population in the Kizell Drain wetland which will be surrounded by residential developments and the potential for food sources to come into contact with the residential contaminants. Currently, storm water from much of the development is managed in the Kizell Drain wetland, with no pre-treatment. Additional storm water treatment has been proposed for the Kizell Wetland. Gravimetric settlement of silt particles is the primary mode of treatment in the Beaver Pond. Residential communities are known to shed heavy metals, pesticides, herbicides, hydraulic fluids, N-P-K nutrients, detergents, oils and grease. Although influxes of herbicides and pesticides should decrease over time in response to provincial regulations, the levels may be expected to increase in the short term with the nearby expansion of residential developments.

APPENDIX E

HABITAT STUDIES – SUPPLEMENTARY INFORMATION

Detailed Methods

In the 2010 Annual Report, Dillon consulted literature, other researchers, the wetland evaluation records, and used direct observation to produce a preliminary "Blanding's Turtle Habitat Suitability Index" or HSI_{BT} (Dillon Consulting Limited, 2010b). The intention of the index was to provide a numerical indicator of whether the evaluated habitat was a site where Blanding's turtles might be found, and thus would indicate appropriate places to focus our sampling effort, or in the future, to look elsewhere in the City for Blanding's turtles. This HSI_{BT} was restricted to high probability habitats within the study area leaving much of the study area unclassified. The HSI_{BT} was updated for the 2011 Annual Report to more habitats, but still did not classify all surfaces of the entire study area. (Dillon Consulting Limited, 2011b).

The 2010 HSI_{BT} indicates that forested areas are considered relatively poor habitat for Blanding's turtles. Although forested habitats are overall important for travel corridors between suitable habitat for feeding, mating, overwintering, and nesting, Blanding's turtles do not spend the majority of their time in forested habitats. However, nesting may occur in or near certain forested areas as determined by the 2011 and 2012 field work, yet it is still unknown what makes certain areas stand out from others in terms of suitable nesting locations. Another alteration with the previous HSI_{BT} was the vernal pools were considered mildly suitable, however, one vernal pool is actually a groundwater fed swamp and the suitability was upgraded to a higher level of suitability.

A different approach was taken in 2012 to further refine the HSI_{BT} developed in 2010. To mitigate any real or perceived bias in the 2010 HSI_{BT} and ensure transparency in the results, this new approach uses a Geographic Information System (GIS) to model Habitat Quality. The updated Blanding's turtle habitat quality index (HSI_{BT}) used a vegetation classification, Topographical Wetness Index (TWI), slope, and distance to water to subjectively classify Blanding's habitat. The Vegetation Classification was determined using Ecological Land Classification (ELC) within the Terry Fox Drive area from 2009 (Dillon, 2010c) and vegetation classes of the South March Highlands Conservation Forests Management Plan (Brunton, 2008). Vegetation classification in areas where there was no information was determined using aerial photos and on-site visits. The ELC categories were generalized to suit the rest of the vegetation classes. The TWI was calculated within the GIS from a Digital Elevation Model (DEM). A 10 m resolution DEM was created using a Triangular Irregular Network (TIN) from 1 m contours (data provided by the MNR) around the study site. The required inputs for the TWI formula were derived from the DEM. This included flow accumulation and slope. The TWI was calculated using the TWI formula (TWI = $\ln(1+\alpha/\text{Tan}(1+\beta)$ where 'α' is the flow accumulation and 'β' is the local slope (in radians). Slope was determined from changes in elevation taken from the DEM. Lastly, distance to streams was determined for the study area calculated as the Euclidian Distance from the watercourse within the property.

To create the new HQI_{BT}, each factor (vegetation classification, TWI, and distance to streams) was given a habitat quality value using the experience obtained from the 2010 HSI_{BT} and through literature review. For instance, vegetation and distance to streams was based on best knowledge of Blanding's turtle preferences (**Table E1**). TWI was scaled from 0-100 in which greater wetness had greater suitability (**Table E1**).

Table E1. Subjective quality for variables used in the Blanding's turtle habitat quality index.

Factor	Variable	Quality
Vegetation characterization	Deciduous Forest	35
	Deciduous Swamp	90
	Developed	10
	Meadow	15
	Mixed Forest	25
	Mixed Swamp	90
	Open Water	60
	Organic Meadow Marsh	90
	Organic Thicket Swamp	95
	Rock Barren	10
	Shrub Thicket	20
	Roadway	5
	Wildlife Crossings	90
Distance to water	0 - 10 m	100
	10 - 50 m	80
	50 - 100 m	40
	100 - 500 m	10
	500 - 600 m	5
Topographical Wetness Index	0 - 1	3

	1 - 2	11
	2-3	18
	3-4	25
	4-5	33
	5-6	40
	6-7	48
	7-8	55
	8-9	63
	9-10	70
	10-11	77
	11-12	85
	12-13	92
	12-13	99
Slope	0-1.5	100
	1.5-3.5	90
	3.5-6	75
	6-10	50
	>10	25

Next, each factor is given a certain weighting and then all factors are combined to create an HSI for the area. The four factors were weighted so the vegetation classification was of equal weight to the two moisture indices and the slope index. (i.e., TWI weight = 16.7, distance to streams weight = 16.7, slope = 16.7, and vegetation weight = 50)

Appendix T

Kanata North Community Design Plan Blanding's Turtle Compensation Plan

(DST Consulting Engineers – June 2015)

consulting engineers

KANATA NORTH COMMUNITY DESIGN PLAN

BLANDING'S TURTLE HABITAT COMPENSATION PLAN

Prepared for: Novatech Engineering Consultants Inc.
240 Michael Cowpland Drive, Suite 200
Kanata, Ontario, K2M 1P6

On Behalf of the Kanata North Landowners Group

June 2015

Final Report

DST File No.: OE-OT-019389

2150 Thurston Dr., Suite 203
Ottawa, ON K1G 5T9
CANADA

Phone: 613.748.1415
Fax: 613.748.1356
www.dstgroup.com