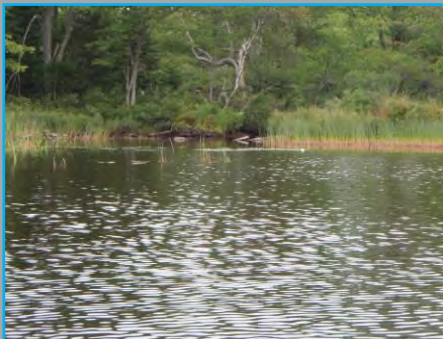


Halifax Regional Municipality

# Sandy Lake Watershed Study Final Report



Project #60303077

Prepared by  
AECOM Canada Ltd  
1701 Hollis Street (SH400)  
(PO Box 576 CRO)  
Halifax, Nova Scotia, B3J 3M8  
[www.aecom.com](http://www.aecom.com)

August 2014

Halifax Regional Municipality  
**Sandy Lake Watershed Study**  
**Final Report**

**Prepared by:**

AECOM

1701 Hollis Street

SH400 (PO Box 576 CRO)

Halifax, NS, Canada B3J 3M8

[www.aecom.com](http://www.aecom.com)

902 428 2021 tel

902 428 2031 fax

**Project Number:**

60303077

**Date:**

August 2014

## Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“Consultant”) for the benefit of the client (“Client”) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations and conclusions contained in the Report (collectively, the “Information”):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”);
- represents Consultant’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to Consultant which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

Consultant shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. Consultant accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

Consultant agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but Consultant makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by Consultant represent Consultant’s professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since Consultant has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, Consultant, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by Consultant and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

Consultant accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information (“improper use of the Report”), except to the extent those parties have obtained the prior written consent of Consultant to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

August 25, 2014

Mr. Cameron Deacoff  
Planning and Infrastructure  
Halifax Regional Municipality  
88 Alderney Drive, 3<sup>rd</sup> Floor  
Dartmouth, Nova Scotia

Dear Mr. Deacoff:

**Project No: 60303077**  
**Regarding: Sandy Lake Watershed Study – Final Report**

AECOM is pleased to submit the attached Final Report for the Sandy Lake Watershed Study. This body of work represents our current understanding of the environmental conditions in the watershed with a focus on lake water quality. The application of a phosphorus load model (Lake Capacity Model) provides a numerical narrative of how development may impact water quality. We identify several methods that can be utilized to mitigate water quality impacts. This report fulfills the requirements of Objective E-17 and we trust it fulfills your expectations for this work.

We look forward to your comments and are available for discussion at your request.

Sincerely,  
**AECOM Canada Ltd.**



Steve Murphy, MBA, P.Eng.  
Senior Manager, Atlantic Canada



## Distribution List

# of Hard Copies	PDF Required	Association / Company Name
	Yes	Halifax Regional Municipality

## Revision Log

Revision #	Revised By	Date	Issue / Revision Description
DRAFT	Timothy Bachiu	July 28, 2014	Draft of Final Report issued to client
R0	Timothy Bachiu	August 25, 2014	Final Report issued to client

## AECOM Signatures

### Report Prepared

By:

\_\_\_\_\_  
Timothy Bachiu, M.Sc., P.Geo.  
Geoscientist

### Report Reviewed

By:

\_\_\_\_\_  
Kimberlea Green, M.Sc. P.Geo.  
Senior Project Manager

### Report Reviewed

By:

\_\_\_\_\_  
Steve Murphy MBA, P.Eng.  
Senior Project Manager

## Executive Summary

Halifax Regional Municipality (HRM) in 2002 accepted the HRM Water Resources Management Study (Dillon 2002) as a basis for watershed planning policies. Following from this study, HRM uses the watershed as the basic unit of land use planning. This approach is consistent with the provincial Water Resources Management Study, which adopts a watershed-based Integrated Water Management approach to water protection and conservation (NSE 2010).

Land development within a watershed is one of the primary activities that may negatively affect a watershed's biophysical environment and by extension, the rivers and lakes downstream from that watershed. Given this, HRM's 2006 Regional Municipal Planning Strategy (also called the Regional Plan) requires that, prior to undertaking secondary municipal planning or considering amendments to existing secondary plans, HRM must complete watershed studies to aid in municipal planning. The objectives of these studies (given in Regional Plan Policy E-17) are both broad and comprehensive, and include the assessment of a range of environmental issues within the study area. The watershed studies are intended to provide solutions to existing issues or issues arising from the anticipated form and degree of development. Recommendations must balance development versus environmental protection, and provide specific recommendations to address the issues identified.

Communities officially listed under either Urban Settlement or Rural Settlement Designations within the Regional Plan are subject to these watershed studies. The Sandy Lake watershed is designated as an Urban Settlement area and currently hosts urban development along main thoroughfares (Hammonds Plains Road, Lucasville Road), in industrial areas and suburban style communities. Portions of the watershed are serviced with municipal water and wastewater services and portions of the watershed utilize on-site water wells and septic systems.

A development constraints map of the watershed identifies areas that are not suitable for development (wetlands, watercourses and riparian zones) and areas that may require environmental mitigation to be included in development plans if the areas are developed. Areas that may require environmental mitigation were identified by developing a groundwater recharge map to define areas with high groundwater recharge and areas with steep slopes identified using GIS.

Historic water quality samples and water samples collected during the course of this study are used to identify water quality objectives for parameters that are influenced by development. The water quality in Sandy Lake and Marsh Lake is currently being affected by urban development as displayed by the increasing phosphorus concentration in Sandy Lake. Both Sandy Lake (12 µg/L) and Marsh Lake (10 µg/L) have median phosphorus concentrations that place them in the lower end of the mesotrophic range. Water quality objectives and early warning values are set at 18 µg/L and 15 µg/L for Sandy Lake and 15 µg/L and 13 µg/L for Marsh Lake respectively.

Parameter	Derivation of Objective	Sandy Lake Watershed Water Quality Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
NO <sub>3</sub> – Nitrate	CCME	• 13 mg NO <sub>3</sub> /L	• ≤10 mg/L	• 75 <sup>th</sup> percentile of 3 year historical data. See footnote <sup>1</sup>
Total Suspended Solids (TSS)	CCME	• Short term <sup>1</sup> : 25 mg/L increase • Long term <sup>2</sup> : 5 mg/L increase	• Lake dependent	• 75 <sup>th</sup> percentile of 3 year historical data not to exceed base line by more than 5 mg/L
Chloride	CCME	• 120 mg/L	≤90 mg/L	• 75 <sup>th</sup> percentile of 3 year historical data
<i>E. coli</i>	Nova Scotia and Health Canada	• 200 <i>E. coli</i> /100 mL • (geometric mean of 5 samples)	• 200 <i>E. coli</i> /100 mL	• Geometric mean of 5 most recent samples

<sup>1</sup> 75<sup>th</sup> percentile of the reported values from the results of previous 3 years of monitoring. This assumes the results are from a technically justifiable monitoring program, such as the program recommended in Section 9.

Lake	Trophic State Objective	Numerical Objective	Early Warning	Evaluation
Sandy Lake	Mesotrophic	< 18 µg/L	15µg/L	Based on 3 year running average
Marsh Lake	Mesotrophic	< 15.5 µg/L	13 µg/	Based on 3 year running average.

Existing conditions and three possible future development scenarios are identified in the watershed and land use maps prepared for this study. The land use maps were used as inputs to a phosphorus load model (Lake Capacity Model) to predict how future development may impact the phosphorus concentrations of the lakes. Phosphorus is identified as a key water quality parameter to assess the trophic status of the lake.

Cumulative impacts of development on phosphorus concentrations are predicted to increase to 16 µg/L for Sandy Lake and 15 µg/L for Marsh Lake when mitigations measures to decrease phosphorus loading are not implemented. These levels are above the early warning values, but below the water quality objectives. Removing point sources of phosphorus such as the Uplands WWTF and septic systems near Sandy Lake by connecting them to municipal wastewater services decreases the predicted phosphorus concentrations to 15 µg/L and 14 µg/L for Sandy Lake and Marsh Lake respectively. Additional phosphorus mitigation measure using advanced stormwater management that reduces phosphorus runoff by 50% is predicted to further decrease the phosphorus concentration of Sandy Lake to 13 µg/L and of Marsh Lake to 12 µg/L.

Scenario	Sandy Lake Predicted Phosphorus (µg/L)	Marsh Lake Predicted Phosphorus (µg/L)
Scenario 1: Existing Conditions	12	11
Scenario 2: Planned Developments	16	15
Scenario 3: Planned Developments + removal of Uplands WWTF and Septic Systems near Sandy Lake	15	14
Scenario 4: Future Developments (Scenario 3) with Advanced Stormwater Management	13	12
Recommended Water Quality Objective	18	15.5

The results of the modeling scenarios provide a numerical narrative of how water quality is predicted to be impacted by development. Full development without mitigation measures to control nutrient loading into the lakes will likely result in steady increases in phosphorus concentrations that will approach the water quality objectives. Removal of nutrient sources such as septic systems, wastewater treatment facilities and stormwater runoff from new development areas will reduce the impact of urbanization in the watershed.

The predictions from the phosphorus load model are consistent with observations of urbanization in other watersheds. However, the degree of influence of urbanization on water quality in Sandy Lake can only be approximated using the phosphorus load model because of limitations arising from assumptions and uncertainty in the application of the model. Therefore a robust water quality monitoring plan is proposed for the Sandy Lake watershed to provide a further assessment of current conditions and to evaluate the impacts of development on the water quality.

Recommendations to maintain the quality and quantity of surface water and groundwater resources in the Sandy Lake watershed include focussed planning strategies, following existing regulatory requirements and stewardship.

# Table of Contents

## Statement of Qualifications and Limitations

### Letter of Transmittal

### Distribution List

### Executive Summary

	page
<b>1. Introduction .....</b>	<b>1</b>
1.1 Municipal Servicing .....	1
1.2 Study Objectives .....	4
1.2.1 Preliminary Report .....	4
1.2.2 Final Report .....	4
<b>2. Environmental Conditions .....</b>	<b>5</b>
2.1 Watershed and Study Area .....	5
2.2 Forests and Wetlands .....	5
2.3 Fish and Fish Habitat .....	8
2.4 Important Habitats .....	8
2.5 Surficial and Bedrock Geology .....	8
2.6 Groundwater .....	9
<b>3. Development in Sandy Lake Watershed .....</b>	<b>13</b>
3.1 Historical and Existing Development .....	13
3.2 Potential Sources of Contamination .....	14
3.3 Development Constraints .....	16
<b>4. Water Quality .....</b>	<b>17</b>
4.1 Water Quality Data Sources .....	17
<b>5. Water Quality Data Analysis .....</b>	<b>20</b>
5.1 Sandy Lake .....	21
5.1.1 Total Phosphorus .....	21
5.1.2 Chlorophyll-a .....	24
5.1.3 Nitrogen .....	25
5.1.4 Chloride and Total Suspended Solids .....	26
5.1.5 Bacteria .....	27
5.2 Marsh Lake .....	27
5.3 Uplands Wastewater Treatment Facility .....	28
5.4 Metals in Surface Water .....	28
<b>6. Establishing Water Quality Objectives .....</b>	<b>31</b>
<b>7. Receiving Water Quality Objectives .....</b>	<b>31</b>
7.1 Development of Total Phosphorus Water Quality Objectives (WQO) .....	31
<b>8. Lakeshore Capacity Modeling .....</b>	<b>32</b>
8.1 Sandy Lake .....	39
8.1.1 Scenario 1: Existing Conditions .....	39
8.1.2 Scenario 2: Future Land Use – Full Build-Out .....	40
8.1.3 Scenario 3: Future Land Use 2 .....	40
8.1.4 Scenario 4: Future Land Use 3 .....	40

8.2	Marsh Lake.....	41
8.2.1	Scenario 1: Existing Conditions .....	41
8.2.2	Scenarios 2 and 3: Future Land Use.....	41
8.3	Lakeshore Capacity Model Summary .....	41
<b>9.</b>	<b>Recommendations for Water Quality Monitoring .....</b>	<b>42</b>
<b>10.</b>	<b>Policy E-17 Objectives .....</b>	<b>44</b>
<b>11.</b>	<b>Summary and Conclusions .....</b>	<b>52</b>
	<b>References .....</b>	<b>53</b>
	<b>Glossary .....</b>	<b>59</b>
	<b>Acronyms .....</b>	<b>64</b>

## List of Figures

Figure 1.	Watershed Boundary and Project Study Area.....	2
Figure 2.	Local Communities and Service Areas .....	3
Figure 3.	Wetlands and Forest Cover.....	7
Figure 4.	Bedrock Geology .....	10
Figure 5.	Surficial Geology.....	11
Figure 6.	Groundwater Recharge in the Sandy Lake Watershed .....	12
Figure 7.	Constraints .....	19
Figure 8.	Sandy Lake Total Phosphorus - Current Conditions .....	22
Figure 9.	Sandy Lake Total Phosphorus - All Samples .....	23
Figure 10.	Sandy Lake Chlorophyll-a 2008-2013.....	24
Figure 11.	Relation between Total Phosphorus and Chlorophyll-a.....	25
Figure 12.	Scenario 1 - Existing Land Use Conditions .....	35
Figure 13.	Scenario 2 - Future Land Use Conditions .....	36
Figure 14.	Scenario 3 - Future Land Use Conditions with Removal of Septic Systems near Sandy Lake and Removal of Uplands WWTF .....	37
Figure 15.	Scenario 4 - Future Land Use Conditions Scenario 3 with Advanced Stormwater Management .....	38
Figure 16.	Phosphorus Contributions to Sandy Lake under Existing Conditions.....	39

## List of Tables

Table 1.	Potential Sources of Contamination.....	15
Table 2.	Data Used to Establish Current Water Quality .....	20
Table 3.	Sandy Lake Water Quality Summary.....	21
Table 4.	Total Phosphorus of Nearby Lakes (2006-2012).....	22
Table 5.	Sandy Lake Shallow and Deep Total Phosphorus .....	23
Table 6.	Nitrogen Compounds in Sandy Lake and the Birch Cove Lakes Watershed.....	26
Table 7.	Marsh Lake Water Quality Summary .....	27
Table 8.	Uplands Park WWTF Water Quality Summary.....	28
Table 9.	Sandy Lake and Marsh Lake Water Quality - Metals.....	30
Table 10.	Recommended Water Quality Objectives for Sandy Lake Excluding TP.....	31

Table 11. Water Quality Objectives and Early Warning Values for Total Phosphorus..... 32

Table 12. Comparison of Phosphorus Contributions in Scenarios ..... 34

Table 13. Phosphorus concentrations predicted by the LCM ..... 41

Table 14. Recommended water quality monitoring (after Stantec 2009) ..... 43

Table 15. Water quality monitoring intervals (after Stantec 2009)..... 43

Table 16. Estimate of Conceptual Residual Capacity Remaining for Each Lake Following Approved  
Developments as per Scenario 2..... 45

**Appendices**

Appendix A. Environmental Conditions

Appendix B. Water Quality Review

Appendix C. Water Quality Data Summary Tables

Appendix D. Groundwater Recharge Model

Appendix E. Lakeshore Capacity Model



# 1. Introduction

Halifax Regional Municipality (HRM) in 2002 accepted the HRM Water Resources Management Study (Dillon 2002) as a basis for watershed planning policies. Following from this study, HRM uses the watershed as the basic unit of land use planning. This approach is consistent with the provincial Water Resources Management Study, which adopts a watershed-based Integrated Water Management approach to water protection and conservation (NSE 2010).

Land development within a watershed is one of the primary activities that may negatively affect the watershed's biophysical environment and by extension, the rivers and lakes downstream from that watershed. Given this, HRM's 2006 Regional Municipal Planning Strategy (also called the Regional Plan) requires that, prior to undertaking secondary municipal planning or considering amendments to existing secondary plans, HRM must complete watershed studies to aid in municipal planning. The objectives of these studies (given in Regional Plan Policy E-17) are both broad and comprehensive, and include the assessment of a range of environmental issues within the study area. The watershed studies are intended to provide solutions to existing issues or issues arising from the anticipated form and degree of development. Recommendations must balance development versus environmental protection, and provide specific recommendations to address the issues identified.

Communities officially listed under either Urban Settlement or Rural Settlement Designations within the Regional Plan are subject to these watershed studies. Sandy Lake is designated as an Urban Settlement zone (**Figure 1**). In June 2013, AECOM was asked by HRM to complete the Sandy Lake Watershed Study and present the findings at public meetings.

As required in the Request for Proposal, the Sandy Lake Watershed Study has been completed in two phases:

1. The Preliminary Report, which presents a series of recommended water quality objectives for key receiving water bodies within the watershed; and,
2. The Final Report, which addresses the remaining objectives of Regional Plan Policy E-17.

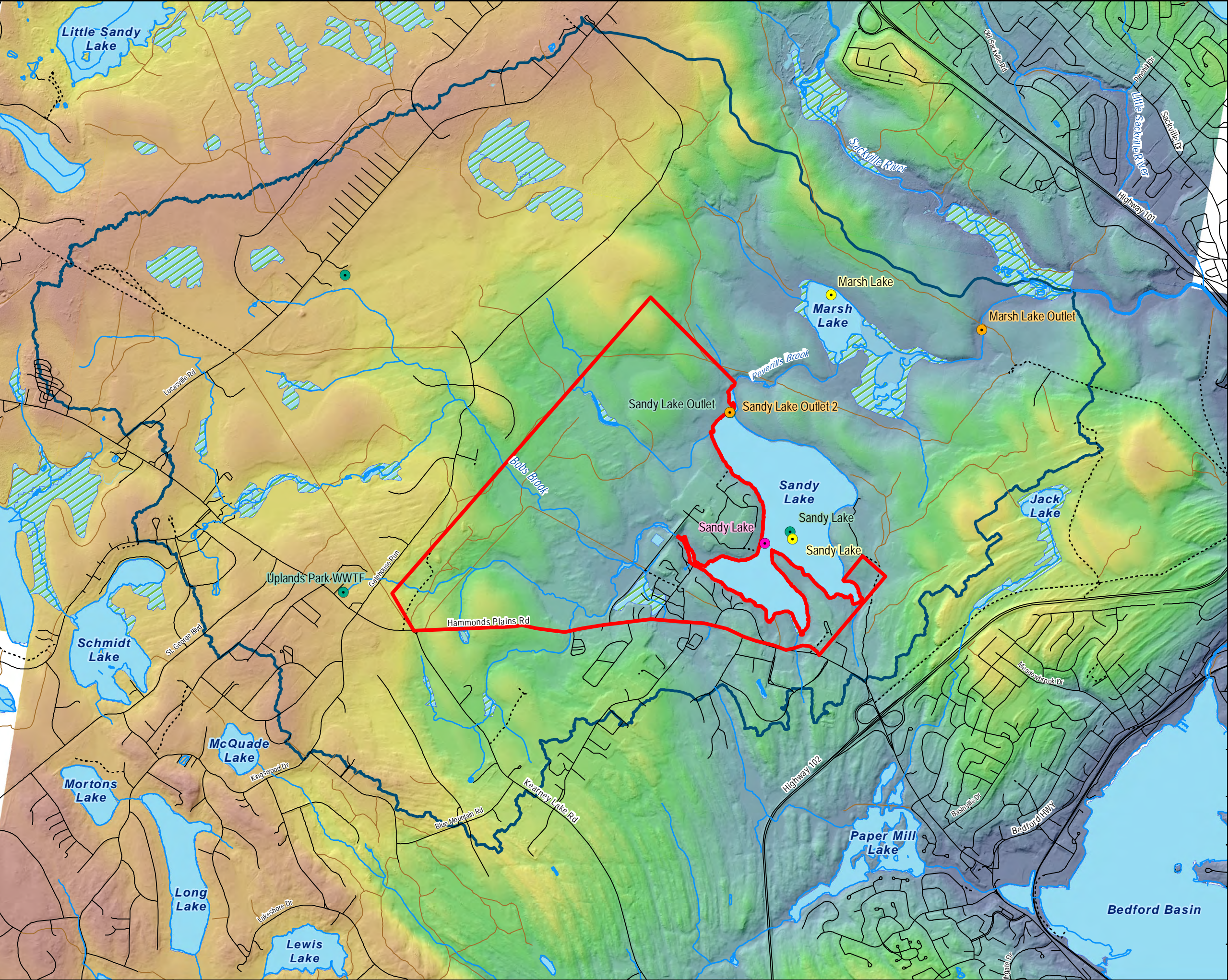
This document, the Final Report, presents a summary of the first phase of work followed by an analysis of the potential effects of proposed development within the watershed on lake water quality. The water quality objectives (WQOs) for phosphorus recommended in the Preliminary Report are compared to the results of a phosphorus loading model to evaluate the impacts of future development. In addition, the remaining objectives of Regional Plan Policy E-17 are addressed by providing recommendations that will mitigate the environmental impacts of development in the Sandy Lake watershed.

## 1.1 Municipal Servicing

The Sandy Lake area is currently provided with municipal water and wastewater services south of Hammonds Plains Road up to approximately Kearney Lake Road, although water and wastewater services are also provided in other areas within the watershed (**Figure 2**). Residences outside these service areas use groundwater for potable water and private septic systems for wastewater disposal.

In 2009, an HRM-commissioned report provided cost estimates to provide municipal services (water, sanitary, stormwater and transportation links) for various development scenarios in the Sandy Lake area (CBCL 2009). In addition, residential development is planned for 110 ha in the southern portion of the Sandy Lake watershed as described in the Bedford West Master Plan. To accommodate future development within the Sandy Lake watershed, the Bedford West development has oversized wastewater infrastructure which can be extended to future development around Sandy Lake. These plans indicate that future development near Sandy Lake will be serviced by municipal water and wastewater services. Areas further north, such as the Kingswood North subdivision, will be serviced by private groundwater wells and septic systems. These differences in water and wastewater servicing were taken into account when predicting future changes to water quality.





Legend

Sampling Location (by sampler)

AECOM

HRM

NSE

Resident

Watercourses

Roads

Trails

Nova Scotia Power Access Roads

Lakes

Wetlands

Study Area

Watershed

Elevation (mASL)

High : 139.00

Low : 0.00

Sandy Lake Area Watershed Study

Watershed and Study Area with Surface Water Sampling Locations

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM

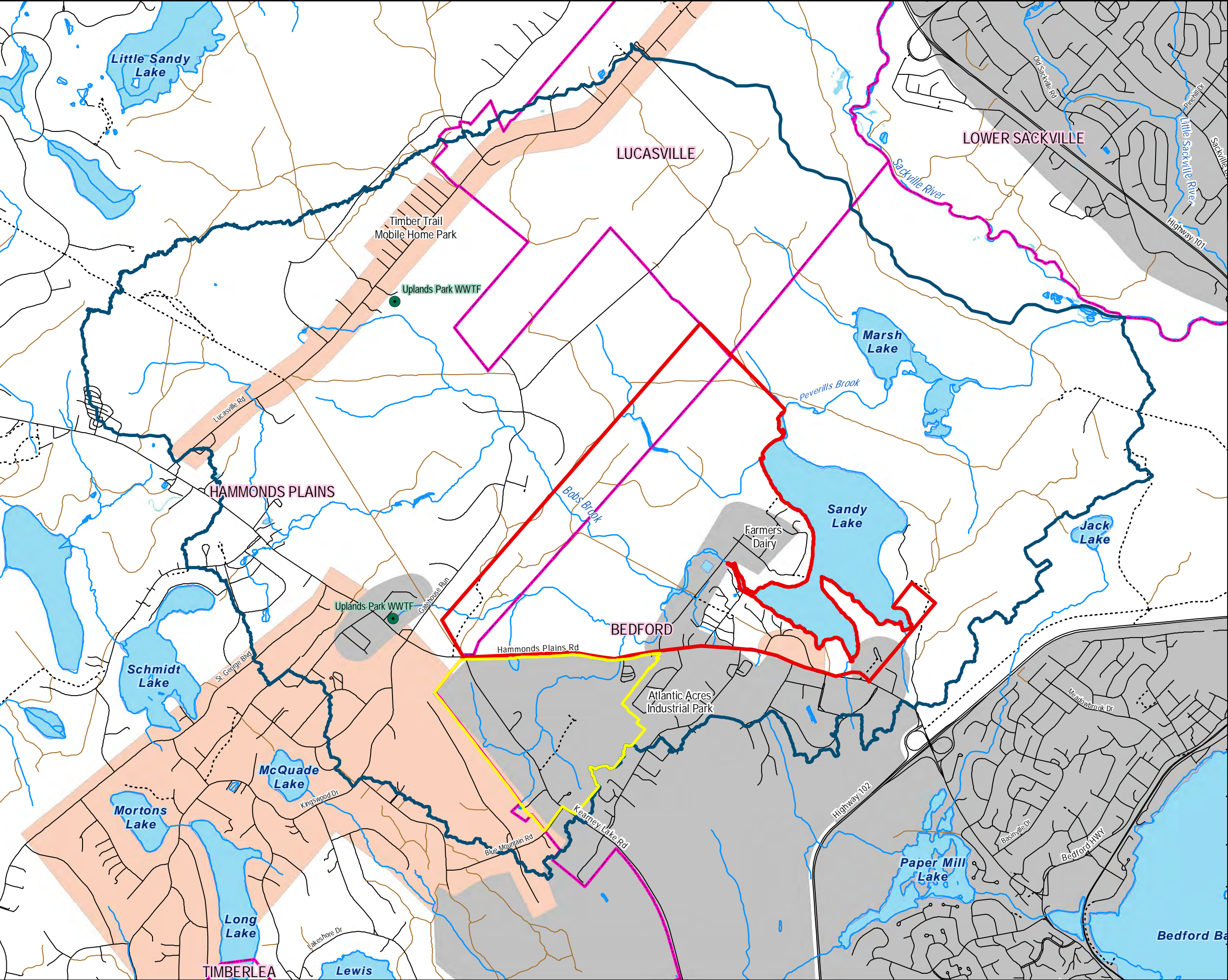
AECOM

Figure 1

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\6030307 Sandy Lk900-CAD-GIS\620 GIS-Graphics\Design\Preston Base Map.mxd





**Legend**

- Watercourses
- Roads
- Trails
- Nova Scotia Power Access Roads
- Lakes
- Community Boundaries
- Bedford West Development
- Study Area
- Sandy Lake Watershed

**Service Requirements**

- Urban Service Area (Water and Sewer Services)
- Water Service Area

**Sandy Lake Area Watershed Study**

Local Communities and Service Areas

September 2014	1:25,000	Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM & Hal. Water
----------------	----------	--

**AECOM**

**Figure 2**

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk\900-CAD-GIS\920 GIS-Graphics\Design\Final Draft Report - Sandy\Figure 2 - Study Area 20140711.mxd

## 1.2 Study Objectives

The primary, overarching objective of the Sandy Lake Watershed Study, as expressed in Regional Plan Policy E-17, is to:

***“...determine the carrying capacity of the watersheds to meet the water quality objectives which shall be adopted following the completion of the studies.”***

Carrying capacity is a measure of the watershed’s ability to accommodate inputs from both man-made and naturally occurring pollutants without experiencing a significant decline in water quality and ecological function. In this study, different land development scenarios are evaluated to understand the potential water quality effects resulting from each scenario. The outcome of the study is to provide a number of guidelines and recommendations for the planning, design and implementation of new developments that will help to maintain existing water quality.

### 1.2.1 Preliminary Report

The Preliminary Report provided a summary of existing conditions within the watershed and recommended water quality objectives which help to define the carrying capacity of the watershed. The term “existing conditions” comprises many of the ecological and hydrological features that define and bring value to the watershed, such as surface and groundwater quality, geology, rare species, fish habitat, and wetlands as well as those features which may negatively impact the watershed, such as pollution sources, dams, forestry practices, and land development.

### 1.2.2 Final Report

The Final Report builds on information presented in the Preliminary Report and addresses the remaining objectives listed in Regional Plan Policy E-17. Among other objectives, the Final Report identifies areas within the watershed that are suitable and not suitable for development, assesses potential impacts of development on water quality in the receiving watercourses, recommends measures to protect and manage quantity and quality of surface and groundwater and recommends regulatory controls and management strategies to achieve the desired water quality objectives. It is important that community perspectives stakeholders are integrated into the report; to this end, the draft Final Report is presented to the public and the Regional Watersheds Advisory Board during the final stages of the study.

## 2. Environmental Conditions

The physical and biological conditions of the Sandy Lake watershed are critical factors that control general surface water quality. Human influences can change the water quality, but the physical and biological characteristics of the ecosystem dictate the sensitivities and resilience of the watershed in the face of human-induced changes. **Appendix A** provides a more detailed description of the biophysical conditions of the watersheds. The text below is summarized from **Appendix A**.

### 2.1 Watershed and Study Area

The Sandy Lake Study Area (the Study Area) includes privately held lands to the west, south and south-east of Sandy Lake as identified in **Figure 1**. The Study Area generally encloses properties that are proposed for eventual residential, commercial and industrial development. Together, the surface area of the properties making up the Study Area is approximately 361 ha (890 acres) (CBCL 2009). However, to effectively evaluate the factors that contribute to water quality, the entire catchment area surrounding Sandy Lake is used as the watershed study area. The watershed hosting Sandy Lake is a 24.2 km<sup>2</sup> (2420 ha) subwatershed of the larger Sackville River watershed (**Figure 1**).

The Sandy Lake watershed is approximately 6.0 km from north to south and 7.3 km from east to west. Drainage follows topography and generally flows from the west and southwest to Sandy Lake. Sandy Lake discharges to Marsh Lake, which drains through Peverills Brook to the Sackville River. The Sandy Lake watershed is adjacent to (north of) the Birch Cove Lakes watershed, which drains north from Suzies Lake through Quarrie, Washmill, Kearney, and Paper Mill Lakes into Mill Cove in Bedford Basin. The highest elevations in the Sandy Lake watershed are found in the west and southwest, where they exceed 135 m above sea level. The lowest elevations are found around Marsh Lake and its outlet Peverills Brook, which are situated at approximately 20 m above sea level.

Within the watershed, wetland areas such as Round Pond and Hickeys Marsh in the upper western and southwestern portions of the watershed drain into several intermittent and permanent watercourses including Bobs Brook (also called Johnson Brook), which flow south to southeasterly into Sandy Lake. The confluence of Peverills Brook (the outlet of the Sandy Lake watershed) with the Sackville River is located 4.7 km upstream from the Bedford Basin (SRA 2011).

Sandy Lake has a surface area of 78.5 ha, a volume of approximately 5,100,000 m<sup>3</sup> and has a relatively short retention time of 0.34 years (White *et al.* 1984). The northwestern part of Sandy Lake is the deepest at 21.7 m. The southwestern portion is much shallower; depths are generally less than 6.0 m. A detailed bathymetric profile of Sandy Lake is presented in Conrad *et al.* 2002, who calculate a lake volume of 6,079,566 m<sup>3</sup>. The Conrad study also calculates a mean depth of 8.2 m, and indicates there were 20 dwellings with septic systems located within 300 m of the lake in 2002.

Marsh Lake is a shallow lake surrounded by swamp and bog wetlands. The surface area of Marsh Lake is approximately 21.8 ha but this does not include the wetlands surrounding the lake. Marsh Lake has a short retention time compared to Sandy Lake and is the last lake before discharge into the Sackville River.

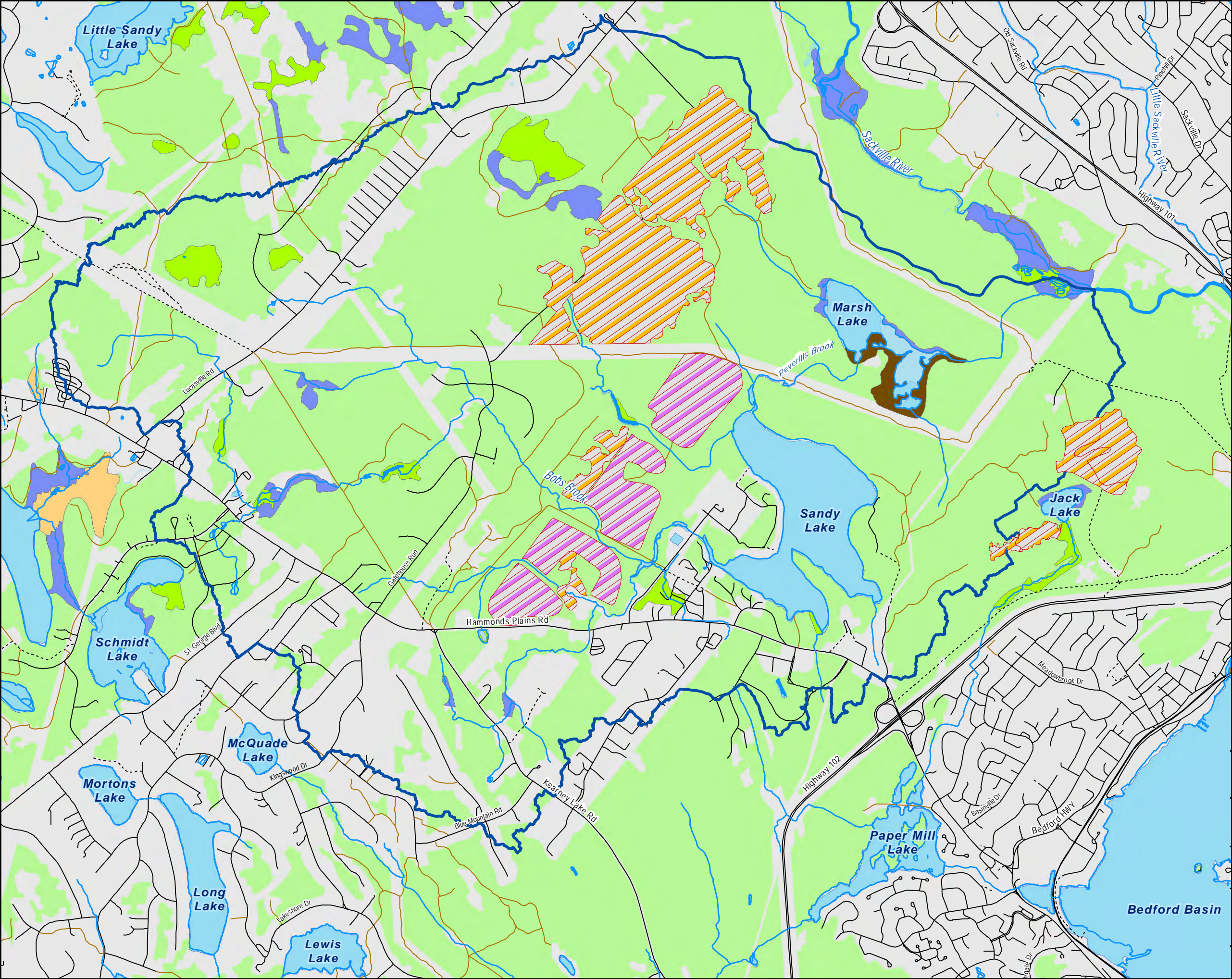
### 2.2 Forests and Wetlands

The Sandy Lake watershed is located the Eastern Ecoregion of Nova Scotia. Ecoregions in Nova Scotia are subdivisions of the larger Acadian Ecozone. Ecoregions are characterized by a distinctive ecological response to climate through soils and vegetation (Neily *et al.* 2003). Ecoregions are further subdivided into ecodistricts that reflect the major landforms within an ecoregion. Ecodistricts have geology and soils that are distinct from adjacent ecodistricts. Two ecodistricts are present within the Sandy Lake subwatershed: the Eastern Drumlins Ecodistrict (unit 420) around Sandy Lake and downstream to the Sackville River and the Eastern Interior Ecodistrict (unit 440) occupying the remaining two thirds of the subwatershed (NSDNR 2007).

The vegetation in the Sandy Lake watershed is typical of mixed hardwood and softwood forests in southern Nova Scotia. Higher proportions of hardwood are found on drumlins and upland soils while softwoods are more common in low lying area with poorly drained soils (Neily *et al.* 2003). The forests within the watershed have been harvested for lumber several times in the past two hundred years, resulting in a mosaic of forest types of various ages and species composition (Thompson 2001). The area covered by forest is defined as area with >70% forest cover using data from NSDNR forestry inventory. Approximately 48% of the surface area within the watershed is currently occupied by forest (**Figure 3**). Mature hemlock forest has been identified on the southern peninsula of Sandy Lake. Orchids and lady slippers have reportedly been observed near the shorelines of Sandy and Marsh Lakes (Dalhousie 2002).

Approximately 85 ha of the watershed are wetlands, which make up about 3.5 % of the watershed area. This is a small proportion relative to the size of the watershed and suggests the watershed is well drained.





**Legend**

—

Watercourses

—

Roads

—

Trails

----

Nova Scotia Power Access Roads

Lakes

Sandy Lake Watershed

2013 Logged Areas\*

Logged Areas\*\*

> 70% Forest Cover

Urban Area

**Wetland Class**

Bog

Fen

Marsh

Swamp

Water

Interpreted from Aerial Photographs

\*\* From Forestry Inventory (NSDNR)

Sandy Lake Area Watershed Study

Wetlands and Forest Cover

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM, NSDNR Forestry Inventory,  
NSDNR Wetland Inventory

**AECOM**

Figure 3

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\6030307 Sandy Lk900-CAD-GIS\020 GIS-Graphics\Design\Preston Base Map.mxd



## 2.3 Fish and Fish Habitat

Historically, Sandy Lake, Peverills Brook and to a lesser extent Marsh Lake were spawning grounds for Atlantic salmon (SRA 2013). However, reductions in surface water pH (Clair *et al.* 2007) and modifications to the Sackville River (such as dams and damage caused by transporting logs in the river) have severely restricted salmon spawning in the watershed. Although the pH of surface water in the watershed has increased in recent years, salmon populations remain limited in the Sackville River. In 2012, the Sackville River Association completed restoration along Peverills Brook to improve spawning conditions upstream and downstream of Marsh Lake. Sandy Lake is used for sport fishing and contains trout, bass, perch, gaspereau, American eel, chub, stickleback, shiner, shad, sea trout and catfish (Dalhousie 2002).

In the early 1980s, the Department of Fisheries and Oceans (DFO) added lime in the form of calcium carbonate to Sandy Lake to increase the pH and create more favourable conditions for fish including Atlantic salmon (White *et al.* 1984). The study concluded that although it is feasible to maintain pH through the addition of calcium carbonate, this material must be added at frequent intervals where lakes are small and the flushing rates are rapid. The program of calcium carbonate supplementation was not continued pursuant to the study findings. Historical and anecdotal evidence suggests Sandy Lake, Marsh Lake and Peverills Brook support a healthy, but vulnerable fish population.

## 2.4 Important Habitats

Historically, Sandy Lake was a sport fishing lake where Atlantic salmon were harvested (Dalhousie 2002). As noted, salmon spawning habitat is currently present along Peverills Brook between Marsh Lake and the Sackville River and between Marsh Lake and Sandy Lake. The Nova Scotia Upland population of Atlantic salmon is designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and so the preservation and enhancement of habitat used by this species is a national priority. The salmon spawning habitat downstream of Marsh Lake is potentially vulnerable to changes in water quality that may result from upstream land development.

Much of the watershed forest has been harvested multiple times, producing a relatively young forest cover throughout most of the watershed. A mature hemlock grove is reported on the southern 'hemlock' peninsula of Sandy Lake. This stand of trees represents a mature forest and is considered an important feature in the local environment by residents of the area (Dalhousie 2002).

Wetlands have been identified in several areas of the Sandy Lake watershed (SRA 2011; Thompson 2001). Wetlands provide habitat for a variety of aquatic and terrestrial species. Within the Sandy Lake watershed these species reportedly includes snapping turtles, eastern wood turtles, numerous amphibians and orchids. Wetlands also improve water quality and moderate storm runoff events, acting as stormwater detention ponds to slow flows and remove contaminants. The wetlands near Marsh Lake contribute to the aquatic health of the Sackville River and are considered an important habitat within the watershed. Marsh Lake and its associated wetlands also appear to be critical habitats for many bird species of conservation concern (Appendix A).

## 2.5 Surficial and Bedrock Geology

The bedrock beneath most of the watershed consists of metamorphosed sandstone called quartzite of the Goldenville Group (**Figure 4**). In contrast, the northwest portion of the watershed along the Lucasville Road is underlain by slate-rich Halifax Group bedrock. Sulphur bearing minerals such as pyrite are abundant in slate but are less common in quartzite. The sulphur bearing minerals in the Halifax Group can produce acid rock drainage when the pyrite-containing rocks are excavated and exposed to oxidizing conditions. This acidic drainage may in turn damage aquatic habitats. As a result of the bedrock geology, there is more acid generating potential in bedrock in the northwest portion of the watershed compared to the south/southeast area where the acid generating potential is low (Conrad *et al.* 2002).

Bedrock in the watershed is covered with glacial till (a mix of clay, sand, gravel and boulders), with a minimum average thickness of approximately 3.0 m (Thompson 2001). In the northwest, this till is largely derived from the

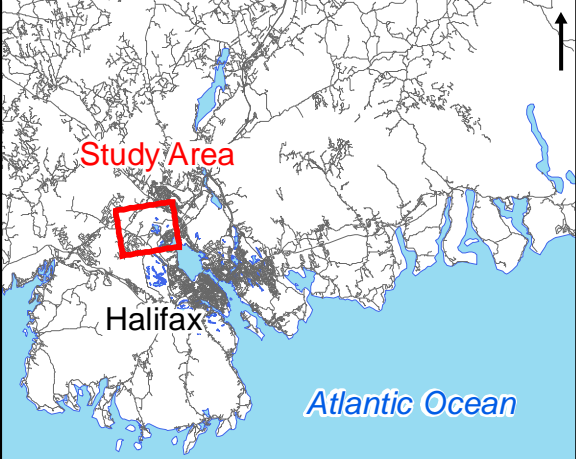
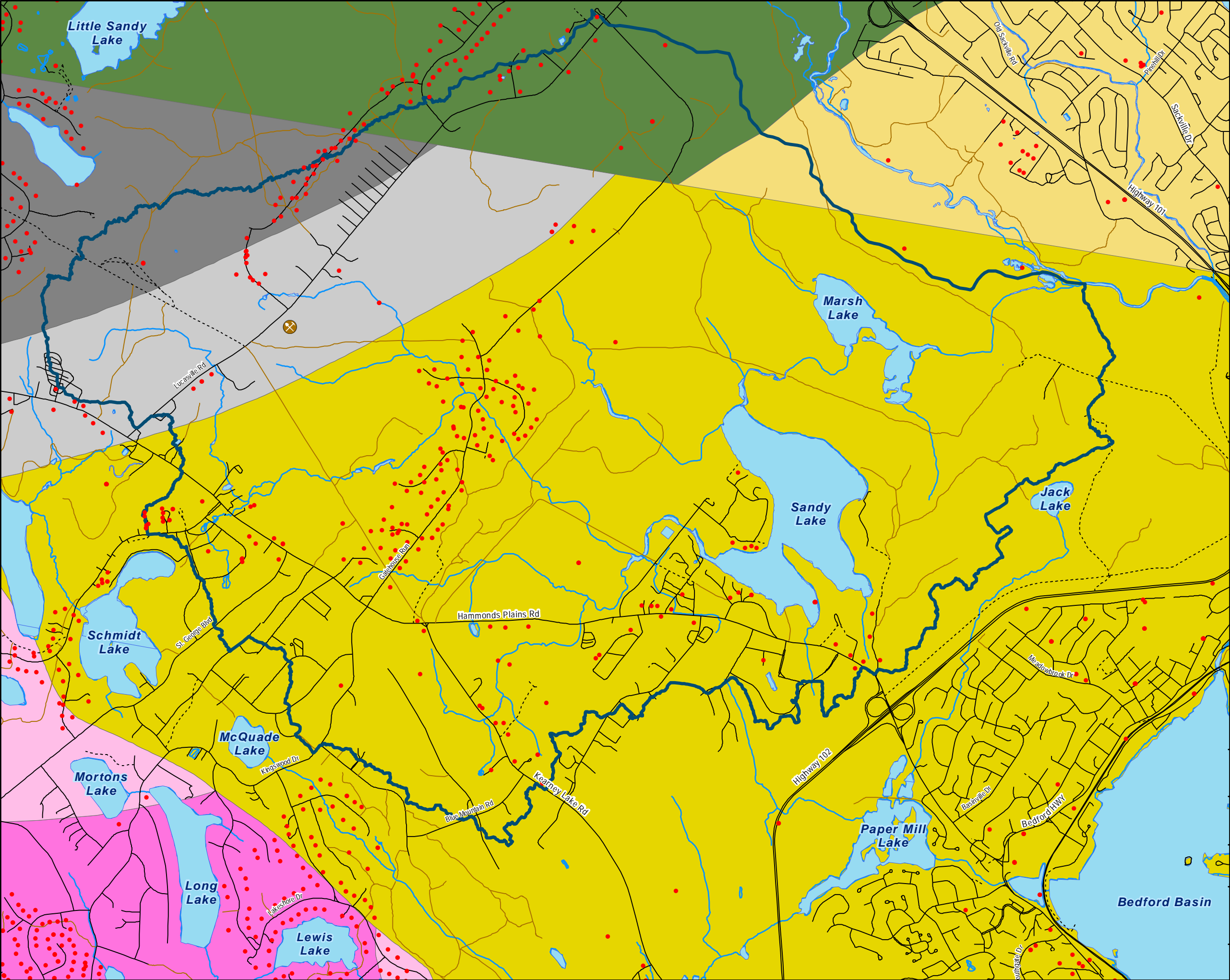
underlying slate while the remainder of the watershed is covered by till derived from the quartzite. In general, both of these tills are loose and sandy (**Figure 5**). Drumlin deposits (low, smoothly rounded, oval mounds of glacial till) dominate much of the area surrounding Sandy Lake itself. Drumlin deposits also dominate the surficial geology in the north and northeast portions of the watershed. These sandy hills are potentially good sources of potable groundwater; a locally significant aquifer is tentatively identified on Figure 5. Between the drumlins, the bedrock is thinly covered by poorly drained glacial till. A possible fluvial (river-based) deposit is interpreted to underlie the drumlins surrounding Sandy Lake and Marsh Lake (Utting 2011b).

## 2.6 Groundwater

As noted, municipal drinking water is provided to many residents along Hammonds Plains and Lucasville Roads. However, groundwater is a source of domestic water for many residents living within the watershed, particularly those along Gatehouse Run and the connecting streets in the central portion of the watershed (**Figure 4**). Groundwater is found in both bedrock and surficial aquifers, but most potable groundwater wells are completed in bedrock. Records of 100 wells installed within the watershed indicate the yield of bedrock wells is typically less than 20 L/min. This is generally sufficient for individual residential consumption and is consistent with observed average yields of HRM bedrock wells (FracFlow 2004).

Groundwater quality data are limited in the Sandy Lake watershed, but results from three samples reported by NSDNR (2013) indicate the groundwater quality is generally good and is consistent with groundwater quality elsewhere in the region (AECOM 2013). One of the three samples was taken from an aquifer in the surficial deposits while the other two were taken from bedrock aquifers. The surficial aquifer sample exhibited elevated concentrations of iron, manganese, sodium and chloride. All three samples exhibited elevated concentrations of dissolved minerals indicating “moderately hard” water.

Groundwater recharge rates were estimated for the Sandy Lake watershed using a GIS based groundwater recharge model (**Appendix D**). Groundwater recharge occurs throughout the study area, but is greatest in areas where the slope is moderate, vegetative cover allows for infiltration and the soils are coarse grained and permeable. Areas with higher recharge are shown on **Figure 6**. These areas are in the drumlin-rich areas north and east of Sandy and Marsh Lakes extending toward the Sackville River. Areas with high groundwater recharge rates are ecologically valuable since they produce cool, clean baseflow to streams, lakes and wetlands during low-flow periods. They also represent areas of potential groundwater vulnerability since pollutants released at surface can access deeper potable water aquifers through the recharge path. The protection of these areas is a priority identified in Regional Plan Policy E-17.



### Legend

- Abandoned Mine
- Water Wells \*
- Watercourses
- Roads
- Trails
- Nova Scotia Power Access Roads
- Lakes
- Sandy Lake Watershed

### Sandy Lake Geology

South Mountain Batholith (Granite)	Quarry Lake Granoidorite
	Sandy Lake Biotite Monzogranite
Halifax Group	Cunard Formation
Goldenville Group	Beaverbank Formation
	Taylors Head Formation

\* Water Well locations are approximate and based on the NSE well database.

### Sandy Lake Area Watershed Study

#### Bedrock Geology

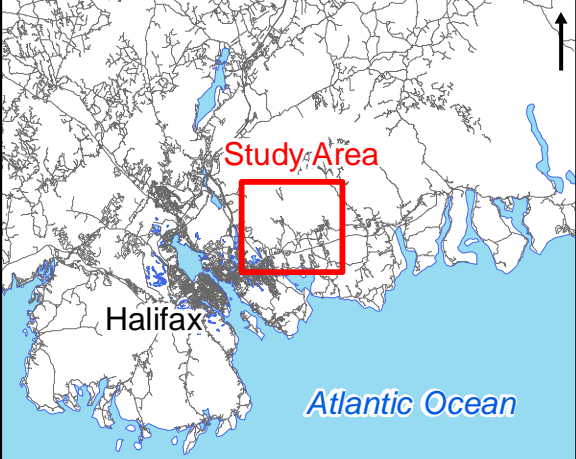
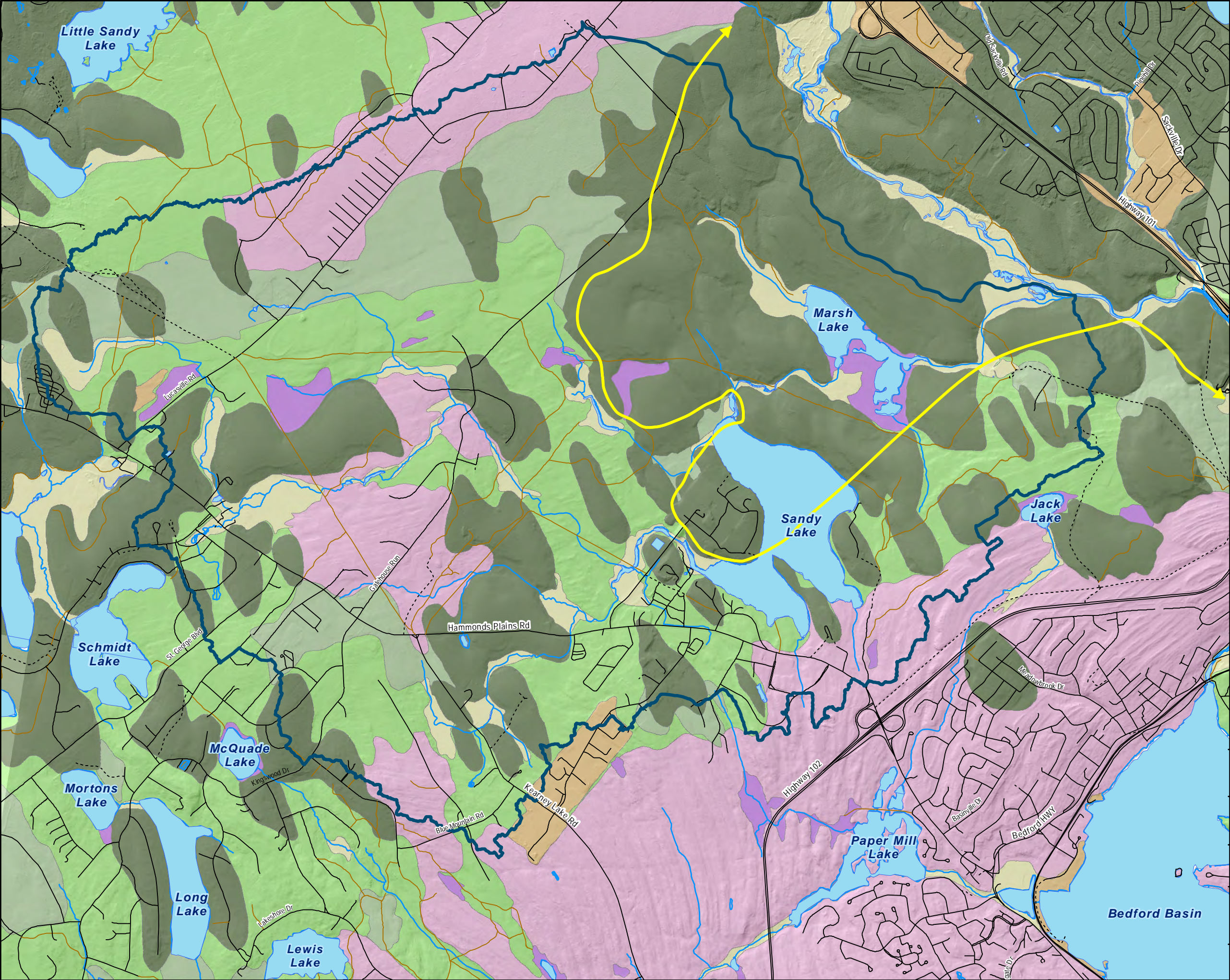
September 2014	1:25,000	Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM, After Keppie 2000 White <i>et al.</i> 2008
----------------	----------	--

### Figure 4

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\6030307 Sandy Lk900-CAD-GIS\920 GIS-Graphics\Design\Preston Base Map.mxd





Legend

Watercourses

Roads

Trails

Nova Scotia Power Access Roads

Approximate extent of Surficial Aquifer\*

Sandy Lake Watershed

Lakes

Wetlands

**Holocene**

Anthropogenic (Geologic Materials Changed by Human Activities)

Alluvial

Lacustrine

**Pleistocene**

Hummocky till

Till blanket

Till veneer

Drumlins

**Paleozoic**

Bedrock

\* Kennedy and Utting 2011

Sandy Lake Area Watershed Study

Surficial Geology

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM, Utting 2011a

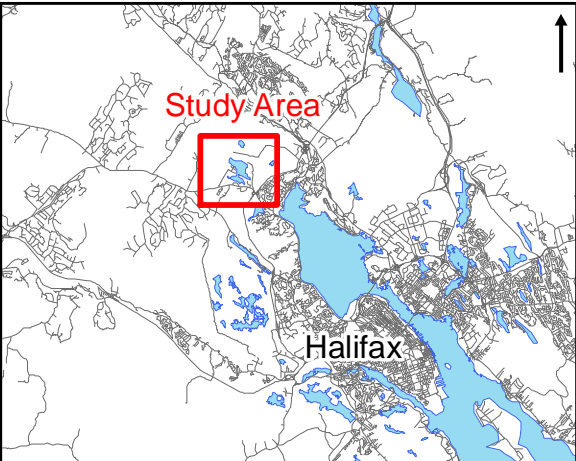
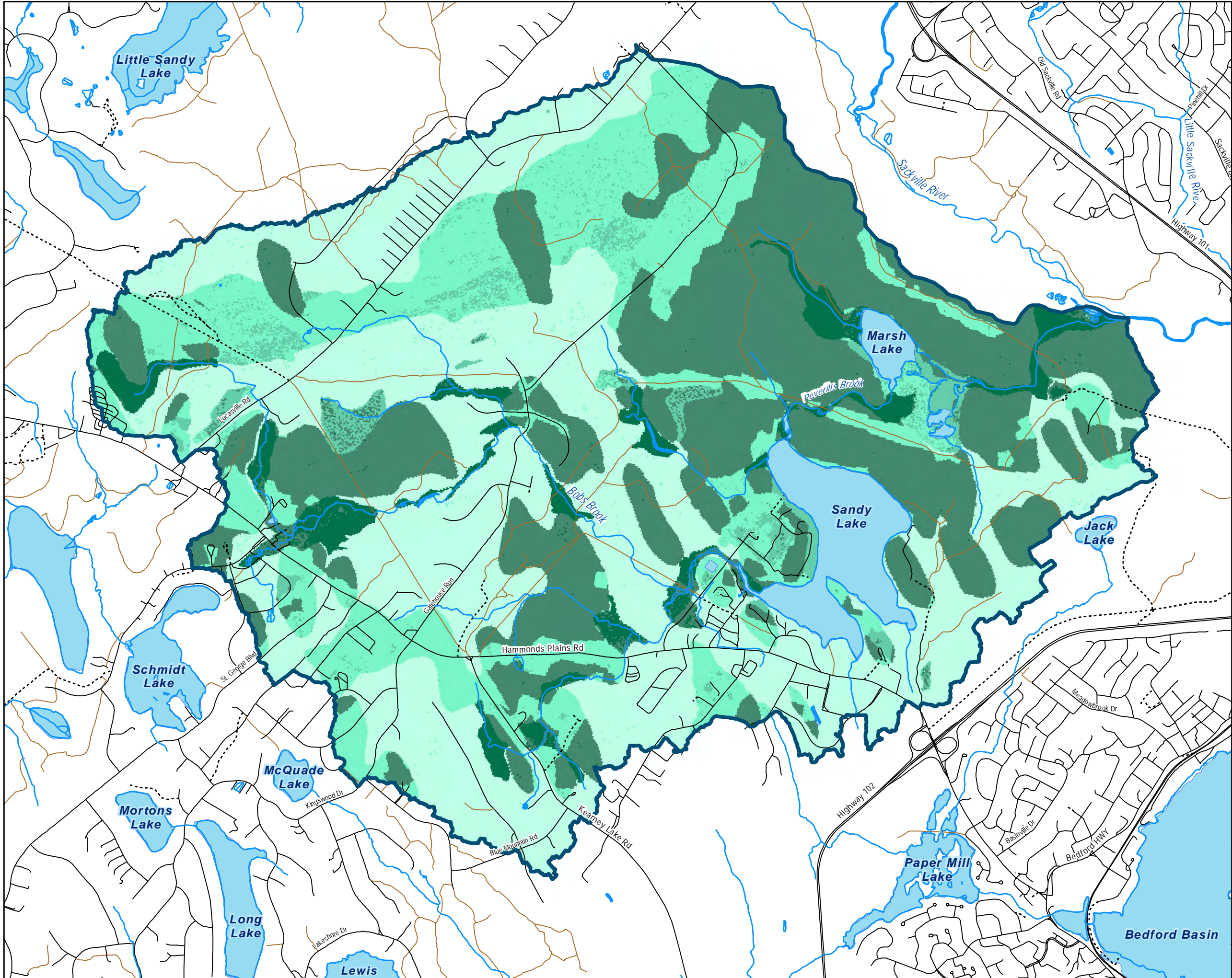
**AECOM**

Figure 5

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk900-CAD-GIS\020 GIS-Graphics\Design\Preston Base Map.mxd





**Legend**

Watercourses

Roads

Trails

Sandy Lake Watershed

**Recharge (m<sup>3</sup>)**

< 50

50 - 100

100 - 150

150 - 200

> 200

Annual Recharge: 2,360,000 m<sup>3</sup>

Annual Runoff: 18,280,000 m<sup>3</sup>

Total Annual Discharge: 20,640,000 m<sup>3</sup>

Sandy Lake Area Watershed Study

Sandy Lake Watershed Groundwater Recharge Potential

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM & Hal. Water

**AECOM**

Figure 6

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk\900-CAD-GIS\920 GIS-Graphics\Design\Final Draft Report - Sandy\Figure 6 - GroundwaterRecharge 20140711.mxd



## 3. Development in Sandy Lake Watershed

### 3.1 Historical and Existing Development

Hammonds Plains Road is one of the oldest roads in Nova Scotia, historically connecting Lunenburg to Halifax. It bisects the southern portion of the Sandy Lake watershed and is still used as a primary commuter route by many residents of Hammonds Plains and nearby villages. Lucasville Road connects Hammonds Plains Road to Sackville and cuts across the northwestern portion of the watershed.

The Sandy Lake area initially used the water and wood resources to operate lumber mills in the 1800s. Residential development of Sandy Lake began in the 1900s with the establishment of cottages and agricultural land. The area was utilized primarily for recreation and seasonal or full-time residence until the 1970s. Beginning in the 1970s development included the Farmers Dairy on 45 acres west of the lake, Peerless subdivision and the 112 acre Atlantic Acres Industrial Park. The development of Atlantic Acres Industrial Park included the infilling of Verge's Marsh with rock and peat. In 1978 the Pockwock Lake water supply for Halifax was completed, including a main supply line across the western portion of the watershed and a secondary line south of Sandy Lake.

Kingswood subdivision south of Hammonds Plains Road was developed in the 1990s and contains hundreds of homes. Although it is serviced by municipal water, residents use individual septic systems for their wastewater treatment. Subsequently, the Kingswood North subdivision (north of Hammonds Plains Road) was developed. It currently contains 50-75 homes with additional residences under construction. Residents of Kingswood North have both private wells and private septic systems. Lucasville is located in the northeastern portion of the watershed and has hundreds of residents on private wells and septic systems, although municipal water is provided along the Lucasville Road itself (**Figure 2**).

In 1970, the Timber Trails mobile home park was established and expanded in 1998. It is currently occupied with 233 homes on Lucasville Road. It will be expanded by 167 units over the next 5 to 8 years. The mobile home park uses a private communal septic system to treat wastewater, but is in the process of having the wastewater treatment system upgraded.

In 2002, the Sandy Lake Lion's Park and Beach opened as a public park on the eastern side of Sandy Lake. The Park contains a dog off-leash area, parking for 100 cars, a 450-person capacity artificial beach, public washrooms and change rooms (Conrad *et al.* 2002).

In 2002 a set of studies were completed by Dalhousie for the Sandy Lake Area Residents Association which documented environmental conditions (Thompson 2001), demographics and development history (Dalhousie 2002a) to provide a set of recommendations for managing development in the watershed (Dalhousie 2002b).

In 2009, an HRM commissioned report (CBCL 2009) provided cost estimates for servicing water, sanitary, stormwater and transportation links using various development scenarios in the 'Greenfield' area near Sandy Lake. In 2012, HRM Council agreed to oversize wastewater infrastructure through Bedford West to service potential future development of the Sandy Lake Greenfield area. In 2013 Armco Communities, developer and largest land owner, initiated forest clearing within the watershed. Armco Communities has since sold this property to Clayton Developments. As noted, HRM intends that future growth around Sandy Lake will be accommodated through central water and sewer services. A stormwater management plan will be developed by the property owner for approval by HRM and Halifax Water, in accordance with its Design and Construction Specifications guide book for the applicable calendar year (HRM request for proposal, this study).

### 3.2 Potential Sources of Contamination

Lakes within urbanized areas are exposed to different pollutant sources than those in rural areas. Residential and commercial development is characterised by concrete, asphalt and hard-surface buildings. This development converts portions of the environment to impermeable surfaces, which restrict infiltration of rainwater and snowmelt. Urbanization also alters the state of natural vegetation, destroying or thinning existing vegetation or changing vegetation types. Urbanization typically leads to an increasing volume of runoff water, faster runoff from the watershed to the lake, decreased ability for water to naturally infiltrate into the soil and introduction of water-borne pollutants to the lake.

Two types of pollutants are found in the Sandy Lake watershed; point sources and non-point sources. Point sources of pollution are from single, identifiable locations where the pollution is entering the environment. An example of point source pollution is a sewage outfall location to a receiving water body. Non-point sources of pollution occur from many locations or are diffuse over a wide area. An example of non-point source pollution is application of pesticide on an agricultural field.

“Point source” pollutant inputs to lakes include outfalls from wastewater treatment plants, industrial effluent, landfill sites, illegal dump sites, underground fuel reservoirs and septic systems. Point source pollutants may degrade the water quality depending on the quality and quantity of discharge. In the case of outfalls from wastewater treatment plants, the facility may overflow and bypass the treatment cycle during storms or malfunctions. Untreated wastewater discharge carries high nutrient loads, especially phosphorus and can significantly add to the natural and non-point loading of phosphorus to lakes resulting in their rapid eutrophication.

This “non-point” source of pollution poses the most serious threat to the water quality of urban lakes. During rainstorms, urban non-point sources of pollution contribute sediments, oil, anti-freeze, road salt, pesticides, nutrients and pet and waterfowl droppings. These are carried into surface waterways by overland runoff and storm sewer systems. This urban runoff generally accelerates the eutrophication or natural aging process of urban lakes by adding sediment and nutrients. The added nutrients can result in algal blooms, decreased water clarity, and an increase in the amount of rooted aquatic plants growing in the shallow near-shore waters of a lake. All of these can reduce the recreational value of a lake by hindering swimming, boating, fishing and reducing its overall aesthetics. Moreover, large algae populations can cause odour problems and can lead to the depletion of a lake’s oxygen supply and possibly to fish kills. Additionally, the increase in impervious surfaces, such as asphalt roads, and heat retention of these surfaces may increase water temperature, which can also adversely affect the lake’s aquatic health.

Urban lakes are invaluable to urban environments. Yet, due to the very fact that they are located within urban watersheds, these lakes are adversely affected by stormwater runoff and heavy recreational use that results from the easy access to urban lakes. A comprehensive management approach that includes techniques both in-lake and within the lake’s watershed must be used to protect urban lakes from pollution sources. It is more cost-effective to manage urban development within the watershed in order to maintain established water quality objectives than to try to improve or restore water quality after the lake has degraded to an unacceptable condition.

A list of potential contaminant sources that may be present within the Sandy Lake watershed is presented in **Table 1**. The potential sources of contamination are discussed in more detail in Section 10 (Policy E-17 Objectives).

**Table 1. Potential Sources of Contamination**

Potential Source of Contamination	Nutrients	Metals	Arsenic	Low pH	Sediments	Petroleum Hydrocarbons	Pesticides/Herbicides	Bacteria	Chloride
Aging Septic Systems	X							X	
Unauthorized Waste Disposal		X				X			
Wastewater Treatment Plants	X							X	
Past/Present Mining Activities		X	X	X					
Bedrock		X	X	X					
Industrial Effluent		X				X			
Forestry Practices	X				X		X	X	
Road Salt Application and Storage									X
Urban Development	X	X			X	X	X	X	X
Gas Stations						X			
Residential Oil Tanks						X			
Landfills	X	X		X		X			
Motor Boats						X			
Dog Park	X							X	

Wastewater in the Sandy Lake watershed is a source of nutrients (nitrogen and phosphorus) to the waterbodies that can impact water quality. Wastewater systems utilized in the Sandy Lake watershed include:

#### *Septic Systems*

Aging septic systems may not be effective at reducing phosphorus from water dispersed in the septic field. The systems may not function as designed because the system components are broken or corroded. The soils in the septic field exhaust their retention capacity and become saturated with phosphorus as the system ages. This saturation results in the discharge of phosphorus to groundwater and surface water that can increase the phosphorus load to lakes. In the Sandy Lake watershed there are no residences on Marsh Lake and there are approximately 20 residences situated within 300 m of Sandy Lake and approximately 200 residences within 300 m of watercourses. These residences rely on private septic systems to treat residential wastewater. In addition, trailhead peat toilets were installed at the Lion's Beach Park in 2002. Given their proximity to the lake, all of these systems are potential sources of nutrients to Sandy Lake depending on their age and maintenance history.

#### *Farmers Dairy*

The Farmers Dairy facilities may have had impacts on water quality since it was constructed in the early 1970s. Erosion from areas logged prior to construction may have resulted in lake siltation in the early 1970s. Treated wastewater discharges from the dairy were associated with water quality impacts as reported by lakeside residents in the 1980s (Dalhousie 2002). The Farmers Dairy currently has a primary wastewater treatment facility consisting

of two open-air lagoons. Discharge from the lagoons is directed to the municipal sanitary and the Mill Cove Wastewater Treatment Plant (T. Blouin, Halifax Water, pers. comm.).

#### *Uplands Park - WWTF*

The Uplands Park Wastewater Treatment Facility (**Figure 1**) was built in 1969 and consists of a primary clarifier, a trickling filter with rock media, a secondary clarifier, and hypochlorite disinfection. The plant has a rated capacity of 91 m<sup>3</sup>/day with a peak capacity of 178 m<sup>3</sup>/day, and serves a population of approximately 170 people. The effluent discharge criteria is 20 mg/L for both biochemical oxygen demand (BOD) and total suspended solids (TSS). In 2009 the plant was upgraded to ultraviolet disinfection (Halifax Water 2008). The plant discharges approximately 40 m<sup>3</sup> of treated effluent per day into a wetland/creek approximately 3.5 km upstream of Sandy Lake (T. Blouin, Halifax Water, pers. comm.).

In the early 2000s sewage leaks from broken sewer lines southwest of Sandy Lake affected lake water quality. Boil water and no swim advisories for Sandy Lake were issued by the municipality. Following the breaks, the force mains were replaced by Halifax Water (K. Mackenzie, Halifax Water, pers. comm.).

#### *Timber Trails*

The Timber Trails mobile home park is serviced by communal septic systems. In 2008, North West Community Council entered into a development agreement to enable an expansion of the Timber Trails mobile home park in support of upgrading its old sewage system. The old system had reportedly suffered from overflows and seepage during heavy rain events. As of August 2012, the park expansion has not occurred but detailed engineering of the new waste water treatment facility was underway (HRM Staff Report 2012). Since then, the waste water treatment facility has been upgraded but is not yet operational (A. Bone, HRM, pers. comm.).

### **3.3 Development Constraints**

The potential impacts of development on water quality in Sandy Lake can be mitigated, to a degree, by the implementation of effective planning strategies. To this effect, a constraints map is developed for the Sandy Lake watershed identifying areas that are not suitable for development and areas that are suitable for development, but may require environmental controls to mitigate potential impacts on surface water quality. Consequently, a constraints map (**Figure 7**) has been developed. Two categories of constraints are identified; Type 1 and Type 2. Type 1 constraints are for areas where development is not recommended to occur to protect water quality. Watercourses, wetlands and watercourse buffers are considered Type 1 constraints. Type 2 constraints are for areas where methods to protect the environment may be required if development occurs in these areas. Areas with high groundwater recharge, areas underlain by acid generating bedrock and slopes greater than 20% are areas recommended for Type 2 constraints.

The Type 1 constraints include watercourses and associated buffers surrounding the watercourses. A review and analysis of setbacks and vegetated buffers in Nova Scotia was undertaken by Hydrologic Systems Research Group (2012) indicating the effectiveness of buffer widths varies depending on the pollutant of interest. For sediment and phosphorus, a 5 m buffer will remove an estimated 50% of these pollutants. The 20 m buffer along all water courses used in the constraint analysis is reported to eliminate more than 70% of suspended sediment and more than 60% of phosphorus (Hydrologic Systems Research Group 2012). As illustrated in **Figure 7** we have assumed there will be an automatic 20 m setback for all development along watercourses, wetlands contiguous with watercourses, and lakes. This buffer should ideally be retained in a natural vegetation state to reduce overland flow during storm events and to provide a buffer zone for nutrients, pesticides and other pollutants from developed areas both during and following construction.

Type 2 constraints are reserved for areas suitable for development but may require additional environmental controls. Areas with steep slopes (>20%) are more likely to erode and contribute sediment to watercourses. The areas in Sandy Lake watershed with slope greater than 20% are identified in **Figure 7** and are recognized as development constraints in the watershed. Prior to development, these areas should be assessed to evaluate if

erosion is likely based on the occurrence of bedrock (less likely) or surficial deposits (more likely). If development proceeds in these areas, sediment control methods are recommended to prevent high sediment loads from entering the watercourses.

Acidification from the exposure of sulphide bearing bedrock can reduce the pH of watercourses in HRM (White and Goodwin 2011). The slates of the Cunard Formation, the Beaverbank Formation and the Halifax Group are especially prone to producing acid drainage when exposed to the air. These slates occur in the extreme northwest part of the Sandy Lake watershed. The areas underlain by the Cunard Formation, the Beaverbank Formation and the Halifax Group rocks (**Figure 4**) are designated as Type 2 constraints. Development in these areas will be required to follow the *Sulphide Bearing Materials Disposal Regulations* under Section 66 of the Environment Act.

Areas with high groundwater recharge potential are important to groundwater users and the lakes and streams in the Sandy Lake watershed. The groundwater recharge model completed for the Sandy Lake watershed used surficial geology, slope and vegetative cover to predict how precipitation is partitioned into groundwater recharge and surface runoff. Areas with high groundwater recharge (>150 mm/yr) provide pathways for water to enter the groundwater system. Protecting these areas with high recharge is important to the groundwater quantity of the watershed which is utilized by water source wells and contributes to the hydraulic budget of the lakes in the watershed. Protecting these areas also protects groundwater quality in the watershed because they are potential pathways for contaminants to enter the groundwater system. Therefore, areas with recharge >150 mm/yr identified in **Figure 6** are included in the development constraints as a Type 2 constraints. It is recommended that areas identified to have high groundwater recharge potential are suitable for development with conditions that allow for recharge rates to be maintained, such as:

- Restricting the types of development to developments with low risk for groundwater contamination; and
- Implementation of groundwater quality protection measures to avoid groundwater contamination.

## 4. Water Quality

Lake chemistry and water quality are discussed in detail in **Appendix B**. Essential to the discussion of lake water quality are the concepts of trophic status and nutrients. The generalized categories of trophic status for lakes based on Total Phosphorus concentrations used for classification in this study are:

- Oligotrophic: 4-10 µg/L;
- Mesotrophic: 10-20 µg/L; and
- Eutrophic: > 20 µg/L.

### 4.1 Water Quality Data Sources

Sandy Lake is historically a low pH, low alkalinity lake typical of lakes in southern Nova Scotia (White *et al.* 1984). In the past, pH generally ranged from 4.5 to 5.0 indicating acidic conditions. As noted above, Sandy Lake was treated with calcium carbonate by DFO in 1981 to improve water quality.

Historical water quality data provide context for current water quality conditions. These data can also be used as a benchmark for understanding how water quality conditions will change over time. Water quality in Sandy Lake has been monitored on an irregular basis from 1980 to the present. **Table 2** presents the data sources used for this report, which are presented in full in **Appendix C**. In keeping with direction given in the Regional Plan, the water quality objectives recommended in this report are based on current or existing water quality. For this reason, the discussion below focuses mainly on water quality data collected over the past five years, which is considered representative of existing conditions.

Sandy Lake was included in water quality monitoring programs conducted by:

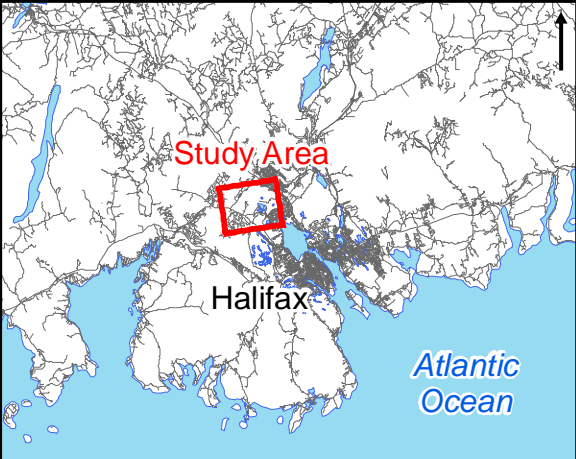
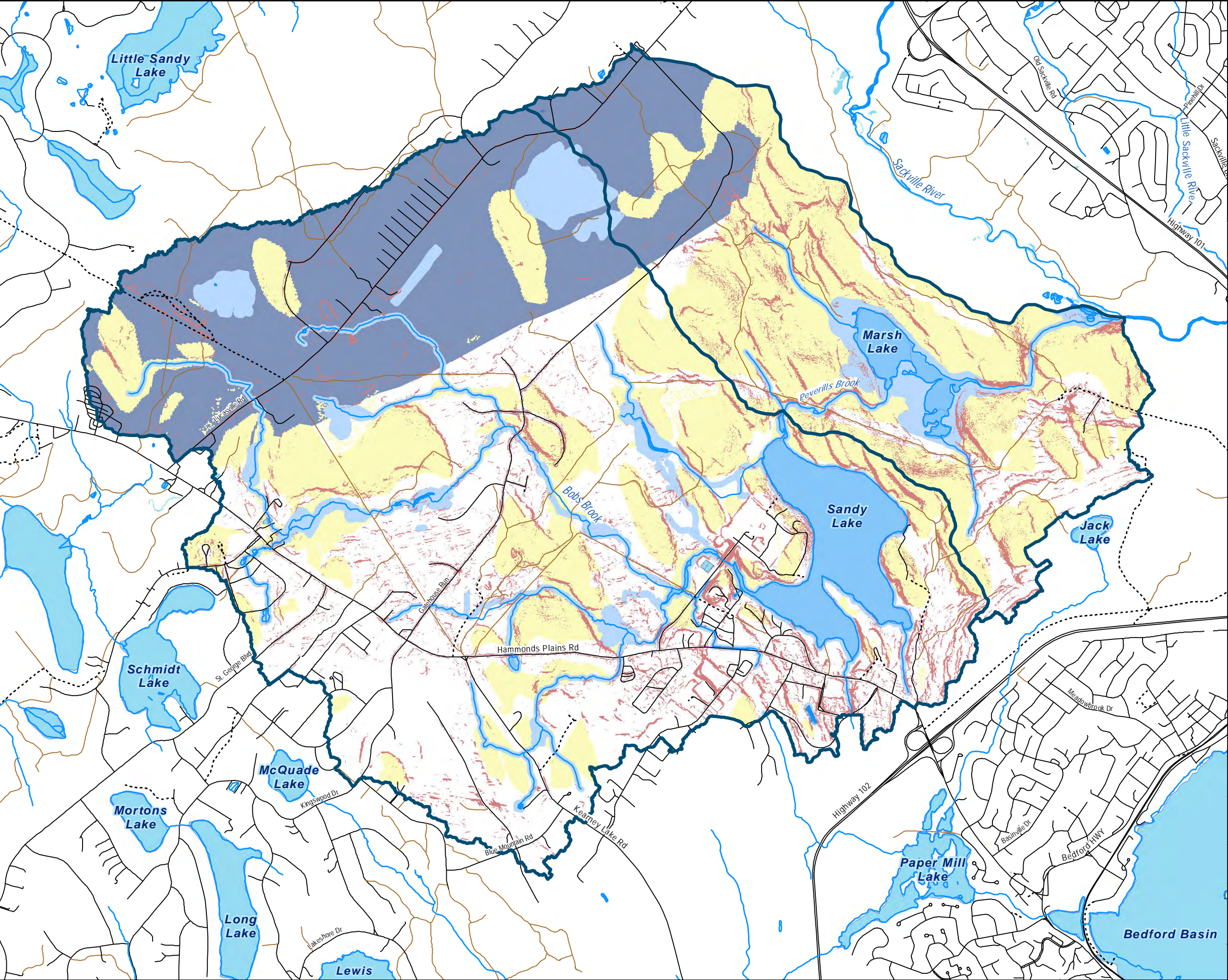
1. The Department of Fisheries and Oceans (DFO) in 1980, 1991 and 2000;
2. Nova Scotia Environment (NSE) in 1998;
3. Dalhousie Environmental Engineering students in 2001 (Conrad *et al.* 2002); and
4. HRM from 2006 to 2011.

In addition, Sandy Lake water quality data from 2005 to 2007 was collected by a resident of the community and a single sample from Marsh Lake was analyzed by NSE in 2007.

AECOM collected samples from the outlets of Sandy Lake and Marsh Lake as part of this study. The AECOM sampling program consisted of three sampling events: low flow conditions (August 2013), following lake turnover (November 2013) and spring run-off (April 2014). Sample locations are shown on **Figure 1**.

Analytical results from the Uplands Park wastewater treatment facility (WWTF) were obtained from Halifax Water and provide information on treated effluent quality discharged from the plant. The samples are collected from a sampling port within the plant (at the end of the treatment process) just prior to entering the discharge pipe. The treated effluent is discharged to a wetland and creek which eventually empties into Sandy Lake approximately 3.5 km from the discharge point. Sample locations are shown on **Figure 1**.





**Legend**

Watercourses

Roads

Trails

Gravel Roads

Sandy Lake Subwatersheds

**Type 1 Constraints**

Watercourses, Wetlands and Riparian Buffers

**Type 2 Constraints**

Slope Greater than 20%

Bedrock with Acid Generating Potential

Groundwater Recharge (>150 mm/yr)

Sandy Lake Area Watershed Study

Constraints Mapping

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM & Hal. Water

**AECOM**

Figure 7

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk\900-CAD-GIS\920 GIS-Graphics\Design\Final Draft Report - Sandy\Figure 7 - Constraints 20140711.mxd



## 5. Water Quality Data Analysis

**Table 2. Data Used to Establish Current Water Quality**

Sampled by	Sampling Location Description	Sampling Period	Number of Samples	Parameters
HRM	Sandy Lake	2006-2011	14	Nutrients, General Chemistry, Bacteria, Ammonia, Metals, Chlorophyll-a
HRM	Sandy Lake Outlet	2007-2011	11	Bacteria
Halifax Water	Uplands Park WWTF	2012 - 2013	32	pH, ammonia, total phosphorus, TSS, fecal coliform, BOD
AECOM	Sandy Lake Outlet and Peverills Brook (Marsh Lake Outlet)	August and November 2013, April 2014	3	Nutrients, Bacteria, Metals, chlorophyll-a
Nova Scotia Environment	Marsh Lake	2007	1	Nutrients, general chemistry, chlorophyll-a

*TSS – total suspended solids. BOD – biological oxygen demand.*

Data analysis is focussed on several key “indicator parameters”. These parameters are particularly sensitive to changes in land use within a watershed, such as when forested land is converted to residential and commercial developments. By examining changes to these parameters over time, probable causes of water quality impacts may be identified. Where available, these parameters included:

### **Indicators of nutrient enrichment and trophic status**

- Total phosphorus (TP);
- Total Kjeldahl nitrogen (TKN); and
- Chlorophyll a.

### **Indicators of water clarity**

- Total suspended solids (TSS); and
- Secchi depth.

### **Indicators of anthropogenic or “human” inputs**

- Nitrate;
- Ammonia;
- E. coli; and
- Chloride.

When analyzing laboratory results, data points that were less than the detection limit were considered equivalent to the detection limit concentration. For example, reported values for total suspended solids of <1 mg/L were processed as 1 mg/L. If however, results showed that some detection limits were well above the background values, then these high detection limit data were discarded. This was especially the case for total phosphorus where the use of ‘high detection limit’ data could significantly affect the determination of average lake concentrations.

Total phosphorus (TP) has different detection limits depending on the technique used to analyze the samples. Care was taken to use only those results with sufficiently low detection limits in the statistical analysis. For example, any phosphorus result equal to or below the detection limit of 20 µg/L was removed from analysis, because the actual concentration could range very widely – from 0 to 20 µg/L. If a result was above the detection limit of 20 µg/L, the value was retained for data analysis, and was considered representative of an actual phosphorus concentration.

## 5.1 Sandy Lake

Lake water quality in Sandy Lake is typical of southern Nova Scotia lakes underlain by metamorphosed sedimentary bedrock and glacial till. The total alkalinity is low (<10 mg/L) reflecting the low buffering capacity of the soils. The pH of Sandy Lake was historically low (4.9 in 1980 and 5.3 in 1991), but pH values now range from 6.45 to 7.36.

Recent water quality data for the key indicator parameters from all sample stations are summarized in **Table 3**. Table 3 summarizes the results of the sampling programs listed in Table 2; older data not included in Table 3 are presented in Appendix C.

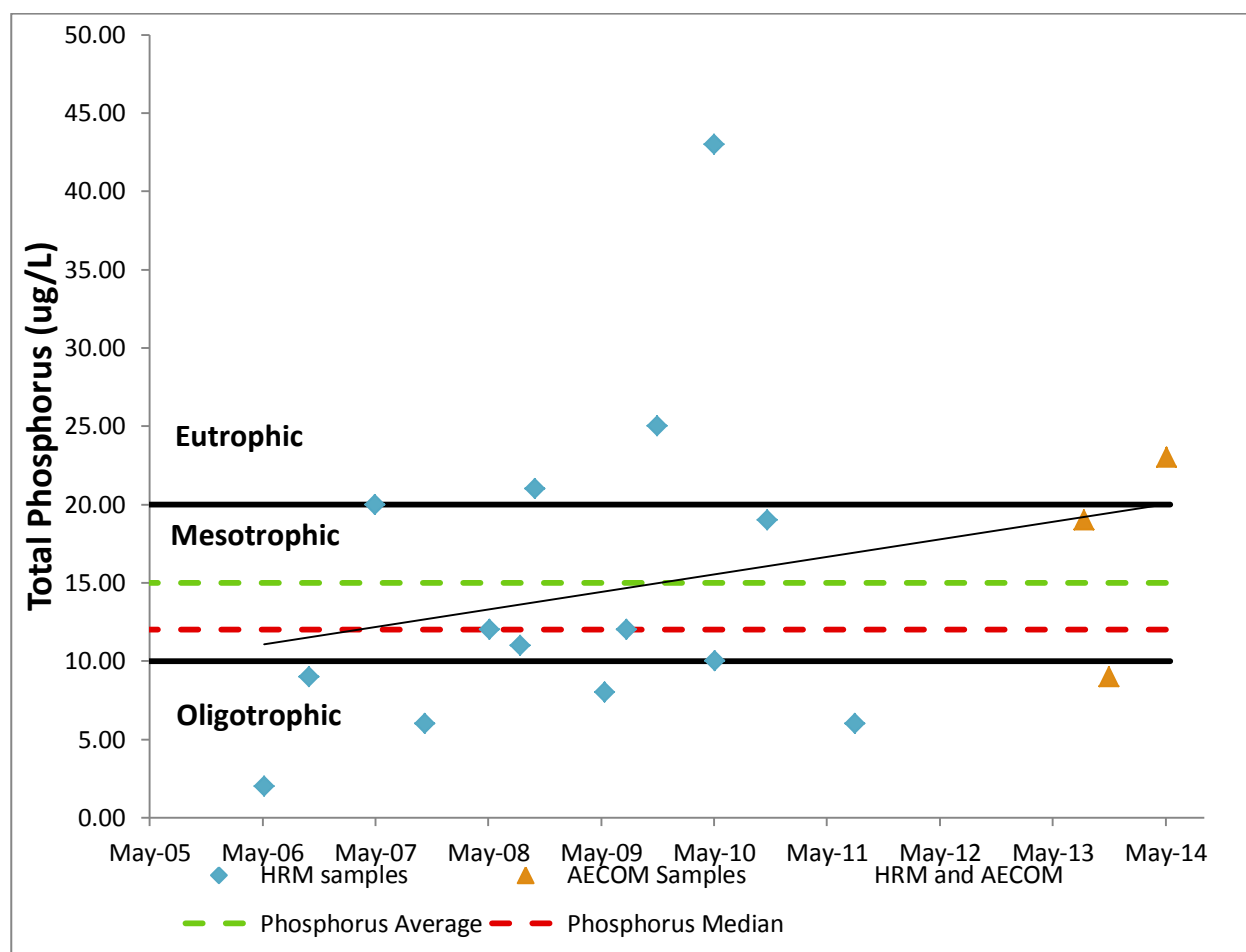
**Table 3. Sandy Lake Water Quality Summary**

Sample Name	Statistical Summary	Anthropogenic Influence Indicator Parameters				Nutrient Enrichment and Trophic Status Indicator Parameters			Water Clarity Indicator Parameter
		Chloride	Nitrate	Total Ammonia	<i>E. Coli</i>	TKN	Total Phosphorus	Chlorophyll	Total Suspended Solids
		mg/L	mg/L	mg/L	MPN/ 100mL	mg/L	µg/L	α µg/L	mg/L
Sandy Lake	n	17	16	14	6	17	17	17	16.0
	min	21	0.01	0.05	1	0.30	2.0	0.3	1.0
	max	50	0.16	0.08	41	3.60	43.0	13.2	5.0
	average	35	0.07	0.05	15	0.78	15.0	5.0	3.1
	median	37	0.06	0.05	4	0.40	12.0	3.6	2.0

*n* = total number of available samples; MPN = most probable number; TKN = total Kjeldahl nitrogen

### 5.1.1 Total Phosphorus

Total phosphorus in **Table 3** ranged from 2 µg/L to 43 µg/L between 2006 and 2013 (**Figure 8**). The median concentration of total phosphorus is 12 µg/L, which places the current water quality of Sandy Lake in the lower end of the **mesotrophic** range. This indicates the lake water quality is good and has moderate biological productivity.



**Figure 8. Sandy Lake Total Phosphorus - Current Conditions**

As a comparison, median total phosphorus concentrations of lakes in the Birch Cove watershed to the south are summarized in **Table 4**.

**Table 4. Total Phosphorus of Nearby Lakes (2006-2012)**

Lake Name	Total Phosphorus (ug/L)	Number of samples
Paper Mill Lake	7.0	16
Kearney Lake	8.0	16
Washmill Lake	8.0	9
Quarrie Lake	9.0	2

(source: AECOM 2013)

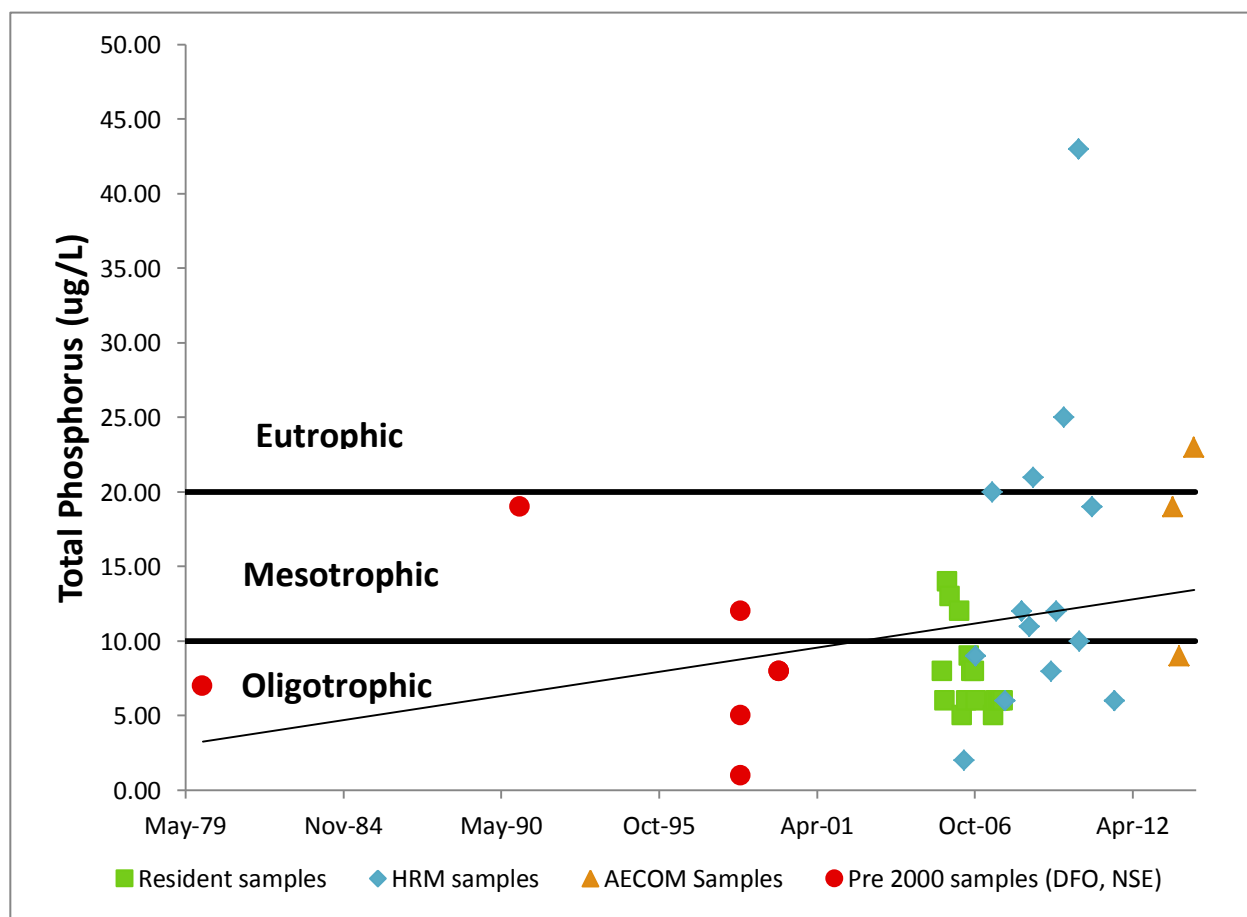
Most of the samples reported in Tables 3 and 4 were taken from near the lake surface, but samples have also been taken periodically from the deeper part of the lake. **Table 5** compares the phosphorus concentrations of shallow (epilimnion) to deep (hypolimnion) samples from three sampling events. Total phosphorus concentrations in the shallow surface (epilimnion) samples are less than in the deep (hypolimnion) samples in two of the three examples. Although the data are limited, this suggests that the deeper portions of Sandy Lake may be fully or partially oxygen-deprived during certain times of the year, a situation that may arise when decomposing organic matter consumes

available oxygen at depth. This in turn promotes the release of phosphorus from lake sediments, which is recorded in the water samples.

**Table 5. Sandy Lake Shallow and Deep Total Phosphorus**

Sample Name	Sample Date	Total Phosphorus (1 m depth)	Total Phosphorus (deep)
		µg/L	µg/L
Sandy Lake	Sept 3, 2008	11.0	15.0
	May 24, 2010	10.0	26.0
	August 19, 2011	6.0	5.0

For a historical perspective **Figure 9** presents the results from all previous sampling events: resident sampling from 2005 to 2007, DFO sampling in 1980, 1991 and 2000, and NSE sampling in 1998. The graph illustrates increasing total phosphorus concentrations over the past 30 years, suggesting Sandy Lake is receiving man-made nutrient inputs from its watershed. The lake appears to have transitioned from a generally oligotrophic state to a mesotrophic state. The observation of increasing total phosphorus is consistent with information presented by Mandeville (SWCSMH 2013a) who considered the phosphorus trends from 1980 to 2011 and used this data and other sources to predict pre-development phosphorus concentrations.

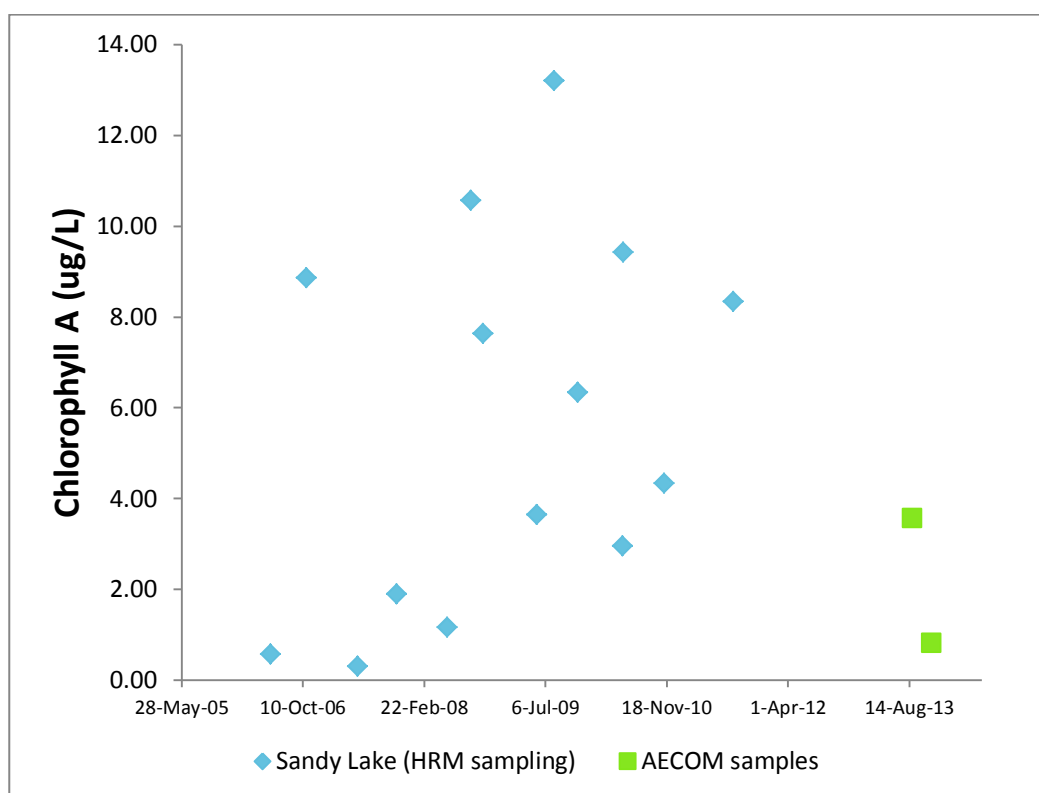


**Figure 9: Sandy Lake Total Phosphorus - All Samples**

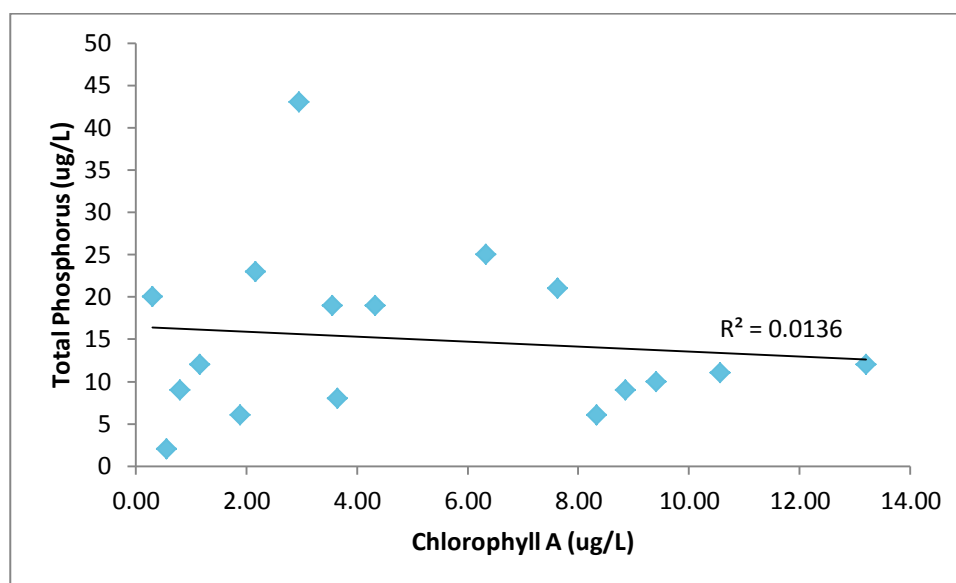
### 5.1.2 Chlorophyll-a

Chlorophyll is the green pigment in plants that allows them to photosynthesize. A chlorophyll measurement in lake water is an indirect measure of the amount of photosynthesizing plants found in the sample. In a lake water sample, these plants are typically algae or phytoplankton. Chlorophyll-a is a measure of the portion of the pigment that is still active; that is, the portion that was still actively respiring and photosynthesizing at the time of sampling.

Chlorophyll-a concentrations represent the biological productivity in lakes. Increases in chlorophyll-a are typically related to increases in nutrients such as nitrogen and phosphorus. The nutrients are consumed by the algae, which grow and reproduce causing cloudy or murky water. Chlorophyll-a concentrations in Sandy Lake were relatively high from 2008 to 2011 (**Figure 10**) and generally reflect the increases in phosphorus during that time period. Samples collected by AECOM in 2013 suggest algae productivity has decreased from the highs recorded in 2009. Plotting chlorophyll-a and phosphorus concentrations suggest there is no significant relationship ( $R^2 = 0.014$ ) between the two parameters (**Figure 11**). The relationship between chlorophyll-a and nitrate is also insignificant ( $R^2 = 0.037$ ) suggesting other factors are influencing chlorophyll-a.



**Figure 10. Sandy Lake Chlorophyll-a 2008-2013**



**Figure 11. Relation between Total Phosphorus and Chlorophyll-a**

### 5.1.3 Nitrogen

The concentrations of nitrogen compounds (nitrate, nitrite and ammonia) in the Sandy Lake watershed are generally low. The sources of nitrogen within the watershed are likely derived from sources such as animal wastes, human waste from sewage treatment plants or septic systems, and lawn fertilizers used on lakeshore property. Nitrogen may enter a lake from surface runoff or groundwater sources.

Nitrogen is a plant nutrient and can exist in oxidized forms, usually nitrate or nitrite, or reduced forms including ammonia and organic nitrogen; that is, nitrogen found in plant tissues and wastewater. The form of nitrogen found in a lake may help to identify its ultimate source.

Nitrate is the most common form of nitrogen in surface waters, while ammonia is predominant in low oxygen environments and in wastewater effluent. Nitrate, nitrite and ammonia represent bioavailable forms of nitrogen. Total Kjeldahl nitrogen (TKN) provides a measure of ammonia plus organic nitrogen, including organic nitrogen in plant and animal tissue.

Nitrate concentrations are generally low within Sandy Lake. The median concentration of 0.05 mg/L and the maximum concentration (of 14 samples) was 0.16 mg/L. For comparison, the Soil and Water Conservation Society of Metro Halifax (SWCSMH 2013b) reported an average nitrate concentration of 0.02 mg/L for 34 pristine lakes in Halifax County, compiled in 1994<sup>2</sup>.

Concentrations of other nitrogen containing compounds, such as total ammonia and TKN, are also low but results suggest some inputs of these compounds to the lake may be occurring. The median ammonia value is 0.05 mg/L (maximum of 0.08 mg/L from 13 samples) while the median TKN concentration is 0.40 (maximum of 3.60 of 15 samples). These values are slightly higher than those recently collected for lakes in the nearby Birch Cove Lakes watershed (**Table 6**).

<sup>2</sup> 0.02 mg/L  $\pm$  standard deviation of 0.03 mg/L.

**Table 6. Nitrogen Compounds in Sandy Lake and the Birch Cove Lakes Watershed**

		TKN (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)
<b>Sandy Lake</b>	<b>No of Samples</b>	15	14	13
	<b>min</b>	0.30	0.01	<0.05
	<b>max</b>	3.60	0.16	0.08
	<b>median</b>	0.40	0.05	<0.05
	<b>average</b>	0.73	0.07	<0.05
<b>Paper Mill Lake</b>	<b>No of Samples</b>	10	8	14
	<b>min</b>	<0.10	0.07	<0.05
	<b>max</b>	0.40	0.49	<0.05
	<b>median</b>	0.25	0.17	<0.05
	<b>average</b>	0.27	0.22	<0.05
<b>Kearney Lake</b>	<b>No of Samples</b>	11	8	14
	<b>min</b>	0.00	0.10	<0.05
	<b>max</b>	0.80	0.21	<0.05
	<b>median</b>	0.30	0.17	<0.05
	<b>average</b>	0.32	0.16	<0.05
<b>Washmill Lake</b>	<b>No of Samples</b>	4	8	9
	<b>min</b>	0.10	0.07	<0.05
	<b>max</b>	0.51	0.21	<0.05
	<b>median</b>	0.24	0.16	<0.05
	<b>average</b>	0.27	0.15	<0.05
<b>McQuade Lake</b>	<b>No of Samples</b>	5	5	n/a
	<b>min</b>	0.32	0.08	
	<b>max</b>	0.40	0.19	
	<b>median</b>	0.40	0.13	
	<b>average</b>	0.37	0.14	

(source: AECOM 2013)

#### 5.1.4 Chloride and Total Suspended Solids

Sources of chloride within the watershed include septic systems (chloride values of 50 to 100 mg/l are common in septic tank effluent), animal waste, potash fertilizer, and drainage from road-salting chemicals. Higher chloride concentrations from spring to fall may indicate lawn fertilizer runoff or heavy use of septic system by summer residents. Higher values in spring after the snow melts may signify runoff from highways. Chloride in precipitation in near coastal environments like the Sandy Lake watershed is a function of distance from the ocean and chloride concentrations in precipitation in the Halifax area are reported between 20-30 mg/L (Underwood et al. 1980). Sea spray and dry deposition of chloride also contribute to chloride budgets in Nova Scotia (Bachiu 2010).

Chloride concentrations in Sandy Lake are low, with median concentration of 28 mg/L and maximum concentration of 50 mg/L. These values are comparable to those found in Washmill, Kearney and Paper Mill Lakes within the Birch Cove Lakes watershed (AECOM 2013). The low chloride concentrations suggest that there are not any large contributions of chloride within the watershed and much of the chloride in Sandy Lake can be attributed to precipitation and dry deposition.



Total suspended solids (TSS) are typically small particles of soil or algal growth that reduce water clarity. Soil particles are also sources of total phosphorus because phosphorus can adsorb to the charged surfaces of soil particles and be transported to lakes and streams with the suspended sediment. Potential sources of TSS include stormwater runoff, erosion, deforestation, construction activities, treatment plant effluent and gravel operations. High concentrations of TSS is an indication of urban runoff or disturbances in the watershed

The TSS concentrations are generally low in Sandy Lake with a median value of 2 mg/L and a maximum of 5 mg/L, suggesting Sandy Lake is not significantly affected by urban runoff or erosion.

### 5.1.5 Bacteria

The bacteria *Escherichia coli* (*E. coli*) is an indicator of human and animal waste, and may originate from treatment plant discharges, aging septic systems, and animal scat. Samples taken at Sandy Lake typically contain *E. coli* but the median concentration is quite low (2 MPN/100 mL<sup>3</sup>). Concentrations over 25 MPN/100 mL are not common (2 of 11 samples). HRM currently uses the guideline of 200 CFU/100 mL for *E. coli* for body contact recreation, which is the same as the Health Canada value of 2000 *E. coli*/L.

## 5.2 Marsh Lake

Three samples are available from Marsh Lake to describe current water quality conditions (**Table 7**). One sample was taken by Nova Scotia Environment in 2007 and two samples were collected by AECOM from Peverills Brook downstream of Marsh Lake as part of this study.

Total phosphorus concentrations indicate Marsh Lake is transitional between oligotrophic and mesotrophic conditions. The median phosphorus concentration is 11 µg/L. For the purposes of this report, Marsh Lake is considered **mesotrophic**.

Nitrate, chloride, *E. Coli* and TSS concentrations in Marsh Lake are similar to Sandy Lake.

**Table 7. Marsh Lake Water Quality Summary**

Sample Name	Statistical Summary	Anthropogenic Influence Indicator Parameters				Nutrient Enrichment and Trophic Status Indicator Parameters			Water Clarity Indicator Parameter
		Chloride	Nitrate	Total Ammonia	<i>E. Coli</i>	TKN	Total Phosphorus	Chlorophyll <i>a</i>	Total Suspended Solids
		mg/L	mg/L	mg/L	MPN/100mL	mg/L	µg/L	µg/L	mg/L
Marsh Lake	n	4	3	3	3	3	4	3	3
	min	25	0.05	0.02	5	0.70	7	0.50	2
	max	44	0.17	0.05	20	0.90	22	0.60	5
	average	31.75	0.09	0.05	9	0.77	13	0.55	3
	median	29	0.05	0.05	5	0.70	11	0.55	2

*n* = total number of available samples; MPN = most probable number; TKN = total Kjeldahl nitrogen.

<sup>3</sup> MPN = most probable number per 100 mL of sample, a standard unit used in bacteria analyses. Two common measurements of bacteria in aquatic environments are most probable number (MPN) and colony-forming unit (CFU). *E. coli* concentrations reported in both units were deemed essentially equivalent and combined for the purpose of data analysis.

### 5.3 Uplands Wastewater Treatment Facility

As noted, the Uplands WWTF was built in 1969 and serves Uplands Park, approximately 170 people. Discharge is to a natural marsh area which drains into Sandy Lake (HRM 2013). The average discharge rate from the WWTF in 2013 was 40 m<sup>3</sup>/day. Water quality samples are collected from within the treatment plant prior to discharge to Bobs/Johnsons Brook. Samples have been collected since January 2012 for a total of 31 samples (**Table 8**).

**Table 8. Uplands Park WWTF Water Quality Summary**

Sample Name	Sampling Date	Biological Oxygen Demand	Total Ammonia	Fecal Coliform	Total Phosphorus	Total Suspended Solids
		mg/L	mg/L	CFU/ 100mL	µg/L	mg/L
Uplands Park WWTF	n	26	31	10	31	31
	min	2.90	1.10	10	940	4.40
	max	34.0	17.0	3400	4700	57.0
	average	9.11	5.48	502	2720	16.05
	median	7.05	5.00	100	2700	12.00

The data in Table 8 indicate that discharge from the Uplands Park WWTF is a point source of nutrients to Sandy Lake. The estimated contributions of phosphorus from the Uplands WWTF to the Sandy Lake phosphorus budget are evaluated in the Lake Capacity Model (Section 8).

### 5.4 Metals in Surface Water

Many different dissolved metals can be present as natural background elements in surface waters. Elevated metal concentrations are not necessarily an indicator of human influence since dissolved metals often reflect the chemistry of the surface soils and bedrock geology. However, acid rain has depleted the buffering capacity of Nova Scotia soils (the ability of soil minerals to neutralize acidity) and resulted in reduced pH in surface waters, which now typically ranges from 4.5 to 5.5 (Clair *et al.* 2007). Low pH (acidic) water promotes the dissolution of soil minerals and the liberation and transport of dissolved metals in water.

The pH in Sandy Lake and Marsh Lake is slightly acidic but is higher than many lakes in the region. The lower pH observed in Marsh Lake compared to Sandy Lake is likely the result of inflows from nearby wetlands, which are high in organic acids produced by decomposing organic matter in wetland environments. The low pH values may be partially responsible for the metal concentrations observed in Sandy Lake.

**Table 9** summarizes the metal concentrations in water samples from Sandy and Marsh Lakes. Underlined values in bold text indicate those values that exceed the *Water Quality Guidelines for the Protection of Aquatic Life* established by the Canadian Council of Ministers of the Environment (CCME).

The following metals exceeded CCME guidelines in Sandy Lake:

- Aluminum;
- Cadmium;
- Chromium;
- Iron; and
- Zinc.

Aluminum, iron and copper exceed the CCME guidelines in Marsh Lake.

Selenium, silver and thallium are shown as exceeding CCME guidelines in **Table 9**, but these results may not be accurate. To maintain reporting consistency and permit statistical analysis of water quality indicators, analytical results that are less than the detection limit are shown in the data tables as “at the detection limit value”. In the case of selenium, silver and thallium, the detection limit values happen to be higher than the CCME guidelines, which is why they are shown as exceeding the guideline. In fact, these metals may or may not exceed the CCME guidelines for freshwater aquatic life.

Other metals such as boron, barium, nickel, strontium, and titanium are present but do not appear to be unusually elevated.

Elevated concentrations of aluminum, iron and to a certain extent cadmium, copper and zinc are common in Halifax area lakes (Stantec 2012a; 2012b). Given the elevated concentrations across HRM, the concentrations of these metals are assumed to be representative of background conditions.

**Table 9: Summary of Available Metals Results (in µg/L)**

		pH	Aluminum	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc
CCME Water Quality Guidelines <sup>1</sup>		6.5-9	5-100 <sup>2</sup>	5.00	-	-	-	-	0.0173	1.00	-	2.0-4.0 <sup>4</sup>	300	1.0-7.0 <sup>5</sup>	-	73	25-150 <sup>6</sup>	1.00	0.10	-	0.80	-	-	-	-	30.00
Sandy Lake	no. of samples	26	8	9	8	8	8	8	4	8	8	12	12	8	12	8	8	8	8	8	8	8	8	8	8	12
	min	<b>6.3</b>	77.0	2.0	14.0	2.0	2.0	6.0	0.02	1.0	1.0	2.0	170.0	0.5	36.0	2.0	2.0	1.0	0.1	18.0	0.1	2.0	2.0	0.1	2.0	5.0
	max	7.3	<b>234.0</b>	2.0	19.0	2.0	2.0	11.0	<b>0.08</b>	<b>18.0</b>	1.0	2.0	<b>933.0</b>	0.6	258.0	2.0	14.0	<b>2.0</b>	<b>0.5</b>	29.0	<b>2.0</b>	2.0	2.0	0.1	2.0	<b>154.0</b>
	average	6.7	<b>140.3</b>	2.0	16.3	2.0	2.0	7.9	<b>0.04</b>	<b>3.6</b>	1.0	2.0	<b>411.5</b>	0.5	101.8	2.0	3.5	<b>1.5</b>	<b>0.3</b>	21.8	0.8	2.0	2.0	0.1	2.0	19.7
	median	6.6	<b>131.0</b>	2.0	16.5	2.0	2.0	7.5	<b>0.03</b>	<b>2.0</b>	1.0	2.0	<b>303.0</b>	0.5	74.0	2.0	2.0	<b>1.5</b>	<b>0.3</b>	21.0	0.1	2.0	2.0	0.1	2.0	6.5
Marsh Lake	25-Jul-07	<b>6.4</b>	<b>144</b>	-	-	-	-	-	-	-	-	2.000	269.000	-	126	-	-	-	-	-	-	-	-	-	-	7.000
	27-Aug-13	<b>6.1</b>	<b>74.0</b>	2.0	14.0	2.0	2.0	9.0	0.017	1.0	1.0	<b>3.0</b>	<b>387.0</b>	0.5	48.0	2.0	2.0	1.0	0.1	20.0	0.1	2.0	2.0	0.1	2.0	5.0

1. CCME Water Quality Guidelines = Canadian Council of the Ministers of Environment, Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life, 1999, July, 2013 update

2. Aluminum guideline: **5 µg/L** at pH <6.5; 100 µg/L at pH >= 6.5

3 Cadmium Guideline:  $10^{(0.86[\log(\text{hardness})] - 3.2)}$

4. Copper guideline: 2 µg/L at Hardness [CaCo3] = 0-120 mg/L; 3 ug/L at hardness=120-180 mg/L; 4 ug/L at hardness>180mg/L; **Guideline of 2 µg/L applied** to Sandy Lake based on median hardness of 16 mg/L measured in Sandy Lake (n=12)

5. Lead guideline: 1 µg/L at hardness = 0-60 mg/L; 2 ug/L at hardness = 60-120 mg/L; 4 ug/L at hardness=120-180 mg/L; 7 ug/L at hardness>180mg/L; **Guideline of 1 mg/L applied** to Sandy Lake based on median hardness of 16 mg/L measured in Sandy Lake (n=12)

6. Nickel guideline: 25 µg/L at hardness = 0-60 mg/L; 65 ug/L at hardness = 60-120 mg/L; 110 ug/L at hardness=120-180 mg/L; 150 ug/L at hardness>180mg/L; **Guideline of 25 µg/L applied** to Sandy Lake based on median hardness of 16 mg/L measured in Sandy Lake (n=12)

**Bold and Underlined** = Parameter exceeds the applicable CCME Water Quality Guideline

## 6. Establishing Water Quality Objectives

**Appendix B** describes how the key water quality indicators respond to human induced changes within the watershed. It also presents a review of water quality guidelines and objectives used in other jurisdictions, both nationally and internationally, as background to establishing water quality objectives (WQOs) for this study.

Water quality objectives are set for indicator parameters that are sensitive to impacts from development. The indicator parameters include:

- Nitrate;
- Total Suspended Solids;
- Chloride;
- E.coli; and
- Phosphorus.

## 7. Receiving Water Quality Objectives

Sandy Lake and Marsh Lake concentrations of the indicator parameters are presently below the CCME Guidelines. Because the Guidelines are set to protect the most sensitive aquatic species, and because water quality in the study area is currently better than these objectives, **we recommend that the CCME Guidelines for nitrate, total suspended solids, and chloride be adopted for the Sandy Lake Watershed.** HRM currently uses the guideline of 200 CFU/100 mL for *E. coli* for body contact recreation, which is the same as the Health Canada value of 2000 *E. coli*/L<sup>4</sup>. We suggest this value is appropriate for the *E. coli* parameter. These values are illustrated in **Table 10**.

**Table 10. Recommended Water Quality Objectives for Sandy Lake Excluding TP**

Parameter	Derivation of Objective	Sandy Lake Watershed Water Quality Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
NO <sub>3</sub> – Nitrate	CCME	• 13 mg NO <sub>3</sub> /L	• ≤10 mg/L	• 75 <sup>th</sup> percentile of 3 year historical data <sup>3</sup> .
Total Suspended Solids (TSS)	CCME	• Short term <sup>1</sup> : 25 mg/L increase • Long term <sup>2</sup> : 5 mg/L increase	• Lake dependent	• 75 <sup>th</sup> percentile of 3 year historical data not to exceed base line by more than 5 mg/L
Chloride	CCME	• 120 mg/L	≤90 mg/L	• 75 <sup>th</sup> percentile of 3 year historical data
<i>E. coli</i>	Nova Scotia and Health Canada	• 200 <i>E. coli</i> /100 mL • (geometric mean of 5 samples)	• 200 <i>E. coli</i> /100 mL	• Geometric mean of 5 most recent samples

1: Short term refers to variation between discrete sampling events

2: Long term refers to variation defined by the 75<sup>th</sup> percentile of 3 year historical data

3: 75<sup>th</sup> percentile of the reported values from the results of previous 3 years of monitoring. This assumes the results are from a technically justifiable monitoring program, such as the program recommended in Section 9.

### 7.1 Development of Total Phosphorus Water Quality Objectives (WQO)

For the Sandy Lake watershed AECOM recommends the use of Environment Canada's trophic status classification to set WQOs for total phosphorus. As noted in section 1.2.1, an objective of the 2006 HRM Regional Plan is to **"maintain the existing trophic status of our lakes and waterways"**. This suggests that both Sandy and Marsh Lakes should be maintained in their current mesotrophic state and so the WQO for total phosphorus should be the upper limit of the mesotrophic range, or 20 µg/L. However, since both lakes are currently at the lower end of the

mesotrophic range, considerable water quality degradation could occur before the lakes were at risk of exceeding such a WQO.

In an effort to maintain current water quality and meet the Regional Plan objective, we recommend a dual management objective: (1) maintain the trophic status of the lake and (2) restrict total phosphorus increases to less than 50% above current conditions. If a monitoring program shows that this WQO is being exceeded, then management action would be warranted to protect the lake. In this approach the WQO becomes a “trigger value” for action. This approach is consistent with the objectives of the Regional Plan, which seeks to maintain the existing trophic status to the extent possible.

Defining the current water quality conditions is essential to establishing WQOs. As presented in Section 5.1.1, Sandy Lake is currently at the lower limit of mesotrophic range with a median total phosphorus concentration of 12 µg/L. An increase of 50% results in a **WQO of 18 µg/L**. Marsh Lake median total phosphorus concentration is 10 µg/L, resulting in a **WQO objective of 15 µg/L**.

Unfortunately, mitigation measures to reduce total phosphorus concentrations are seldom instantaneous or completely effective, so WQOs combined with early warning values are often used to manage lake quality rather than waiting for the specific phosphorus water quality objective to be met or exceeded. Early warning indicators such as trends in phosphorus concentrations or trigger concentrations just below the objective value are highly useful management tools for water bodies. As can be seen from the water quality summary of the Sandy Lake watershed above, there is considerable variability in phosphorus measurements and single values (low or high) are not an appropriate basis for management decisions. Thus, the approach to setting phosphorus water quality objectives needs to be accompanied by a scientific rationale for testing whether or not the water quality is changing.

Lake-specific total phosphorus objectives and early warning values have been developed based on existing data.

**Table 11** provides a summary of the total phosphorus water quality objectives and early warning values and a method to evaluate whether or not the objective or alert value is being approached for each lake.

**Table 11. Water Quality Objectives and Early Warning Values for Total Phosphorus**

Lake	Trophic State Objective	Numerical Objective	Early Warning	Evaluation
Sandy Lake	Mesotrophic	< 18 µg/L	15µg/L	Based on 3 year running average
Marsh Lake	Mesotrophic	< 15.5 µg/L	13 µg/	Based on 3 year running average.

## 8. Lakeshore Capacity Modeling

A refined version of Ontario's Lakeshore Capacity Model (LCM) was used to assess potential changes in water quality from proposed development within the Sandy Lake watershed. The model, developed by Dillon and Rigler (1975) was calibrated on Canadian Shield lakes in Ontario (Dillon *et al.* 1986; Hutchinson *et al.* 1991) and has since been applied to lakes in Nova Scotia (e.g. Brylinsky 2004, Jacques Whitford 2004; Soliman 2008; AECOM 2013). The LCM is a mass balance, steady state model that quantifies the natural and human phosphorus inputs to a watershed and estimates the resulting phosphorus concentrations of the watershed's lakes (MOE 2010). The model is also used to predict how future land developments may impact the lake phosphorus concentrations.

Inputs to the model include:

1. Surface areas for each land use (e.g. forest, meadow, residential, etc.);
2. Phosphorus export coefficient for each land use;

3. Hydraulic inputs; and,
4. Point sources of phosphorus (e.g., septic systems, waste water treatment plant discharge and sanitary sewer overflows).

Using this information the model calculates:

- Hydraulic budget;
- Phosphorus loads from all land uses, point sources and septic systems; and
- Predicted lake total phosphorus concentrations.

The model version used for the Sandy Lake watershed was based on the version developed by Brylinsky (2004) for Nova Scotia lakes.

The objective of the modeling was to evaluate the long-term impact of development in the Sandy Lake watershed on Sandy and Marsh Lake phosphorus concentrations. To complete this, the Sandy Lake watershed was delineated into two catchments or subwatersheds (Sandy Lake and Marsh Lake subwatersheds) and phosphorus concentrations were modeled for the lake in each subwatershed. Four land use scenarios were modeled and displayed in **Figures 12 to 15**. The modeling scenarios include one current scenario and three future scenarios:

1. Modeling Scenario 1: Existing Conditions;
2. Modeling Scenario 2: Future Developments;
3. Modeling Scenario 3: Future Developments plus (a) Removal of Upland Waste Water Treatment Facility and (b) Sandy Lake Cottages converted to small lot residential supplied with waste water services; and
4. Modeling Scenario 4: Future Developments (Scenario 3) with Advanced Stormwater Management.

Scenario 1 represents the existing land use conditions in the Sandy Lake watershed (**Figure 12**). The surface areas occupied by the different land uses in each subwatershed were interpreted through analysis of aerial photographs, parcel fabric GIS layers obtained from HRM, and subdivision development plans. The Existing Conditions scenario is used to calibrate the Lake Capacity Model to the measured phosphorus concentration of the lakes as defined in **Section 5**.

Scenario 2 land use is based on the Existing Conditions Scenario with modifications to represent possible future developments that have been identified in the watershed (**Figure 13**). The possible developments included in the Future Developments scenario(s) were defined in consultation with HRM and include:

- Possible development identified in a municipal servicing study completed by the engineering firm CBCL (CBCL 2009);
- Planned development of Kingswood North;
- Planned development of the Thistle Grove (formerly Peerless) subdivision;
- Planned developments of the Bedford West project in the Sandy Lake watershed; and
- Possible development in the Jack Lake Lands.

Scenario 2 assumes the Uplands WWTF will remain in operation with phosphorus discharges remaining the same as in the Existing Conditions. The scenario also assumes that all septic systems in the Existing Conditions will remain in place and discharge phosphorus the same as in the Existing Conditions.

Scenario 3 (**Figure 14**) is similar to Scenario 2, but includes the conversion of all cottages along the western shore of Sandy Lake from well and septic to municipal water and wastewater services. The scenario also includes the removal of the Uplands WWTF and Uplands Park to be provided with wastewater services.

Scenario 4 (**Figure 15**) is the same as Scenario 3, but also includes Advanced Stormwater Management for all the possible development areas.

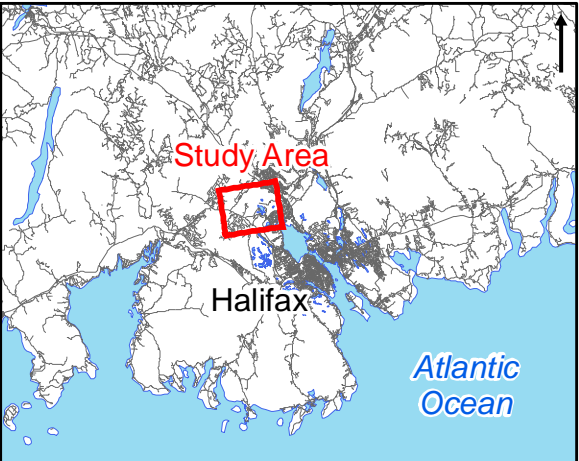
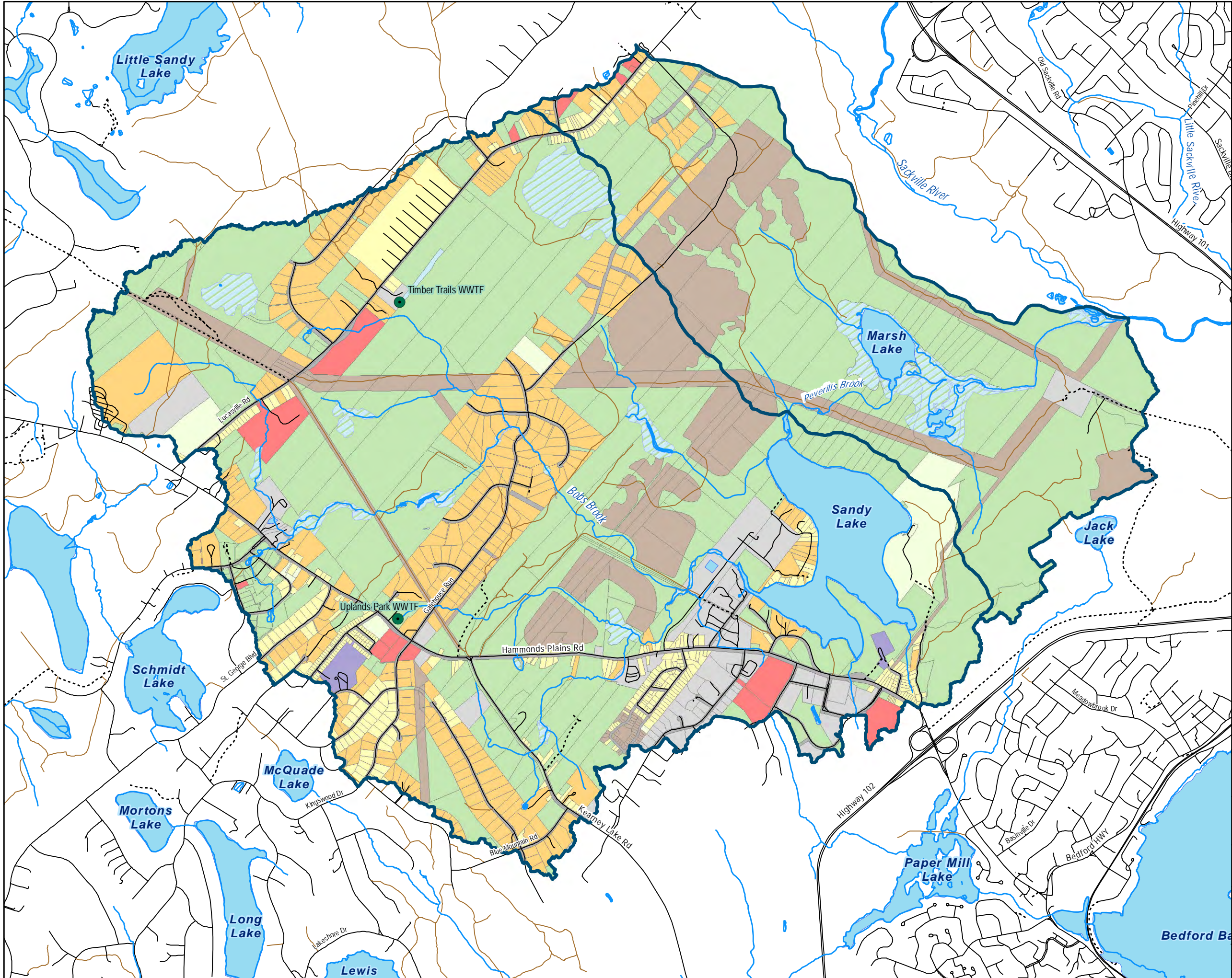
The results from the future scenarios are compared to the existing conditions to evaluate how development may impact water quality (**Tables 12 and 13**).

**Table 12. Comparison of Phosphorus Contributions in Scenarios**

	Scenario 1: Existing Land Use	Scenario 2: Future Land Use 1		Scenario 3: Future Land Use 2		Scenario 4: Future Land Use 2 with ASM	
Phosphorus Source	% of Total Phosphorus	% of Total Phosphorus	% Change Phosphorus Export from Land Use Type <sup>1</sup>	% of Total Phosphorus	% Change Phosphorus Export from Land Use Type	% of Total Phosphorus	% Change Phosphorus Export from Land Use Type
Forested	11.4	5.8	-37.0	6.3	-37.0	6.9	-37.0
Deforested	3.5	1.2	-53.1	1.3	-53.1	1.6	-53.1
Wetlands	1.0	0.7	-0.7	0.8	-0.7	2.1	117
Water	3.4	2.6	0.0	2.8	0.0	3.2	0
Roads	11.8	11.1	22.4	11.9	22.4	13.8	22.4
Industrial	7.1	5.4	-2.2	5.7	-2.2	6.7	-2.2
Institutional	0.6	0.3	-25.8	0.3	-25.8	0.4	-25.8
Commercial	4.1	5.9	97.3	6.6	97.3	7.3	87
Large Lot Residential	10.3	8.2	3.1	8.4	-0.7	9.8	-1
Small Lot Residential	10.4	28.9	284.6	33.9	295.7	14.0	-14
Park	3.4	2.6	0.0	2.8	0.0	3.3	0
Uplands WWTF	6.5	5.0	0.0	0.0	n/a	0.0	27
Timber Trails WWTF	5.0	4.9	27.5	5.3	27.5	6.1	27.5
Septic within 300m of Sandy Lake	4.5	3.5	0.0	0.0	N/A	0	N/A
Septic within 300m of watercourses	17.0	13.1	0.0	14.3	0.0	16.3	0

Table notes: 1 calculated as the phosphorus flux in the scenario minus the flux in existing conditions, divided by the flux in existing conditions.





**Legend**

- Wastewater Discharge Point
- Watercourses
- Roads
- Trails
- Gravel Roads
- Sandy Lake Subwatersheds

**Land Use Classifications**

- Commercial
- Deforested
- Forest
- Industrial
- Institutional
- Park
- Small Lot Residential (<0.5 ha)
- Large Lot Residential (>0.5 ha)
- Roadway
- Water
- Wetland

**Sandy Lake Area Watershed Study**

Scenario 1:  
Existing Land Use

September 2014	1:25,000	Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM & Hal. Water
----------------	----------	--

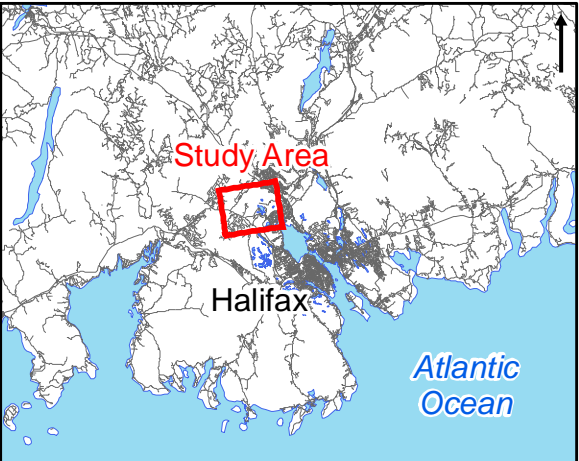
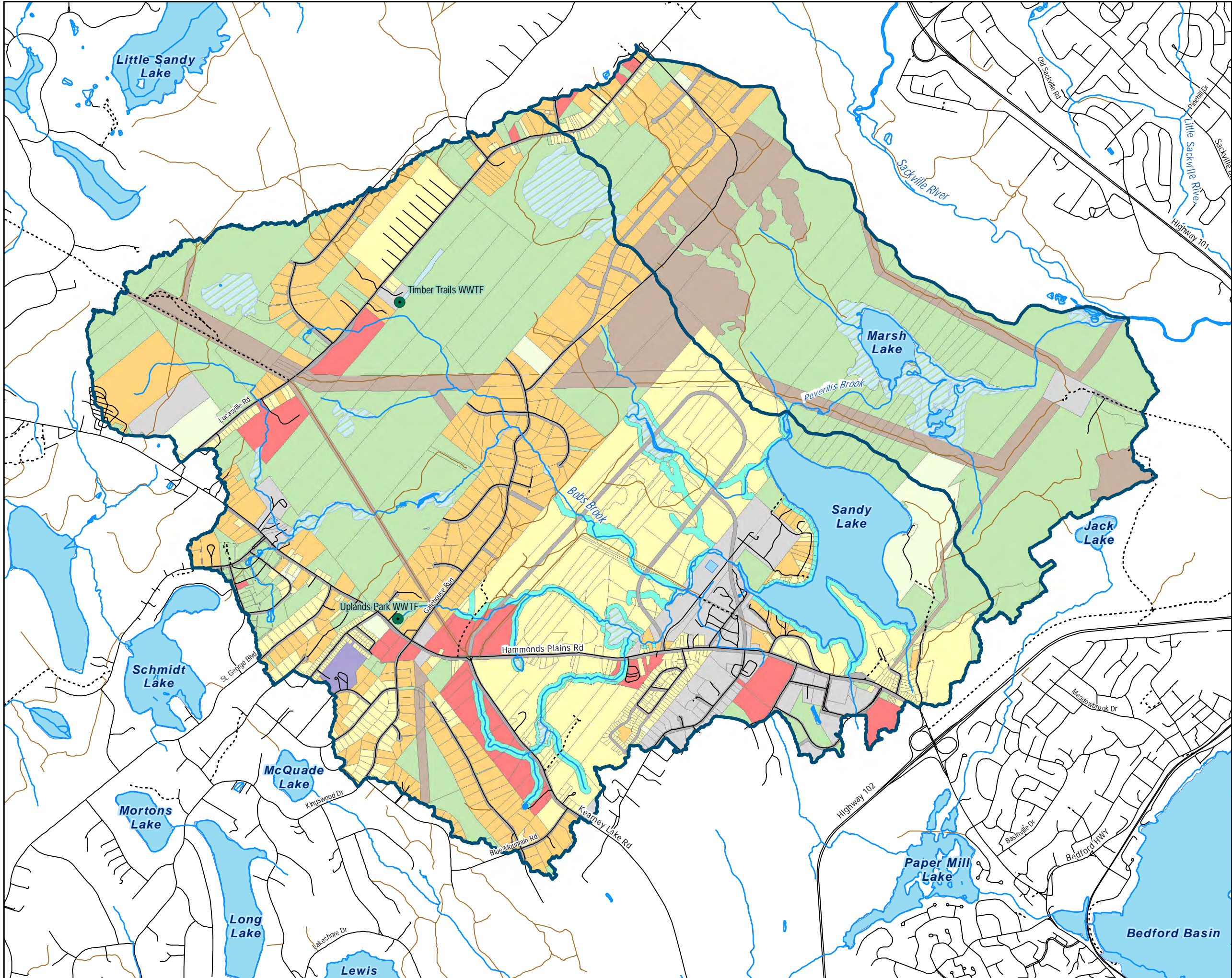
**AECOM**

**Figure 12**

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk\900-CAD-GIS\920 GIS-Graphics\Design\Final Draft Report - Sandy\Figure 12 - Land Use Existing 20140711.mxd





**Legend**

- Wastewater Discharge Point
- Watercourses
- Roads
- Trails
- Gravel Roads
- Sandy Lake Subwatersheds

**Land Use Classifications**

- Commercial
- Deforested
- Forest
- Industrial
- Institutional
- Park
- Small Lot Residential (<0.5 ha)
- Large Lot Residential (>0.5 ha)
- Roadway
- Water
- Wetland
- Wetland/Watercourse Buffer

**Sandy Lake Area Watershed Study**

Scenario 2:  
Full Build Out

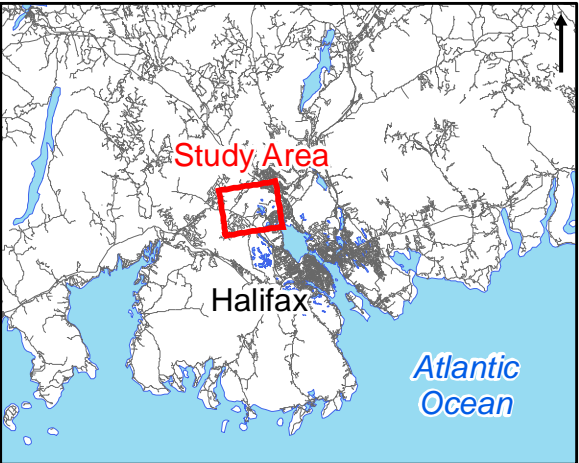
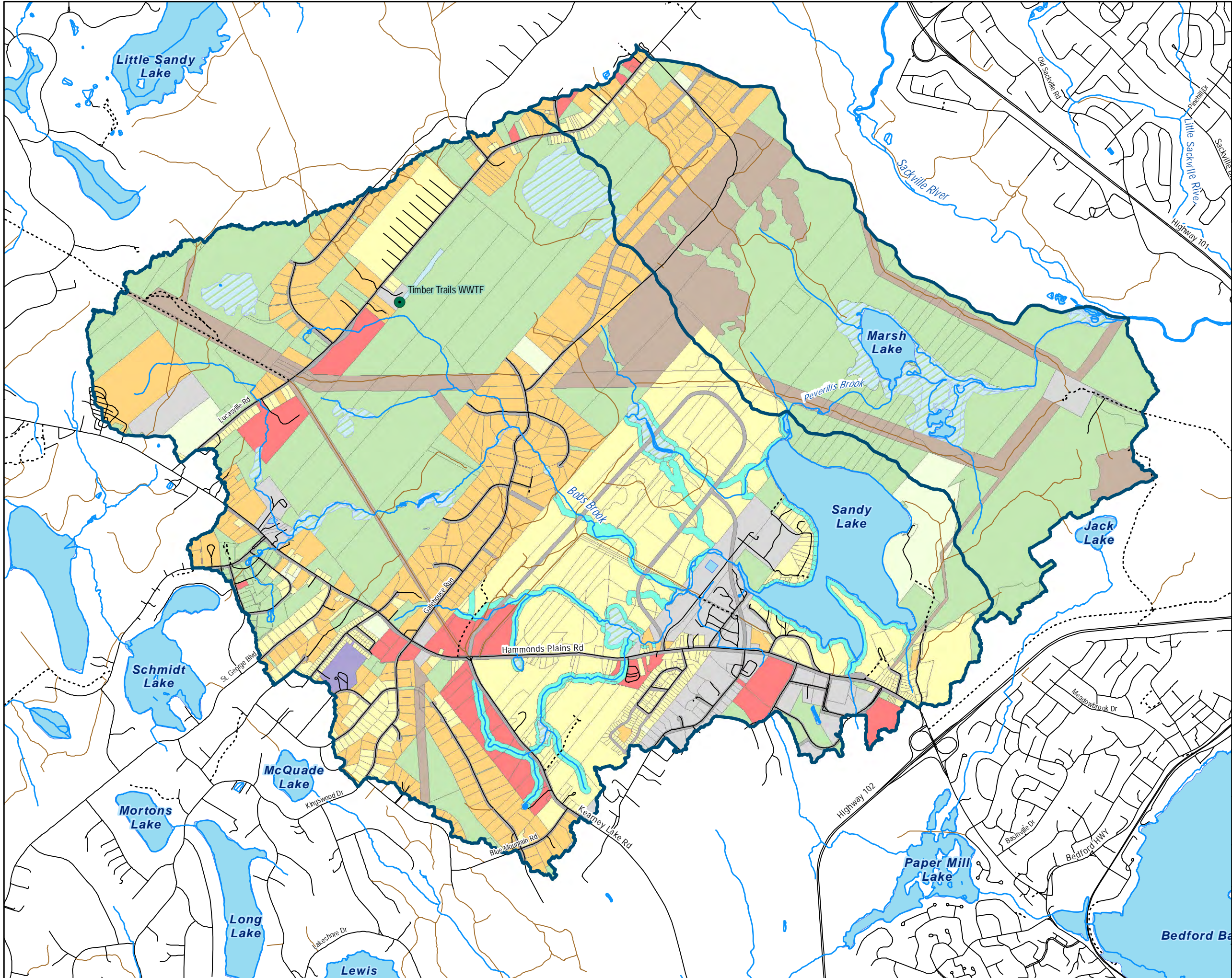
September 2014	1:25,000	Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM & Hal. Water
----------------	----------	--

**AECOM**

**Figure 13**

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.





**Legend**

- Wastewater Discharge Point
- Watercourses
- Roads
- Trails
- Gravel Roads
- Sandy Lake Subwatersheds

**Land Use Classifications**

- Commercial
- Deforested
- Forest
- Industrial
- Institutional
- Park
- Small Lot Residential (<0.5 ha)
- Large Lot Residential (>0.5 ha)
- Roadway
- Water
- Wetland
- Wetland/Watercourse Buffer

**Sandy Lake Area Watershed Study**

Scenario 3: Full Build Out with Septic near Sandy Lake and Uplands WWTF Removed

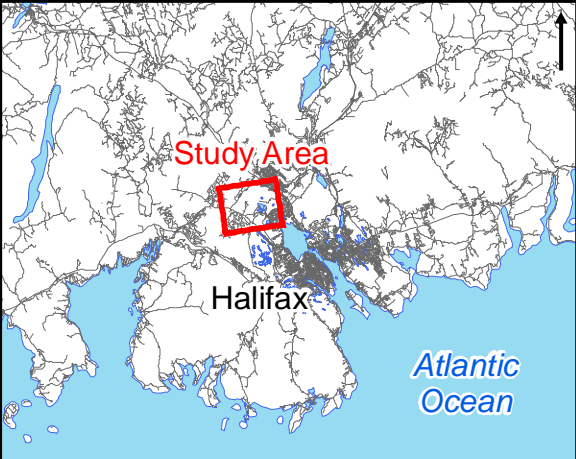
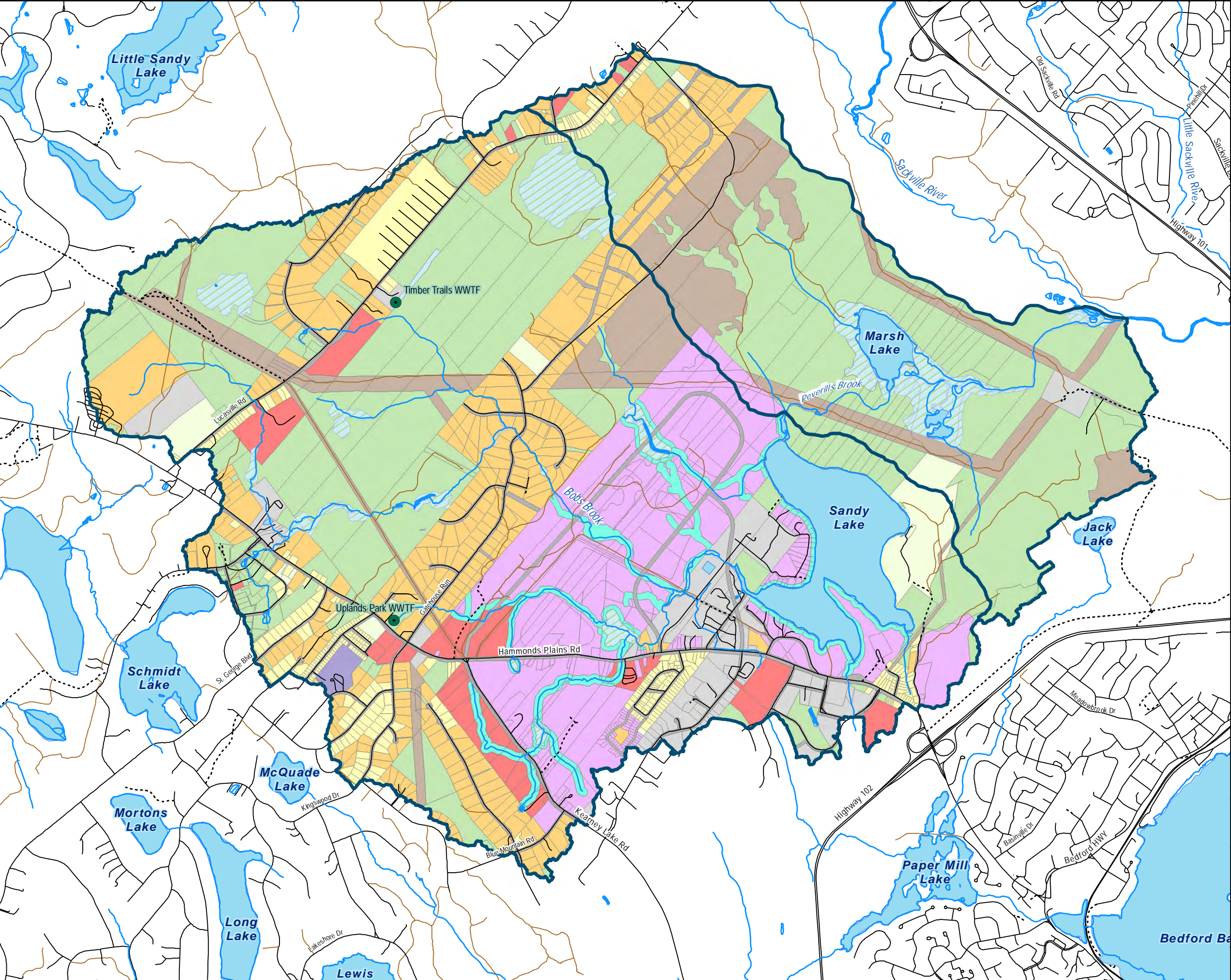
September 2014	1:25,000	Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM & Hal. Water
----------------	----------	--

**AECOM**

**Figure 14**

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.





**Legend**

- Wastewater Discharge Point
- Watercourses
- Roads
- Trails
- Gravel Roads
- Sandy Lake Subwatersheds

**Land Use Classifications**

- Commercial
- Deforested
- Forest
- Industrial
- Institutional
- Park
- Small Lot Residential with Advanced Stormwater Management
- Small Lot Residential (<0.5 ha)
- Large Lot Residential (>0.5 ha)
- Roadway
- Water
- Wetland
- Wetland/Watercourse Buffer

Sandy Lake Area Watershed Study

Scenario 4: Full Build Out with Advanced Stormwater Management

September 2014

1:25,000

Datum: ATS 1977 MTM  
5 Nova Scotia  
Source: HRM & Hal. Water

**AECOM**

Figure 15

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

Map location: P:\60303077 Sandy Lk\900-CAD-GIS\920 GIS-Graphics\Design\Final Draft Report - Sandy\Figure 15 - Land Use 4 20140711.mxd

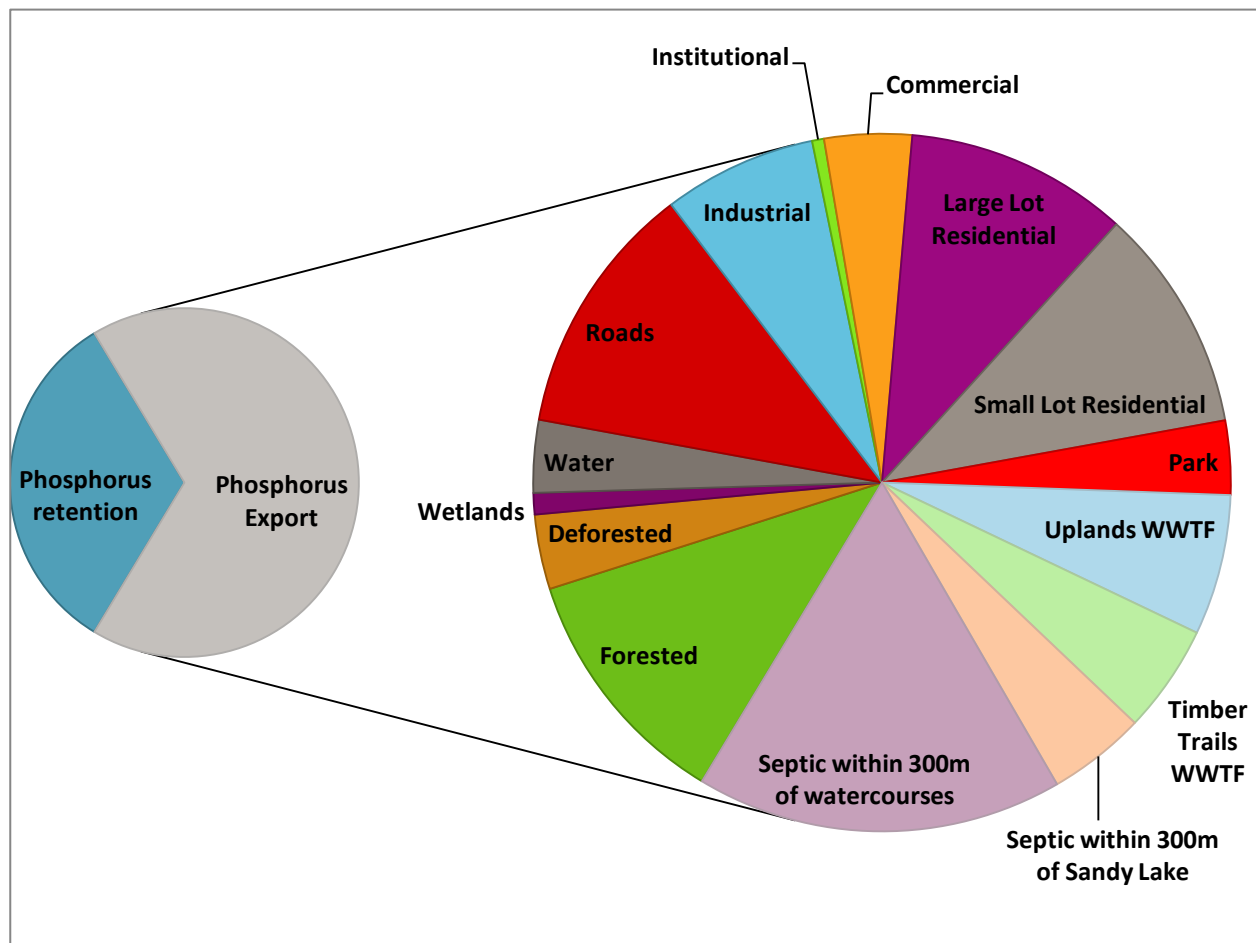


## 8.1 Sandy Lake

### 8.1.1 Scenario 1: Existing Conditions

Under existing conditions (**Figure 16**), the undeveloped portions of the watershed (forest, deforested, wetlands, park and water) contribute 23% of the phosphorus input to Sandy Lake. Developed land use (institutional, industrial, commercial, residential, parks and roads) contribute 44% of the phosphorus into Sandy Lake and wastewater systems (Uplands WWTF, Timber Trails WWTF and septic systems) contribute 33% of the phosphorus budget.

The phosphorus retention coefficient estimated from the areal load and settling rate (12.4 m/year) for oxygenated hypolimnion predict one third (33%) of the phosphorus entering the lake will be sequestered in the lake sediments.



**Figure 16. Phosphorus Contributions to Sandy Lake under Existing Conditions**



### 8.1.2 Scenario 2: Future Land Use – Full Build-Out

The land use areas for Scenario 2 (Future Land Use) are summarized in **Appendix E** and displayed on **Figure 13**. As noted, this scenario models full development of the Greenfield area identified in CBCL 2009, Kingswood North, Peerless subdivision, Jack Lake Lands, as well as the replacement of the wastewater treatment system of Timber Trails. **The predicted Sandy Lake phosphorus concentration in Scenario 2 is 16 µg/L, which represents an increase of 4 µg/L or 30% over current concentrations (12 µg/L) due to future development.** This value (16 µg/L) is below the recommended water quality objective of 18 µg/L.

The change in phosphorus concentrations in Scenario 2 comes primarily from the development of forested and deforested land to small lot residential. The small lot residential land use category contains more paved and impermeable surfaces and so the phosphorus export coefficient is higher than undeveloped land. In the existing land use Scenario 1, forested, roads, large lot residential, small lot residential and septic systems within 300 m of watercourses each contribute more than 10% of the total phosphorus. In Scenario 2 the contribution from small lot residential increases by a factor of 3 and is the dominant source of phosphorus at 25% of the total load in this scenario.

### 8.1.3 Scenario 3: Future Land Use 2

Scenario 3 also includes conversion of forested and deforested land to small lot residential (like Scenario 2) but Scenario 3 includes three additional modifications to Scenario 2 as displayed on **Figure 14** and described in **Appendix E**:

- Cottages along Sandy Lake are converted from large lot residential to serviced small lot residential,
- Septic systems at the Sandy Lake cottages are removed as phosphorus inputs, and
- Uplands WWTF is removed as a phosphorus input.

The changes to land use and phosphorus inputs in Scenario 3 predict Sandy Lake phosphorus concentration to be **15 µg/L, which is 3 µg/L greater than existing conditions and 1 µg/L less than Scenario 2.** The conversion of the large lot residential to small lot residential land use results in an increase in phosphorus of 4.68 kg/year (<1% of total phosphorus). The removal of the septic systems results in a decrease of 27.46 kg/year (4% of total phosphorus) and the removal of the Uplands WWTF results in a decrease of 39.42 kg/year (5% of total phosphorus).

### 8.1.4 Scenario 4: Future Land Use 3

Scenario 4 has the same land use conditions as Scenario 3 but also includes Advanced Stormwater Management in the future development areas of Greenfield area, Bedford West and Jack Lake Lands as displayed on **Figure 15** and described in **Appendix E**.

It is recognized that future development within the watershed will be required to implement stormwater management facilities to control runoff water quantity and quality. In this study, a detailed knowledge of the type and size of each stormwater management facility is not defined for future developments. Consequently, a simplified approach was taken for all future developments to estimate the effects on total phosphorus loadings based on the implementation of Advanced Stormwater Management within all new developments. In this study Advanced Stormwater Management is considered to be methods that remove 50% of total phosphorus from stormwater runoff. The HRM Stormwater Management Guidelines (Dillon Consulting Limited 2006) give an example of wet pond method that removes 50% of total phosphorus.

The removal of 50% of the total phosphorus is integrated into the Lake Capacity Model by creating a separate land use classification: Small Lot Residential with Advanced Stormwater Management (Figure 13). This land use classification includes the future development areas in the Greenfield, Bedford West and Jack Lake Lands. The phosphorus export coefficient for this land use is reduced by 50% to 300 g/ha/yr in order to represent the

phosphorus removal by stormwater management. These removal rates are optimal and have been used here as an indication of what may be achieved through the rigorous application of stormwater management measures.

## 8.2 Marsh Lake

### 8.2.1 Scenario 1: Existing Conditions

The phosphorus concentration of Marsh Lake under the existing land use conditions was calculated with the land use areas in and the phosphorus export coefficients in **Appendix E**. The predicted phosphorus concentration is 12 µg/L which is 20% greater than the observed value for Marsh Lake (10 µg/L) and below the water quality objective recommended for this lake (15 µg/L). Adjusting the phosphorus retention coefficient from 0.05 to 0.2 rectifies the predicted to measured.

### 8.2.2 Scenarios 2 and 3: Future Land Use

The predicted phosphorus concentration Marsh Lake in Scenario 2 is 13 µg/L which is a 30% increase from existing conditions but below the recommended water quality objective (15 µg/L). The predicted phosphorus concentration Marsh Lake in Scenario 3 is 12 µg/L which is a 20% increase from existing conditions but below the recommended water quality objective (15 µg/L).

The land use changes in Scenarios 2 and 3 do not directly affect much of the land use in the Marsh Lake subwatershed (Table 2-3) but does include an increase in land use as small lot residential and large lot residential in the northern portion of the subwatershed (**Appendix E**). Marsh Lake receives water flowing from Sandy Lake resulting in changes to the Sandy Lake subwatershed also impacting the water quality in Marsh Lake.

## 8.3 Lakeshore Capacity Model Summary

In summary, the LCM predicts the Scenario 2 full build out of all planned developments in the Sandy Lake watershed will result in an increase in phosphorus concentrations to 16 µg/L in Sandy Lake and 15 µg/L in Marsh Lake (**Table 13**). Scenario 3 includes full development in the watershed but reduces phosphorus inputs by removing the Uplands WWTF and removing the septic systems within 300 m of Sandy Lake. The LCM predicts phosphorus concentrations in Scenario 3 to be 15 µg/L in Sandy Lake and 14 µg/L in Marsh Lake. Development in the Sandy Lake watershed will increase in phosphorus concentrations in lake water by 20 to 30 % from existing conditions, but will remain within the recommended water quality objectives for Sandy Lake and Marsh Lake. Scenario 4 predicts increases of phosphorus concentrations to 13 µg/L in Sandy Lake and 12 µg/L in Marsh Lake.

**Table 13. Phosphorus concentrations predicted by the LCM**

Scenario	Sandy Lake Predicted Phosphorus (µg/L)	Marsh Lake Predicted Phosphorus (µg/L)
Scenario 1: Existing Conditions	12	11
Scenario 2: Planned Developments	16	15
Scenario 3: Planned Developments + removal of Uplands WWTF and Septic Systems near Sandy Lake	15	14
Scenario 4: Future Developments (Scenario 3) with Advanced Stormwater Management	13	12
Recommended Water Quality Objective	18	15.5

The LCM in this study is used to predict how future developments in the Sandy Lake watershed will affect lake water quality in the future. The LCM is a simple model with several assumptions that contribute to uncertainty in the precision of the modeled values. This application of the LCM has attempted to reduce the uncertainty in the model by adjusting parameters in the model to reflect the local conditions of the watershed. However, given the inherent uncertainty in the model, the values should be viewed in the context of a narrative describing how activities in the watershed will affect the lake water quality.

The results of the model predict that development in the watershed without phosphorus reduction offsets will increase the phosphorus concentration in the lakes and push the lake water quality closer to the upper mesotrophic range. Reductions in phosphorus load to the lakes can be achieved through two general approaches; reduce the wastewater effluent to the watershed and utilize stormwater management. While development in the Sandy Lake watershed would increase the phosphorus load from impermeable surfaces, the development would also provide an opportunity to reduce the phosphorus load from septic systems near the lake and WWTF effluent by directing wastewater away from watercourses and into waste water services. The meaning of the term Advanced Stormwater Management does not reflect any specific methods of stormwater management, but represents any methods that could reduce phosphorus discharge to lakes by 50%. Adoption of ASM systems would help offset the phosphorus load produced by changes in land use from undeveloped to developed.

The application of the LCM for the Sandy Lake watershed illustrates how phosphorus concentrations would be affected by development. The results suggest that changes in lake phosphorus concentrations from development can be mitigated by reducing the phosphorus load from wastewater effluent and Advanced Stormwater Management.

## 9. Recommendations for Water Quality Monitoring

The review of existing water quality for Sandy Lake, to establish the water quality guidelines (Section 5), identifies a long term trend of changes in Sandy Lake water quality, highlighted by changes in trophic status from oligotrophic to mesotrophic. Development plans include the conversion of approximately 350 ha (15% of the watershed area) from undeveloped (forested or deforested) to developed (small or large lot residential). Considering the trend of changes in water quality and the scale of planned development in the watershed, a robust water quality monitoring plan is recommended for Sandy Lake.

The report prepared for HRM entitled “Water Quality Monitoring Functional Plan” Stantec (2009) undertakes a review of best practices and provides a rationale for water quality monitoring program development including program costs and funding sources, data management and community engagement and education. This report provides an excellent context for recommendations of a water quality and quantity monitoring plan for the Sandy Lake watershed.

The Water Quality Monitoring Functional Plan identifies Sandy Lake as a Tier I waterbody or “High Vulnerability” to be sampled with a sampling program consisting of monthly collections during the ice free season (April – December) and at least one sample during the winter season. Groups of parameters and sampling periods are reproduced in **Tables 14 and 15**.

**Table 14. Recommended water quality monitoring (after Stantec 2009)**

Group 1	Group 2	Group 3
pH	Sodium	Aluminum
Conductivity	Potassium	Antimony
Temperature profile	Calcium	Arsenic
Dissolved oxygen profile	Magnesium	Barium
Secchi depth	Hardness as mg CaCO <sub>3</sub>	Beryllium
Air temperature	TDS (calculated)	Bismuth
Cloud cover	Alkalinity as mg CaCO <sub>3</sub>	Boron
Ice depth	Bicarbonate as mg CaCO <sub>3</sub>	Cadmium
Time	Carbonate as mg CaCO <sub>3</sub>	Chromium
Total phosphorus (low level)	Sulphate	Cobalt
Chlorophyll a	Chloride	Lead
E. Coli	Reactive Silica	Molybdenum
Turbidity	Nitrate-Nitrite (as N)	Nickel
Colour	Ammonia (as N)	Selenium
Incidental wildlife sightings	Total Organic Carbon	Silver
-	Iron	Strontium
-	Copper	Thallium
-	Manganese	Tin
-	Zinc	Titanium
-	-	Uranium
-	-	Vanadium

**Table 15. Water quality monitoring intervals (after Stantec 2009)**

April	May	June	July	August	September	October	November	December	January to March
Group 1	Group 1	Group 1	Group 1	Group 1	Group 1	Group 1	Group 1	Group 1	Group 1
Group 2				Group 2		Group 2			Group 2
Group 3						Group 3			

Temperature and dissolved oxygen profiles are recommended to be collected during each sampling event at 1 m intervals with profiling intervals increased to up to 3 m below the 20 m level. Water samples should be collected from 0.5 m below the lake surface, at mid-depth, and 1 m above the lake bottom.

Both discrete and volume-weighted samples from Sandy Lake are recommended to be analyzed. Total phosphorus and chlorophyll a testing must be performed on all discrete water samples. E. coli need only be measured for the 0.5 metre (top) water sample. Volume-weighted samples made up of top, middle and bottom water samples are to be tested for the remaining grouped analytical parameters specified in **Table 14**.

The water quality monitoring program for Tier 1 lakes (Stantec 2009) is recommended as a suitably robust water quality monitoring plan for Sandy Lake that will allow for the identification of seasonal and long term patterns in water quality and to evaluate how water quality may be impacted by development in the Sandy Lake watershed.

## 10. Policy E-17 Objectives

A complementary objective of the study is to provide a number of guidelines and recommendations for the planning, design and implementation of new developments that will protect water quality from further degradation. More specifically, the objectives of a watershed study are listed in Policy E-17 of the Regional Plan. Each sub-heading of Policy E-17 is listed below with a reference to where the item is addressed within the report, or if the sub-heading is not addressed directly in the report, it is addressed below.

### a) Recommend measures to protect and manage quantity and quality of groundwater resources.

As summarized in Section 2.6 (Groundwater) and **Appendix A** (Environmental Conditions), groundwater is a source of domestic water for many residents living within watershed and contributes 11 % of the flow from the watershed (**Appendix D**). The constraints mapping (Section 3.3) identifies areas with high recharge rates (>150 mm/yr) as Tier 2 constraints that can allow for development, but with controls in place to allow for recharge to continue to contribute to groundwater quantity and with controls that protect water quality. These areas provide pathways for water to enter the groundwater system at higher rates than other areas in the watershed. Protection measures during future development are recommended to preserve the hydraulic properties of these areas. Recommendations to protect these areas include maintaining a high proportion of permeable surfaces, maintaining native plants, avoiding compaction of soils and use of rain gardens. Protecting the areas with high recharge rates to encourage sustainable groundwater use will need to be coupled with measures to protect the quality of water entering the groundwater system. Recommendations to protect the quality of recharge water include prohibition of bulk fuel storage, prohibition of hazardous material facilities, prohibition of aggregate extraction, spill prevention for home heating fuel tanks, limited lawn fertilizer use and reduced use of road salts in these areas of high recharge potential.

### b) Recommend water quality objectives for key receiving watercourses in the watershed.

Water quality objectives are established in [Section 7 Receiving Water Quality Objectives](#) for nitrate, un-ionized ammonia, total suspended solids, chloride, *E. coli* and total phosphorus objectives for each lake based on maintaining the current lake trophic state as measured by TP concentrations. The objective, an early warning alert value and the method of determining each was provided.

### c) Determine the amount of development and maximum inputs that receiving lakes and rivers can assimilate without exceeding the water quality objectives recommended for the lakes and rivers within the watershed.

It is very difficult to provide a single expression of the amount of development or nutrient inputs that a lake can assimilate before the water quality objectives are exceeded. This is because of the inter-connectedness of the lakes and streams within a watershed and because of the range of nutrient concentrations derived from different development types (that is, different land uses). With respect to the inter-connectedness, “using up” the available capacity on an upstream lake will also use some portion of available capacity on all downstream lakes. Alternatively, using available capacity on a downstream lake may eliminate or preclude the development on an upstream lake. With respect to the effect of different types of development, for example, the phosphorus export coefficient used in the LCM in this study ranges from 200 g/ha/yr to 600 g/ha/yr for large lot residential and commercial land uses, respectively. This means that a given watershed can accommodate more hectares of large lot residential development than of commercial development. Given this variability in export coefficients, the type of development must be known before the amount of allowable development can be defined. In addition, municipal policy requires that stormwater management plans, designed to manage both runoff water quality and quantity, are submitted in support of applications for development agreement. These stormwater management plans use various combinations of best management practices and engineered facilities to manage runoff and each of these practices and installations have different efficiencies and effects on water quality.



With this variability in mind, the effects of the different development scenarios modeled for this study are described in [Section 8 Lakeshore Capacity Model](#). The results of Scenario 2 (Planned Developments) indicate that water quality objectives are not exceeded for Sandy Lake and Marsh Lake.

**Table 16** summarizes the estimated residual phosphorus concentration “capacity” for each lake in the watershed following the completion of the approved developments as per Scenario 2.

**Table 16. Estimate of Conceptual Residual Capacity Remaining for Each Lake Following Approved Developments as per Scenario 2**

Lake	Measured and Predicted TP Concentration Following Implementation of Approved and Planned Developments from Table 21 (Scenario 2)	Water Quality Objective	Early Warning Alert Value	Conceptual Residual Capacity (Difference Between Objective and Modeled Concentration Following Implementation of Scenario 2)
Sandy Lake	16	18	15	2
Marsh Lake	13	15	13	2

**d) Determine the parameters to be attained or retained to achieve marine water quality objectives**

The Sandy Lake Watershed does not have a marine component. Due to the relatively good quality of Sandy Lake and Marsh Lake, existing and future inputs from the Sandy Lake Watershed to the Sackville River and Bedford Basin will not have a measureable effect on marine water quality. In fact, nitrate loadings (which are more important in saltwater ecosystems than in freshwater systems) and other nutrient inputs due to changes in upstream land use will be minimal compared to discharges from the Mill Cove Sewage Treatment Plant.

**e) Identify sources of contamination within the watershed**

Several sources and potential sources of contamination are located in the Sandy Lake watershed. Non-point sources of contamination are distributed throughout the watershed and point sources of contamination have discreet locations. Both types of contamination present risks and impacts to the water quality of the waterbodies in the Sandy Lake watershed. The sources and potential sources are identified and discussed, while mitigation and prevention methods are presented in Section f, below.

Non-point sources:

- Deforestation
  - Deforestation may impact water quality by increasing the organic content and sedimentation of runoff. Studies completed in the Pockwock watershed (NFA 2005) indicate the impact of deforestation on water quality is negligible when compared to the changes in phosphorus, chlorophyll-a, Secchi depth or pH from seasonal variations. However, best management practices for logging will limit the potential for impacts on water quality from deforestation.
- Stormwater runoff
  - Stormwater runoff directs overland flow from developed areas through rudimentary drainage systems to streams and lakes. Sandy Lake is the primary receiving waterbody in the Sandy Lake watershed. Overland flow from developed areas represents a significant urban non-point source of pollution and contributes sediments, oil, anti-freeze, road salt, pesticides, nutrients and pet and waterfowl droppings to Sandy Lake. This urban runoff generally accelerates the eutrophication or natural aging process of urban lakes by adding sediment and nutrients. The added nutrients can contribute to algal blooms, decreased water clarity, and an increase in the amount of rooted aquatic plants growing in the shallow near-shore waters of a lake. All of these can reduce the recreational value of a lake by hindering swimming, boating, fishing and reducing its overall aesthetics.

- **Bedrock**
  - Acid rock drainage (ARD) is a naturally occurring process that results from the oxidation of sulphide minerals when the rock is exposed to oxygen. The breakdown of the sulphide minerals releases sulphuric acid, iron, and may also release arsenic, aluminum, cadmium, copper, manganese and zinc into the environment. The oxidation process and release of ARD is accelerated when bedrock is exposed to air by excavation or blasting. In HRM, several examples of ARD impacting water quality (Fox et al. 1997) are documented, resulting in low pH surface waters that were attributed to fish kills (Scott 1961, Porter-Dillon 1985). The Nova Scotia Environment Act limits the excavation and requires disposal of displaced rock with sulphide weight more than 0.4%. Detailed bedrock mapping and chemical analyses of distinct lithologies by White and Goodwin (2011) identify the Cunard Formation of the Halifax Group (northwest area of Sandy Lake watershed) and the Beaverbank Formation of the Goldenville Group (~1km band trending northeast near Lucasville) have acid generating potential. The Beaverbank Formation also displays high concentrations of metals such as arsenic, copper and zinc. The remaining bedrock underlying the Sandy Lake watershed is composed of Taylors Head Formation of the Goldenville Group and is not anticipated to have significant acid generating potential (White and Goodwin 2011). Despite the generalizations of White and Goodwin (2011), water quality results from the tributary draining into the northwest arm of Sandy Lake displayed decreased pH and elevated metal concentrations compared to other Sandy Lake water quality data (Conrad 2002). Development, excavation or aggregate removal that disturbs bedrock in Sandy Lake will generate acidic discharge. The north western portion of the watershed is more likely to have significant ARD and development in that area should avoid exposing bedrock to air and in situations where this is unavoidable, mitigation measures should be put in place to prevent ARD entering Sandy Lake.
  - Historic mine shafts: Five historic mine shafts are located in the northwest area of the Sandy Lake watershed. The Nova Scotia Abandoned Mine Database indicates the mine shafts were for gold exploration and reached a depth of 12 m. The mine shafts are filled in and considered to have low hazard potential.
- **Road salt application:** road salts pose a risk to plants and animals in the aquatic environment. Road salt application can also impact groundwater quality, leading to elevated concentrations of chloride in drinking water. HRM recognizes the potential impacts to surface and groundwater quality and utilizes several best management practices to reduce the impacts when possible (HRM 2012). However, the application of road salts along Hammonds Plains Road and to a lesser extent on secondary residential roads contributes to chloride loading in Sandy Lake.

**Point sources:**

- **Septic systems:** Properly functioning septic systems allow the infiltration of clarified discharge to soils. Nutrients and bacteria are utilized by organisms in the soil. Septic systems less than 300 m to water bodies and malfunctioning septic systems likely contribute nutrients and bacteria to the water bodies in Sandy Lake. There are approximately 20 residences within 300 m of Sandy Lake and approximately 200 residences within 300 m of watercourses that utilize septic systems.
- **Illegal garbage disposal** occurs when garbage is dumped in ditches, forests, pits or ponds that are not designated for waste disposal. Contamination from illegal dumping depends on the quantity and type of materials disposed of. Sandy Lake watershed is not known to have significant illegal dumping; however illegal dumping is known to occur in rural Nova Scotia and has likely occurred within the watershed. If illegally dumped material is found on HRM property, the municipality should be notified. The municipality is not responsible for removing illegally dumped material on private property. If dumped material is found on private property it should be placed for curbside collection or arrangements should be made for the material to be removed from their property.
- **Wastewater treatment facilities:** The Uplands Park Wastewater Treatment Facility (WWTF) is located in the Sandy Lake watershed. It has been operational since 1969 and is a source of nutrients to Sandy Lake. The facility may overflow and bypass the treatment cycle during storms or malfunctions. Untreated wastewater discharge carries high nutrient loads, especially phosphorus and can significantly add to the natural and non-point loading of phosphorus to lakes resulting in their rapid eutrophication. The impact of the wastewater overflows is difficult to quantify for several reasons:

- Overflows typically occur during extreme weather events. The timing, frequency and severity of these events are not possible to predict and so the water quality impacts from overflows cannot be quantified or modeled.
- Halifax Water monitors the volumes and locations of overflows but does not measure the concentration of effluent released to the environment during an overflow event. Given this, it is not possible to gauge the nutrient loading that may occur during these events.

We assume that reduction and ideally elimination of these overflows will be a priority within the plans for expansion of the waste water collection and treatment system within the watershed.

- Timber Trails mobile home park: Timber Trails is serviced by a private communal septic system. Approximately 233 homes are located in Timber Trails and a proposed expansion of the park is conditional on improvement and expansion of the septic system. The septic system is a source of phosphorus, nitrate and bacteria to surface water and groundwater. In the past, the park has struggled with wastewater treatment issues such as overflow and seepage during rain events. The park is approximately 4 km from Sandy Lake, so it doesn't represent a direct impact on the water quality of Sandy Lake. However, the septic system can impact local groundwater which is used for potable water supply in the area.
- Gas Stations: gas stations hold large quantities of fuel in underground and above ground storage tanks. Under typical conditions gas stations represent a minor risk of hydrocarbon impact from small spills during fuel transfer. However, the large volume of fuel represents potential large impacts to groundwater and surface water. Leaks of fuel and large releases of fuel are not common, but are known to occur.
- Residential oil tanks: Nova Scotia Environment considers a domestic oil spill to be a release of petroleum at a private residence such as an oil tank leak. A domestic fuel spill can impact soils, groundwater and potentially surface water. Hundreds of residential oil spills occur in Nova Scotia each year (NSE 2013). The risk of residential oil spills on the surface water of Sandy Lake is low considering the small volumes of oil and the distance of most residences from water bodies.
- Landfills (current or historic): There are currently no active landfills in the Sandy Lake watershed. However, considering the watershed has been populated for a long period of time, there is potential for historic landfills or dumping areas that have been abandoned. Neglected historic landfills could leach metals and toxic chemicals into the waterbodies of Sandy Lake.
- Motor boats: Motorized water crafts can impact water quality and lake ecology by increasing turbidity and re-suspension of sediments which can increase phosphorus concentrations. They can also lead to an increase in hydrocarbons.
- Animal feces: Animal feces contribute bacteria and nutrients to Sandy Lake. Bird populations such as ducks, loons and gulls contribute the nutrient and bacteria load to Sandy Lake. However, the excrement of pets also contributes to the loading of Sandy Lake through the stormwater drainage system and more directly at the Sandy Lake Park on-off leash area. Sandy Lake was closed for swimming in July 2013 because of high bacteria levels. It is not clear what the source of the bacteria was, but pet feces may have contributed.
- Fertilizers used on lawns and gardens are used to promote healthy lawns and gardens on residential and commercial properties. Excessive or improper application of fertilizers can lead to nutrient loading of surface water bodies.

#### **f) Identify remedial measures to improve fresh and marine water quality**

There are several ways that water quality can be improved. These improvements generally fall into two categories: management practices and engineered solutions. Not all the improvements identified below are necessarily practical or viable: some may be cost prohibitive, technically impossible, or lack a regulatory requirement or enforcement mechanism. Nevertheless, these remedial measures represent options that may be considered to improve water quality.

1. Undertake a survey of septic systems to better characterize their age, maintenance and functionality. Older systems (more than 15 years) can be subjected to a dye test to verify they continue to function as designed.

Replace degraded septic systems or require alternatives (aerobic systems, holding tanks etc.) if the site is not capable of accommodating a conventional septic system under current design specifications. Encourage residents to have systems inspected and pumped on a regular basis. HRM can consider adopting a by-law that requires period inspection, testing and pumping of private septic systems, similar to that enacted in Chelsea, QC.

2. Retrofit or improve existing stormwater management systems through the introduction of sediment/water control basins, constructed wetlands, vegetated swales, flow-through filter strips, stormwater infiltration systems and disconnection of roof drains from stormwater systems.
3. Ban phosphorus-containing fertilizers and encourage proper and minimal use of other fertilizers and herbicides.
4. Encourage homeowners to plant naturalized riparian buffers or increase the width and density of existing buffers.
5. Encourage homeowners to pick up after pets.
6. Educate residents to use non phosphate soaps when washing vehicles or use a car wash.
7. Educate residents to refrain from disposing of oil, antifreeze or other potentially harmful wastes into municipal drains and provide collection centers for these liquid wastes for safe disposal.
8. Require sediment management on construction projects including silt fencing to control runoff and washing of vehicles prior to departing the site to avoid mud and dirt being deposited on roadways for eventual runoff into storm sewers.
9. Report illegal dumping or unusual conditions in lakes and streams (high suspended sediments, oil sheens, algae blooms).
10. Strive to eliminate sewage system overflows through expansion of the system and upgrades as appropriate.
11. Maintain the water quality and water quantity monitoring program at a base level such as recommended here to ensure compliance with water quality objectives and expand the database for future modeling enhancements.
12. Apply a no net change to flow, suspended sediment and phosphorus loads from new developments by requiring site specific evaluations and implementation and maintenance of storm water mitigation measures.

Marine water quality was not considered during this study since the watershed does not include a marine estuary component.

**g) Recommend strategies to adapt HRM's stormwater management guidelines to achieve the water quality objectives set out under the watershed study**

HRM's Stormwater Management Guidelines (Dillon Consulting Ltd. 2006) describes criteria for the design of stormwater management best management practices (BMPs) to minimize the negative water quality effects of stormwater runoff from urban development. In this report, the term "best management practice" applies to both in-ground infrastructure (pipes, retention basins, etc.) as well as activities, such as street cleaning and land use restrictions, that may impact water quality. As the report notes:

There is no single BMP that suits every development, and a single BMP cannot satisfy all stormwater control objectives. Therefore, cost-effective combinations of BMPs may be required that will achieve the objectives.

At this time, stormwater control infrastructure requires provincial approval from Nova Scotia Environment under the Environment Act and in accordance with the Storm Drainage Works Approval Policy. HRM's authority with respect to stormwater management comes from the HRM Charter Act, which allows HRM to make and enforce municipal by-laws related to land use. Existing municipal planning strategies already include certain land use restrictions that have beneficial effects on water quality. These restrictions include, for example, prohibiting or limiting construction within flood plains, wetlands and steep slopes. In addition, municipal planning strategies also include stormwater management provisions, such as the requirement to obtain municipal approval of stormwater management plans, water quality monitoring plans and erosion control plans prior to development approval.

Other strategies that may be useful in adapting HRM's stormwater management guidelines to achieve the water quality objectives include:

- Implementation of financial resources or financial mechanisms (including cost sharing) to fund infrastructure, testing, operating and maintenance;
- Exploration of new stormwater management and treatment technology;
- Educational programs to encourage homeowners to reduce sediment and other pollutant discharge (fertilizers, grass cuttings) to storm sewers; and
- Apply a no net change to flow, suspended sediment and phosphorus loads from new developments by requiring site specific evaluations and implementation and maintenance of storm water mitigation measures.

**h) Recommend methods to reduce and mitigate loss of permeable surfaces, native plants and native soils, groundwater recharge areas, and other important environmental functions within the watershed and create methods to reduce cut and fill and overall grading of development sites;**

The protection of areas and functions that are important to a healthy watershed can be achieved through the implementation of general planning principles and through the integration of site specific design plans.

The replacement of permeable soils by roads, sidewalks and roofs can be reduced during the planning process and through specific design features. An effective planning method is to cluster buildings and infrastructure in defined, less permeable or otherwise less sensitive areas in order to maximize permeable vegetated open space.

Stormwater management best management practices and design standards aimed at promoting infiltration rather than runoff can be required during the site plan approval process. These measures are described in detail in HRM's Stormwater Management Guidelines and would include, for example, discharge of roof drainage to infiltration trenches or ponds, the use of vegetated swales and perforated conveyance pipes, and the installation of wet ponds and artificial wetlands. Design of properties and landscape provides opportunities to improve infiltration and partially offset the loss of permeable surfaces. Lawns and driveways can be designed to promote infiltration and water from roof drains can be collected in rain barrels, discharged to rain gardens or retained with roof top gardens. Disconnecting foundation drainage from storm sewer reduces the flow to the stormwater system and increases infiltration. Landscaping effects water drainage and when used effectively can be designed to encourage infiltration and reduce runoff.

Reducing the loss of native plants and soils is an effective way of reducing sediment and water runoff to stormwater systems. The design of new developments requires the removal and displacement of some native soils and plants, but the extent of the displacement can be mitigated through planning and local design.

Development may inadvertently disturb or destroy vegetation communities such as wetlands, riparian buffers and vegetation found in indistinct flow conveyance channels that play a significant role in maintaining water quality.



Developers should be requested to provide detailed “wet areas mapping” of properties proposed for development so these vegetation communities can be accurately delineated and their hydrological functions maintained.

Groundwater recharge in the Sandy Lake area is presented in **Figure 6**. The areas of highest recharge are located near Sandy Lake and Marsh Lake. These areas contribute to local groundwater and to Sandy Lake. The surficial aquifer located in the northeastern part of the watershed is not well defined and has not been tested and characterized. However, considering its proximity to Sandy Lake, Marsh Lake and the Sackville River, it is likely hydraulically connected to the surface water bodies. Development in the areas of high recharge should include specific plans to reduce impermeable surfaces. In addition, development in the areas of high recharge should include aquifer protection measures similar to wellhead protection areas. Recommended land use restrictions include prohibition of bulk fuel storage, prohibition of hazardous material facilities, prohibition of aggregate extraction, spill prevention for home heating fuel tanks, limited lawn fertilizer use, and reduced use of road salts.

**i) Identify and recommend measures to protect and manage natural corridors and critical habitats for terrestrial and aquatic species, including species at risk**

As noted in Appendix A Section 5.1, Atlantic salmon of the Nova Scotia Southern Upland population are known to be in Sandy Lake. Atlantic salmon are listed by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as endangered. Fish habitat in Peverills Brook was modified in 2012 by the Sackville Rivers Association to encourage salmon migration and spawning. Maintenance of the fish stream modifications and upgrading as needed will ensure the modifications continue to function as designed. A monitoring program of salmon populations in the Sandy Lake watershed is recommended to evaluate the salmon population and identify measures to encourage growth in the population. Additional design measures aimed at maintaining water quality, especially mitigating stormwater quality, will equally protect aquatic habitat. These measures are described above.

Within the Sandy Lake watershed, no plant species of federal conservation concern have been recorded. Seven vascular plants of provincial concern have been recorded within five kilometers of the centre of the watershed; of these seven species, two – the wavy leaved aster (*Symphyotrichum undulatum*) and the Greenland stitchwort (*Minuartia groenlandica*) have been observed in the Marsh Lake area. Both plants are listed as S2 (provincially rare); their general status rank is sensitive. Constraints to development on slopes will help to protect and preserve these species.

The Atlantic Canada Conservation Data Centre records 25 animal species of conservation concern within the Sandy Lake watershed (Appendix A). Although most of these species are birds, there are two amphibians present: the snapping turtle and the wood turtle. The wood turtle is classified as threatened under Canadian Species at Risk Act (SARA) and COSEWIC. Wood turtles are fairly tolerant of changes to adjacent land uses, but require stream and woodland habitat to remain intact. An assessment of the wood turtle habitat range in the Sandy Lake watershed would provide site specific information that could be used to assess habitat improvements and protection. Until a habitat assessment can be completed, it is recommended that a 20 m buffer to all streams and waterbodies be kept free from disturbance and development.

**j) Identify appropriate riparian buffers for the watershed**

Under Watercourse Setbacks and Buffers The Halifax Mainland Land Use By-Law” [14QA(1)] states:

“No development permit shall be issued for any development within 20 m of the ordinary high water mark of any watercourse. Where the average positive slopes within the 20 m buffer are greater than 20%, the buffer shall be increased by 1 m for each additional 2% of the slope, to a maximum of 60 m.”

As noted in Section 3.3 Development Constraints, a 20 m buffer along all water courses is reported to eliminate more than 70% of suspended sediment and more than 60% of phosphorus (Hydrologic Systems Research Group

2012). The maintenance of a minimum 20 m wide riparian buffer is appropriate for all watercourses within the watershed.

#### **k) Identify areas that are suitable and not suitable for development within the watershed**

Please refer to Section 3.3 Development Constraints and Figure 7, which identifies areas suitable and not suitable for development. Unsuitable areas include:

##### Type 1 Constraints

- Watercourses, wetlands and riparian buffers

##### Type 2 Constraints

- Slopes greater than 20%
- Bedrock with acid generating potential
- Groundwater recharge (>150 mm per year)

If land is not constrained, then it is potentially suitable for development. The total area that can or should be developed and the nature of the development both need to be carefully planned so that established water quality objectives will be maintained following development.

#### **l) Recommend potential regulatory controls and management strategies to achieve the desired objectives**

Regulatory controls and programs already in place that contribute to the maintenance of water quality include:

- Halifax Water Regulations and Guidelines for Stormwater Management;
- Design and Construction Specifications (referring to quantity of stormwater only);
- HRM Municipal Design Guidelines 2013; and,
- 2009 Stormwater Inflow Reduction program.

A stormwater management by-law would be helpful to manage and enforce stormwater related nutrient and sediment inputs to watercourses. In addition to such a by-law, the following additional controls and strategies are recommended for consideration:

1. Adopt the proposed water quality objectives.
2. Preserve natural storage, infiltration and filtration functions; develop SWM systems that reproduce or mimic natural functions.
3. Revisit land use planning restrictions that provide for stormwater management (such as restricting development in flood zones, in sensitive areas, on slopes, in wetlands, etc.) and compare them with similar policies in other jurisdictions to determine if these policies should be updated or upgraded to improve their effectiveness.
4. Require developers to demonstrate no net increase of sediment and TP loadings to adjacent water features.
5. Require developers to financially support a water quality monitoring program to assess compliance with the water quality objectives.
6. Enforcement of stormwater management for quality and quantity as per the HRM Stormwater Management Guidelines.
7. Elimination of sanitary sewer overflows within the watershed.

8. Elimination of Waste Water Treatment Plant by-passes.
9. Inspection and testing of septic systems in the watershed; phased replacement if they are not functioning due to high water table, poor design, inadequate maintenance, close to surface water. Consideration of alternative treatment systems to replace existing septic systems.

**m) Recommend a monitoring plan to assess if the specific water quality objectives for the watershed are being met**

The monitoring plan is described in Section 9: Recommendation for Water Quality and Quantity Monitoring.

## **11. Summary and Conclusions**

The Sandy Lake watershed is designated as an Urban Settlement area and currently hosts urban development along main thoroughfares (Hammonds Plains Road, Lucasville Road), in industrial areas and in suburban style communities. Portions of the watershed are serviced with municipal water and wastewater services and portions of the watershed utilize on-site water wells and septic systems.

A development constraints map of the watershed identifies areas that are not suitable for development (wetlands, watercourses and riparian zones) and areas that may require environmental mitigation to be included in development plans if the areas are developed.

Possible future development scenarios are identified in the watershed and land use maps depicting existing conditions and three future development scenarios were prepared. The land use maps were used as inputs to a phosphorus load model (Lake Capacity Model) to predict how future development may impact the phosphorus concentrations of the lakes. Phosphorus is identified as a key water quality parameter to assess the trophic status of the lake.

Historic water quality samples and water samples collected during the course of this study were used to identify water quality objectives for parameters that are influenced by development. The water quality in Sandy Lake and Marsh Lake is currently being affected by urban development in the water as displayed by the increasing phosphorus concentration in Sandy Lake. Both Sandy Lake (12 µg/L) and Marsh Lake (10 µg/L) have median phosphorus concentrations that place them in the lower end of the mesotrophic range. Water quality objectives and early warning values are set at 18 µg/L and 15 µg/L for Sandy Lake and 15 µg/L and 13 µg/L for Marsh Lake respectively.

Cumulative impacts of development on phosphorus concentrations are predicted to increase to 16 µg/L for Sandy Lake and 15 µg/L for Marsh Lake when mitigation measures to decrease phosphorus loading are not implemented. These levels are above the early warning values, but below the water quality objectives. Removing point sources of phosphorus such as the Uplands WWTF and septic systems near Sandy Lake by connecting them to municipal wastewater services decreases the predicted phosphorus concentrations to 15 µg/L and 14 µg/L for Sandy Lake and Marsh Lake respectively. Additional phosphorus mitigation measures using advanced stormwater management that reduces phosphorus runoff by 50% is predicted to decrease the phosphorus concentration of Sandy Lake to 13 µg/L and of Marsh Lake to 12 µg/L.

## References

- AECOM. 2013. Birch Cove Lakes Watershed Study – Final report. April 1, 2013. Project 60221657. 419 pp.
- ASCF Atlantic Salmon Conservation Foundation (2013) Peverills Brook Habitat Restoration Project. Retrieved from: [http://salmonconservation.ca/en/projects/peverills\\_brook\\_habitat\\_restoration\\_project/](http://salmonconservation.ca/en/projects/peverills_brook_habitat_restoration_project/) on June 17, 2013.
- Bachiu T.P. 2010. Investigating sources of stream chloride near Kejimikujik National Park, Southwestern Nova Scotia: A chlorine stable isotope approach. M.Sc. Thesis Dalhousie University.
- Brylinsky, M. 2004 User's Manual for Prediction of Phosphorus Concentration in Nova Scotia Lakes: A Tool for Decision Making Version 1.0. Acadia Centre for Estuarine Research. Prepared for the Nova Scotia Water Quality Objectives and Model Development Steering Committee, NS Department of Environment and Labour. 82 p.
- Caissie D., Robichaud S. 2009. Towards a better understanding of the natural flow regimes and streamflow characteristics of rivers of the Maritime Provinces. Canadian Technical Report of Fisheries and Aquatic Sciences 2843. Fisheries and Oceans Canada.
- CBCL. 2009. Cost of Servicing Plan – Regional Planning Greenfield Sites. Prepare for Halifax Regional Municipality Report No. 071065. February 2009. 46 pp.
- Chambers, P.A., M. Guy, E.S. Roberts, M.N. Charlton, R. Kent, C. Gagnon, G. Grove and N. Foster. 2001. Nutrients and their impact on the Canadian environment. Agriculture and Agri-Food Canada, Environment Canada, Fisheries and Oceans Canada, Health Canada and Natural Resources Canada. 241 p.
- Conrad, D., Sidhom, H. And S. Matthews. 2002. Sandy Lake Development Impact Assessment Final Report. Biological Engineering Department, Dalhousie University, Halifax, NS. 88 pp.
- CCME - Canadian Council of Ministers of the Environment. 2004. Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems Report No. 1-8. Prepared and published by National Guidelines and Standards Office Water Policy and Co-ordination Directorate, Environment Canada, Ottawa. Cat. No. En1-34/8-2004E-PDF.
- Clair T.A., Dennis I.F., Scruton D.A., Gilliss M. 2007. Freshwater acidification research in Atlantic Canada: a review of results and predictions for the future. Environmental Review; 15: 153-167.
- Dillon Consulting. 2009. Class 1 Environmental Impact Assessment Report, Highway 113 Project. Submitted by Nova Scotia Transportation and Infrastructure Renewal. November 13, 2009.
- Dillon Consulting Limited 2002 (revised 2003). HRM Water Resource Management Study Report. File 00-8283-9000. 366 p.
- Dillon, P.J. and F.H. Rigler. 1975. A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status. Journal of the Fisheries Research Board of Canada, Vol. 32 No. 9:1519-1531.
- Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan, and D.S. Jeffries. 1986. Lakeshore Capacity Study, Trophic Status. Ontario Ministry of Municipal Affairs. Research and Special Projects Branch. Queens Printer for Ontario. ISBN 07743 80772
- Dillon, P.J., W.A. Scheider, R.A. Reid D.S. Jeffries. 1992. Lakeshore capacity study: Part I – Test of effects of shoreline development on the trophic status of Lakes. Lake and Reserv. Manage. 8(2):121-129.



- Dalhousie and Nova Scotia College of Art and Design 2002a. Sandy Lake Community Profile. Sandy Lake Community Research Group.
- Dalhousie and Nova Scotia College of Art and Design 2002b. Suggestions for Managing Development. Sandy Lake Community Research Group.
- Dillon Consulting. 2006. Stormwater Management Guidelines. Prepared for Halifax Regional Municipality.
- Dillon, P.J. and F.H. Rigler. 1975. A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status. Journal of the Fisheries Research Board of Canada, Vol. 32 No. 9:1519-1531.
- Dillon, P.J., K.H. Nicholls, W.A. Scheider, N.D. Yan, and D.S. Jeffries. 1986. Lakeshore Capacity Study, Trophic Status. Ontario Ministry of Municipal Affairs. Research and Special Projects Branch. Queens Printer for Ontario. ISBN 07743 80772
- Dodds W.K., J.R. Jones, E.B Welch. 1998. Suggested classification of stream trophic state: Distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Res. 32:1455-1462.
- EDM - Environmental Design and Management Limited. 2006. Blue Mountain/Sandy Lake Assessment Study. Final Report. Prepared for: Halifax Regional Municipality, Nova Scotia Department of Transportation and Public Works, and Nova Scotia Department of Natural Resources. March 2006.
- Environment Canada. 2014. Water Office. Near Real Time Water Level Information. Sackville River at Bedford, NS Station 01EJ001. Retrieved on January 6, 2014 from [http://www.wateroffice.ec.gc.ca/graph/graph\\_e.html?stn=01EJ001](http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=01EJ001)
- Environment Canada. 2013. Canadian Climate Normals. 1981-2010 Climate Normals and Averages. Microsoft Access Database.
- Environment Canada 2014. National Water Data Archive (HYDAT). Access February 2014 from: <http://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=9018B5EC-1>.
- FOC: Fisheries and Oceans Canada 2013. Risk-based assessment of climate change impacts and risks on the biological systems and infrastructure within Fisheries and Oceans Canada's mandate – Atlantic Large Aquatic Basin. Canadian Science Advisory Secretariat Science Response 2012/044.
- Fox, D., Robinson, C. and M. Zentilli 1997 Pyrrhotite and associated sulphides and their relationship to acid rock drainage in the Halifax Formation, Meguma Group, Nova Scotia. Atl. Geol. 33, 87-103.
- Fracflow Consultants Inc. (Fracflow) 2004. Screening Level Assessment of the Groundwater Resource Potential of Bedrock in HRM: a Component of HRM's Wastewater Management Options Study. Submitted to Land Design Engineering Services.
- Government of Nova Scotia. 2011. Nova Scotia Wetland Conservation Policy. September 2011. Available online: <http://www.gov.ns.ca/nse/wetland/docs/Nova.Scotia.Wetland.Conservation.Policy.pdf>
- Halifax Water. 2008. Uplands Park Wastewater Treatment Plant Upgrades. Request for Proposal. November 2008. 10 pp.
- Hart, W.C. and D.H. Waller. 1984. Application of a phosphorus loading model to water quality in the Shubenacadie River Basin. Proc. National Eng. Conf. Halifax, May 1984. Pp. 1011-1021.

- Hart, W.C., R.S. Scott and J.G. Ogden III. 1978. A phosphorus loading model for lakes in the Shubenacadie River Headwaters. Shubenacadie-Stewiacke River Basin Board. Technical Report #2.
- Health Canada. 2010. Guidelines for Canadian Drinking Water Quality – Summary Table. Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. 15 p.
- HESL & MOE: Hutchinson Environmental Sciences Limited and Ministry of Environment. 2011. Lake Simcoe Phosphorus Loading Tool. Version 1.4, June 2012. By: Hutchinson Environmental Sciences Limited and Ontario Ministry of Environment, Greenland, Stoneleigh Data.
- Hodgkins G.A., Dudley R.W., Huntington T.G. 2003. Changes in the timing of high river flows in New England over the 20<sup>th</sup> Century. *Journal of Hydrology*; 278: 244-252.
- HRM Staff Report. 2012. Case 17901: Partial Discharge of Development Agreement – Timber Trails Mobile Home Park, Lucasville. North West Planning Advisory Committee August 1, 2012. 13 pp.
- HRM – Halifax Water. 2013. Community Plants. Uplands Park Wastewater Treatment Facility. Retrieved December 11, 2013 from: <http://www.halifax.ca/hrwc/wastewaterTreatmentPlantscommunity.html>
- HRM 2013. Municipal Design Guidelines.
- HRM Staff Report. 2008. Case 00908: Development Agreement – Expansion of Timber Trails Mobile Home Park, Lucasville Road, Hammonds Plains. 13 pp. North West Planning Advisory Committee October 1, 2012. 38 pp.
- HRM Staff Report. 2012. Road Salt Impacts on Lakes. Environmental and Sustainability Standing Committee. April 16, 2012. 47 pp.
- Hutchinson, N.J., Neary, B.P. and P.J. Dillon. 1991. Validation and use of Ontario's trophic status model for establishing lake development guidelines. *Lake and Reserv. Manage.* Vol 7:13-23.
- Hutchinson, N.J. 2002. Limnology, plumbing and planning: Evaluation of nutrient-based limits to shoreline development in Precambrian Shield watersheds, p.647-680. In R.L. France, [ed.], *Handbook of water sensitive planning and design*, Lewis Publishing.
- Hydrologic Systems Research Group. 2012. Setbacks and Vegetated Buffers in Nova Scotia – A review and analysis of current practice and management options. Unpublished Report, 123 pp.
- Jacques Whitford. 2004. Bedford West Planning Area Subwatershed Management Plan. Prepared for: Annapolis Group Inc. May 2004.
- Jones, J. A., Achterman, G. L., Augustine, L. A., Creed, I. F., Folliot, P. F., MacDonald, L., & Wemple, B. C. 2009. Hydrologic effects of a changing forested landscape – challenges for the hydrological sciences. *Hydrological Processes*, 23, 2699-2704.
- Kennedy, G.W and Utting, D.J. 2011. LiDAR, Surficial Geology Mapping, and Water Wells: Uncovering Potential Surficial Aquifers in Halifax, NS. Geohydro Conference 2011.
- Kennedy G.W., Garroway K.G., Finlayson-Bourque D.S. 2010. Estimation of regional groundwater budgets in Nova Scotia. Nova Scotia Department of Natural Resources.

- Kharin V.V., Zwiers F.W., Zhang X., Hegerl G.C. 2007. Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations. *Journal of Climate*; 20.
- MOE Ministry of the Environment. 2010. Lakeshore Capacity Assessment Handbook – Protecting water quality in inland lakes on Ontario's Precambrian Shield.
- Neily, P.D., Quigley E., Benjamin, L., Stewart, B., Duke T. 2003. Ecological Land Classification for Nova Scotia Volume 1 - Mapping Nova Scotia's Terrestrial Ecosystems Nova Scotia Department of Natural Resources Renewable Resources Branch April 2003 Report DNR 2003-2
- Nova Forest Alliance (NFA) 2005. Watershed Study Understanding the Impacts of Forest Practices on Water.
- NSDNR Nova Scotia Department of Natural Resources. 2004a. Wetland Inventory. Updated May 3, 2011. Available online at: <http://gis4.natr.gov.ns.ca/website/nssighabnew/viewer.htm>.
- NSDNR - Nova Scotia Department of Natural Resources. 2004b. Significant Species and Habitats Database. Updated April 11, 2012. Available online at: <http://gis4.natr.gov.ns.ca/website/nssighabnew/viewer.htm>. A1pg13
- NSDNR - Nova Scotia Department of Natural Resources. 2007. Ecological Land Classification Map of Nova Scotia. Map DNR 2007-2 October 2007, Scale 1:500 000. Available at [http://www.novascotia.ca/natr/forestry/ecological/pdf/ELC\\_Map.pdf](http://www.novascotia.ca/natr/forestry/ecological/pdf/ELC_Map.pdf)
- NSDNR Nova Scotia Department of Natural Resources. 2013. Groundwater Maps and Databases, On-line Viewer. Nova Scotia Department of Natural Resources. Accessed from: <http://gis4.natr.gov.ns.ca/website/nsgroundwater>
- Nova Scotia Department of Natural Resources (NSDNR) 2013. Nova Scotia Forest Inventory. Accessed July 2013 from: <http://novascotia.ca/natr/forestry/programs/inventory/>
- NSE Nova Scotia Environment. 2013. Nova Scotia Well Logs Database, Microsoft Access Format (2010). <http://www.gov.ns.ca/nse/groundwater/welldatabase.asp>
- NSE Nova Scotia Environment. 2010. Water for Life: Nova Scotia's Water Resource Management Strategy. Retrieved from: [http://www.gov.ns.ca/nse/water.strategy/docs/WaterStrategy\\_Water.Resources.Management.Strategy.pdf](http://www.gov.ns.ca/nse/water.strategy/docs/WaterStrategy_Water.Resources.Management.Strategy.pdf) July 2013.
- NSE Nova Scotia Environment. 2013. Homeowners guide to heating oil tank systems. Retrieved on January 10, 2014 from: <http://www.novascotia.ca/nse/petroleum/docs/OilTankGuide.pdf>
- Ogden, J.G. III. 1972. Water Quality Survey for Selected Metropolitan Area Lakes. Task Group on Water and Waste Disposal. MAPC (Report to Metropolitan Area Planning Committee). 210 pp.
- Pancura, M. and G.S. Lines. 2005. Variability and Extremes in Statistically Downscaled Climate Change Projections at Greenwood, Nova Scotia. Meteorological Service of Canada, Atlantic Region Science Report Series 2005-10.
- Paterson, A.M., P.J. Dillon, N.J. Hutchinson, M.N. Futter, B.J. Clark, R.B. Mills, R.A. Reid and W.A. Scheider. 2006. A review of the components, coefficients, and technical assumptions Ontario's Lakeshore Capacity Model. *Lake and Reserv. Manage.* Vol 22 (1):7-18.

- Porter Dillon Limited. 1996. Birch Cove Lakes Area Environmental Study, Task 2 Report. With Contributions from the Eastcan Group Limited Centre for Water Resources Studies, TUNS, R. H. Loucks Oceanology Limited, and Avens Isle Consulting. June 1996.
- Porter Dillon Limited 1985. Environmental study of the Salmon River Watershed in the Vicinity of the Halifax International Airport, Halifax, Nova Scotia. Report to Transport Canada
- Reckhow, K.H., M.N. Beaulac, and J.T. Simpson, 1980: Modeling phosphorus loading and lake response under uncertainty. A manual and compilation of export coefficients. Michigan State University. East Lansing, Michigan.
- Richards W., and Daigle R. 2011. Scenarios and Guidance for Adaptation to Climate Change and Sea-Level Rise – NS and PEI Municipalities. Prepared for Nova Scotia Department of Environment.
- Scott J.S. 1961. Toxicity of surface waters in part of the Shubenacadie drainage system. Nova Scotia Geological Survey, Topical Report 34.
- Scott, R.S., W.C. Hart, and G. Patterson. 2000. Phosphorus Export from Stream Catchments in Nova Scotia. CWRS Internal Report 99-3. Faculty of Engineering, Dalhousie University, Halifax, N.S.
- Scott, R.S. and W.C. Hart. 2004. Water Quality Impact Assessment of Water Bodies Contained in the Bedford West Planning Area Using a Phosphorus Loading Model Approach. Centre for Water Resources Studies, Dalhousie University.
- Seatech Investigation Services. 1983. Hydrated Lime Treatment of Sandy Lake, Halifax Co., Nova Scotia.
- Sinclair A.C. 2014. An integrated modeling approach for evaluation of phosphorus loading in rural Nova Scotia watersheds. Ph.D. Thesis, Dalhousie University.
- Soliman, 2008 Watershed Scale Modelling of Phosphorus and Dissolved Oxygen Concentrations in Nova Scotia Lakes: Implications for Water and Habitat Quality, Restoration Goals and Development Capacity, M.Sc. Thesis, Faculty of Arts and Science, Trent University, 126 p.
- SRA Sackville River Association. 2011. Sackville River Watershed Wetland Inventory Pt. 2. Prepared for the Nova Scotia Department of Transportation and Infrastructure Renewal.
- SRA Sackville River Association. 2013. Sackville River Fishway. Retrieved from: <http://sackvillerivers.ns.ca/river-restoration/fishway/> June 17, 2013.
- Stantec 2009. Final Report: Water Quality Monitoring functional Plan. Prepared for Halifax Regional Municipality.
- Stantec (2012a) An Analysis of the HRM Lakes Water Quality Monitoring Program Data (2006-2011) Final Report. File 121510918 180 pp.
- Stantec (2012b) Analysis of Regional Centre Lakes Water Quality Data (2006-2011) Final Report. File 121510918 81 pp.
- SWCSMH Soil and Water Conservation Society of Metro Halifax (2013a). Sandy Lake, Bedford – Accelerated eutrophication signs and suggested restoration parameters. Memo to Chair and Members, North West Community Council.
- SWCSMH Soil and Water Conservation Society of Metro Halifax (2013b). Background lakes and comparisons in Nova Scotia, Guidelines. Retrieved on January 3, 2014 from: <http://lakes.chebucto.org/lakecomp.html#Nitrate>



- Thompson K. 2001. Sandy Lake – Marsh Lake Lands and Jack Lake Land Assembly - an Environmental Inventory, Analysis and Synthesis. Prepared for the Sandy Lake Residents Association.
- Thornthwaite C.W., Mather J.R.. 1957. Instructions and tables for computing potential evapotranspiration and the water balance: Centerton, NJ., Laboratory of Climatology, Publications in Climatology, v.8 1-104.
- Underwood J.K., Waller D.H., Thirumurthi D. 1980. The influence of the ocean on the chemistry of precipitation in Nova Scotia. *Atmosphere-Ocean*, 26: 3, 467-479.
- U.S. Geological Survey, 1999, The Quality of Our Nation's Waters— Nutrients and Pesticides: U.S. Geological Survey Circular 1225, 82 p.
- Utting, D.J. (2011a) Digital Geological Data Generated as Part of the Surficial Mapping Project of the Halifax Metropolitan and Surrounding Areas, Halifax, and Hants Counties, Nova Scotia. DP ME 447, Version 1, 2011.
- Utting, D.J. (2011b) Surficial Geology Mapping in the Metropolitan Area of Halifax Regional Municipality: New Discoveries. Report of Activities 2010.
- Vollenweider, R.A., and Kerekes, J. 1982. Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris. 156p.
- Wagner, R.A., T.S. Tisdale and J. Zhang. 1996. A framework for phosphorus transport modeling in the Lake Okeechobee watershed. *Wat. Res. Bull.* 31(1):57-73
- Waller, D.H. and W.C. Hart. 1986. Solids, Nutrients and Chlorides in Urban Runoff. NATO ASI Series, Vol.G10, Urban Runoff Pollution, H.C. Torno, J. Marsalek and M. Desordes (ed), Springer-Verlag, Berlin Heidelberg, 59-85.
- Washburn and Gillis Associates Limited. 2000. Highway 113 Environmental Assessment Registration – Project ES-99-002 Final Report. Submitted to the Nova Scotia Department of Transportation and Public Works. 1236 p.
- Watt W.D., Scott D., Ray S. 1979. Acidification and other chemical changes in Halifax county lakes after 21 years. *Limnology Oceanography*, 24: 1154-1161.
- Watt, W. 2009. Outline of a Model of Total Phosphorus Levels in the Lakes of the Paper Mill Lake Watershed. Prepared for the Bedford Waters Advisory Board. 16 pp.
- White, W.J., Watt, W.D., Scott, C.D. 1984. An Experiment on the Feasibility of Rehabilitating Acidified Atlantic Salmon Habitat in Nova Scotia by the Addition of Lime. *Fisheries*; 9, 1.
- White, C.E., Bell, J.A., McLeish, D.F., MacDonald, M.A., Goodwin, T.A., MacNeil, J.D. 2008. Geology of the Halifax Regional Municipality, Central Nova Scotia. In Mineral Resources Branch, Report of Activities 2007, Nova Scotia Department of Natural Resources, Report ME 2008-1.
- White, C.E., and Goodwin, T.A. 2011. Lithogeochemistry, petrology and the acid-generating potential of the Goldenville and Halifax groups and associated granitoid rocks in metropolitan Halifax Regional Municipality, Nova Scotia, Canada. *Atlantic Geology*; 47, 158-184.

## Glossary

<b>Acidification</b>	Raising the acidity (lowering the pH) of a water body by adding an acid.
<b>Alluvial</b>	Soil or earth material which has been deposited by running water, as in a riverbed, flood plain, or delta.
<b>Anoxic</b>	(1) Denotes the absence of oxygen, as in a body of water. (2) Of, relating to, or affected with anoxia; greatly deficient in oxygen; oxygenless as with water.
<b>Anthropogenic</b>	Referring to changes or activities that are man-made, rather than those resulting from natural processes.
<b>Aquifer</b>	A geologic formation, a group of formations, or a part of a formation that is water bearing. A geological formation or structure that stores or transmits water, or both, such as to wells and springs. Use of the term is usually restricted to those water-bearing structures capable of yielding water in sufficient quantity to constitute a usable supply.
<b>Aquitard</b>	A saturated, but poorly permeable bed that impedes ground-water movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important ground-water storage unit. Aquitards are characterized by values of leakance that may range from relatively low to relatively high. Aerial extensive aquitards of relatively low leakance may function regionally as boundaries of aquifer flow systems.
<b>Baseflow</b>	Runoff that has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.
<b>Batholith</b>	A mass of igneous rock that forms intrusively and can rise to the surface.
<b>Bathymetry</b>	(1) The measurement of the depth of large bodies of water (oceans, seas, ponds and lakes). (2) The measurement of water depth at various places in a body of water. Also the information derived from such measurements.
<b>Bedrock</b>	Solid rock that lies beneath soil, loose sediments, or other unconsolidated material.
<b>Bog</b>	A wet, overwhelmingly vegetative substratum which lacks drainage and where humic and other acids give rise to modifications of plant structure and function. Bogs depend primarily on precipitation for their water source, and are usually acidic and rich in plant residue with a conspicuous mat of living green moss. Only a restricted group of plants, mostly <i>mycorrhizal</i> (fungi, heaths, orchids, and saprophytes), can tolerate bog conditions.
<b>Catchment Area (syn. watershed or subwatershed)</b>	All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.
<b>Chloride</b>	Negative chlorine ions, Cl <sup>-</sup> , found naturally in some surface waters and groundwaters and in high concentrations in seawater. Higher-than-normal chloride concentrations in fresh water, due to sodium chloride (table salt) that is used on foods and present in body wastes, can indicate sewage pollution. The use of highway deicing salts can also introduce chlorides to surface water or groundwater. Elevated groundwater chlorides in drinking water wells near coastlines may indicate saltwater intrusion.

<b>Chlorophyll</b>	(1) The green pigments of plants. There are seven known types of chlorophyll, <i>Chlorophyll a</i> and <i>Chlorophyll b</i> are the two most common forms. A green photosynthetic coloring matter of plants found in chloroplasts and made up chiefly of a blue-black ester. (2) Major light gathering pigment of all photosynthetic organisms and is essential for the process of photosynthesis. The amount present in lake water depends on the amount of algae and is therefore used as a common indicator of water quality.
<b>Dissolved Organic Carbon</b>	A measure of the organic compounds that are dissolved in water. In the analytical test for DOC, a water sample is first filtered to remove particulate material, and the organic compounds that pass through the filter are chemically converted to carbon dioxide, which is then measured to compute the amount of organic material dissolved in the water.
<b>Dissolved Oxygen</b>	The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors. Dissolved oxygen levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. The ideal dissolved oxygen level for fish is between 7 and 9 milligrams per liter (mg/l); most fish cannot survive at levels below 3 mg/l of dissolved oxygen. Secondary and advanced wastewater treatment techniques are generally designed to ensure adequate dissolved oxygen in waste-receiving waters.
<b>Drumlin</b>	An elongated hill or ridge of glacial drift.
<b>Ecoregion</b>	A recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterize that region.
<b>Epilimnetic</b>	Relation to an epilimnion. An epilimnion is the warm upper layer of a body of water with thermal stratification, which extends down from the surface to the thermocline, which forms the boundary between the warmer upper layers of the epilimnion and the colder waters of the lower depths, or hypolimnion. The epilimnion is less dense than the lower waters and is wind-circulated and essentially homothermous.
<b>Eutrophication</b>	Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs.
<b>Fen</b>	Low land covered wholly or partly with water. A type of wetland that accumulates peat deposits. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.
<b>Fluvial</b>	Of or pertaining to rivers and streams; growing or living in streams ponds; produced the action of a river or stream.
<b>Glaciation</b>	Alteration of the earth's solid surface through erosion and deposition by glacier ice.
<b>Hydraulics</b>	(1) The study of liquids, particularly water, under all conditions of rest and motion. (2) The branch of physics having to do with the mechanical properties of water and other liquids in motion and with the application of these properties in engineering.

<b>Hydrology</b>	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
<b>Hypolimnion</b>	The lowermost, non-circulating layer of cold water in a thermally stratified lake or reservoir that lies below the thermocline, remains perpetually cold and is usually deficient of oxygen. Also see Thermal Stratification.
<b>Impervious Surface</b>	A surface that prevents or severely limits the infiltration of surface precipitation from rainwater and snowmelt to the soil below. Typical impervious surfaces include roads, driveways, sidewalks, buildings, and certain types of non-fractured bedrock.
<b>Lacustrine</b>	Pertaining to, produced by, or inhabiting a lake.
<b>LiDAR</b>	An acronym for Light Detection And Ranging. A system for measuring ground surface elevation from an airplane.
<b>Marsh</b>	An area of soft, wet, low-lying land, characterized by grassy vegetation that does not accumulate appreciable peat deposits and often forming a transition zone between water and land. A tract of wet or periodically inundated treeless land, usually characterized by grasses, cattails, or other monocotyledons (sedges, lilies, irises, orchids, palms, etc.). Marshes may be either fresh or saltwater, tidal or non-tidal.
<b>Mesotrophic</b>	A lake or other body of water characterized by moderate nutrient concentrations such as nitrogen and phosphorous and resulting significant productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs.
<b>Morphometry</b>	The shape and structure of the lake basin
<b>Non-Point Source of Pollution</b>	Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution, by contrast, is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants such as nutrients and pesticides. Some of the polluted runoff infiltrates into the soil to contaminate (and recharge) the groundwater below. The rest of the runoff deposits the soil and pollutants in rivers, lakes, wetlands, and coastal waters. Originating from numerous small sources, non-point source pollution is widespread, dispersed, and hard to pinpoint.
<b>Oligotrophic</b>	Pertaining to a lake or other body of water characterized by extremely low nutrient concentrations such as nitrogen and phosphorous and resulting very moderate productivity. Oligotrophic lakes are those low in nutrient materials and consequently poor areas for the development of extensive aquatic floras and faunas. Such lakes are often deep, with sandy bottoms and very limited plant growth, but with high dissolved-oxygen levels. This represents the early stages in the life cycle of a lake.
<b>Overburden</b>	The earth, rock, and other materials that lie above a desired ore or mineral deposit.
<b>Pelagic</b>	Referring to the open sea or open part of a large lake at depth.



<b>Phosphorus</b>	An element that is essential to plant life but contributes to an increased trophic level (eutrophication) of water bodies.
<b>Point Source Pollution</b>	Pollutants discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.
<b>Quartzite</b>	A hard metamorphic rock made up of interlocking quartz grains that have been cemented by silica.
<b>Sediment</b>	Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion, and transported by water, wind, ice, and gravity.
<b>Surficial Geology</b>	The loose deposits of soil, sand, gravel and other material deposited on top of the bedrock
<b>Recharge</b>	Introduction of surface or ground water to groundwater storage such as an aquifer.
<b>Riparian</b>	Pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant and animal communities along such bodies of water.
<b>Run Off</b>	(1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. It is the same as streamflow unaffected by artificial diversions, imports, storage, or other works of humans in or on the stream channels. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.
<b>Stormwater Runoff</b>	The water and associated material draining into streams, lakes, or sewers as the result of a storm.
<b>Swamp</b>	Wet, spongy land; low saturated ground, and ground that is covered intermittently with standing water, sometimes inundated and characteristically dominated by trees or shrubs, but without appreciable peat deposits. Swamps may be fresh or salt water and tidal or non-tidal.
<b>Till</b>	The mixture of rocks, boulders, and soil picked up by a moving glacier and carried along the path of the ice advance. The glacier deposits this till along its path on the sides of the ice sheet, at the toe of the glacier when it recedes, and across valley floors when the ice sheet melts. These till deposits are akin to the footprint of a glacier and are used to track the movement of glaciers. These till deposits can be good sources of ground water, if they do not contain significant amounts of impermeable clays.
<b>Thermal Stratification</b>	The vertical temperature stratification of a lake or reservoir which consists of: (a) the upper layer, or epilimnion, in which the water temperature is virtually uniform; b) the middle layer, or thermocline, in which there is a marked drop in temperature per unit of depth; and (c) the lowest stratum, or hypolimnion, in which the temperature is again nearly uniform.
<b>Thermocline</b>	(1) The region in a thermally stratified body of water which separates warmer oxygen-rich surface water from cold oxygen-poor deep water and in which temperature decreases rapidly with depth. (2) A layer in a large body of water, such as a lake, that sharply separates regions differing in temperature, so that the temperature gradient across the layer is abrupt. (3) The intermediate summer or transition zone in lakes between the overlying epilimnion and the

underlying hypolimnion, defined as that middle region of a thermally stratified lake or reservoir in which there is a rapid decrease in temperature with water depth. Typically, the temperature decrease reaches 1°C or more for each meter of descent.

<b>Total Kjeldahl Nitrogen</b>	Total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.
<b>Total Phosphorus</b>	The sum of reactive, condensed and organic phosphorous.
<b>Total Suspended Solids</b>	Solids, found in waste water or in a stream, which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt.
<b>Trophic State</b>	A measurement of the biological productivity of a water feature.
<b>Turbidity</b>	Water containing suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. The turbidity may be caused by a wide variety of suspended materials, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and other microscopic organisms and similar substances.
<b>Water Quality</b>	A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
<b>Watershed</b>	(1) All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream. Also called a catchment area. (2) A ridge of relatively high land dividing two areas that are drained by different river systems.
<b>Wetland</b>	Areas where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the surrounding environment. The single feature that all wetlands have in common is a soil or substrate that is saturated with water during at least a part of the growing season. These saturated conditions control the types of plants and animals that live in these areas. Other common names for wetlands are Swamp, Fen, Bog, and Marsh.

## Acronyms

ACCDC	Atlantic Canada Conservation Data Centre
ARD	Acid Rock Drainage
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DEM	Digital Elevation Model
DOC	Dissolved Organic Carbon
GCDWQ	Guidelines for Canadian Drinking Water Quality
GHG	Greenhouse Gas
GIS	Geographical Information System
GPS	Global Positioning System
HRM	Halifax Regional Municipality
LCM	Lakeshore Capacity Model
LiDAR	Light Detection and Ranging
NH <sub>3</sub>	Ammonia
NO <sub>3</sub>	Nitrate
NSDFA	Nova Scotia Department of Fisheries and Aquaculture
NSE	Nova Scotia Environment
NSDNR	Nova Scotia Department of Natural Resources
NSEA	Nova Scotia Endangered Species Act
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WWTF	Waste Water Treatment Facility

# Appendix A

## Environmental Conditions



## Table of Contents

	page
<b>1. Geography .....</b>	<b>1</b>
<b>2. Climate .....</b>	<b>1</b>
2.1 Climate Change .....	3
2.2 Acid Rain .....	5
<b>3. Hydrology .....</b>	<b>5</b>
<b>4. Geology and Hydrogeology .....</b>	<b>6</b>
4.1 Bedrock Geology .....	6
4.2 Surficial Geology .....	7
4.3 Hydrogeology .....	8
4.3.1 Groundwater Recharge .....	9
4.3.2 Groundwater Quality .....	10
<b>5. Biological .....</b>	<b>11</b>
5.1 Fisheries and Aquatic Habitat .....	11
5.2 Wetlands .....	11
5.3 Vegetation .....	11
5.3.1 Rare Flora .....	12
5.4 Wildlife and Habitat Management .....	13

## List of Tables

Table A1. Temperature and Precipitation Climate Normals .....	2
Table A2. Wind Speed and Direction Normals .....	2
Table A3. Lake Evaporation Normals .....	3
Table A4. Sandy Lake Study Area Well Log Summary .....	9
Table A5. Groundwater Quality .....	10
Table A6. Wildlife Species of Conservation Concern .....	14

## 1. Geography

The Sandy Lake watershed is located the Eastern Ecoregion of Nova Scotia. Ecoregions in Nova Scotia are subdivisions of the larger Acadian Ecozone and are characterized by a distinctive ecological response to climate through soils and vegetation (Neily *et al.* 2003). Ecoregions are further subdivided into ecodistricts that reflect the major landforms within an ecoregion. Ecodistricts have geology and soils that are distinct from adjacent ecodistricts. Two ecodistricts are present within the Sandy Lake subwatershed: (1) the Eastern Drumlins Ecodistrict (unit 420) around Sandy Lake and downstream to the Sackville River and (2) the Eastern Interior Ecodistrict (unit 440) occupying the remaining two thirds of the subwatershed (NSDNR 2007).

Drumlins are low, rounded, oval mounds of glacial till. The Eastern Drumlins Ecodistrict is underlain by greywacke and slate, which in turn are covered by fine-textured tills derived from these underlying and adjacent rocks. The soils are predominantly fine textured loams over sandy clay loams (Neily *et al.* 2003). The well-drained drumlins and hummocks in the Eastern Drumlin Ecodistrict support hardwood stands composed of yellow birch, sugar maple and beech on the upper slopes. Lower slopes are typically occupied by red spruce; black spruce dominates where drainage is poor between the drumlins.

In contrast, the soils of the Eastern Interior Ecodistrict are typically thinner and interspersed with exposed bedrock consisting of Meguma Group quartzite and slate. Soils are typically sandy loams, often stony and well drained on till derived from quartzites. On the shallow soils forest cover may consist of scrub hardwoods such as red maple and white birch, with scattered white pine and black spruce underlain by a dense layer of shrubby vegetation. On the deeper, well drained soils stands of red spruce may be present. Stands of hardwood may be found on the crests and upper slopes of hills and both beech and hemlock occur on these deeper, well drained soils (NSDNR 2007).

## 2. Climate

The climate of Sandy Lake watershed is influenced by the Atlantic Ocean and is characterized by warm summers and mild winters with precipitation falling as both rain and snow. Temperature, precipitation, wind speed and evaporation normals between 1981 and 2010 are presented in **Table A1** to **Table A3**. These data are summarized from Environment Canada's Stanfield Airport meteorological station located 25 km northeast of the Sandy Lake watershed. The mean annual temperature is 6.6°C, while the mean summer temperatures are from 15 to 19°C and the mean winter temperatures are from -2 to -6°C. The mean annual precipitation is 1,396 mm with 16% precipitation as snowfall and 84% as rainfall. In comparison, mean annual precipitation in Toronto is approximately 790 mm, in Winnipeg approximately 515 mm and in Vancouver approximately 1200 mm.

The mild winters with high levels of precipitation affect lake ice formation and spring runoff patterns. Lake ice cover is often intermittent during November to March allowing for greater lake mixing during winter compared to lakes that remain frozen over the winter. The mix of rain and snowfall during the winter months creates runoff contributions to the lake throughout the year and dampens the effect of the spring runoff (the freshet). The mild winters contribute to lake thermal and hydrological conditions that are distinct from conditions in colder parts of Canada where ice cover is consistent through the winter and the hydrology is marked by a pronounced spring freshet.

**Table A1. Temperature and Precipitation Climate Normals**

Air Temperature Climate Normals ( 1981 - 2010)				Precipitation Climate Normals (1981 - 2010)			
Month	Mean Daily Maximum (°C)	Mean Daily Minimum (°C)	Daily Average (°C)	Month	Rainfall (mm)	Snowfall (mm)	Precipitation (mm)
January	-1.3	-10.38	-5.86	January	83.45	58.45	134.31
February	-0.59	-9.72	-5.17	February	64.99	45.39	105.79
March	3.14	-5.69	-1.28	March	86.93	37.13	120.06
April	9.05	-0.28	4.41	April	98.17	15.94	114.51
May	15.31	4.63	9.99	May	109.81	1.99	111.89
June	20.39	9.73	15.08	June	96.21	0	96.21
July	23.84	13.73	18.81	July	95.51	0	95.51
August	23.62	13.72	18.69	August	93.46	0	93.46
September	19.39	9.69	14.56	September	102.04	0	102.04
October	13.13	4.23	8.7	October	124.58	0.37	124.93
November	7.32	-0.37	3.49	November	139.13	16.58	154.19
December	1.72	-6.38	-2.35	December	101.77	45.37	143.27
Year	11.25	1.91	6.59	Year	1196.05	221.22	1396.17

Wind data over the same period and location are summarized in **Table A2**. The predominant wind in the winter months is from the north and northwest, whereas the wind in the summer months is most frequently from the south. Maximum wind speed and mean hour wind speed are the greatest during the winter months.

**Table A2. Wind Speed and Direction Normals**

Wind Climate Normals (1981-2010)			
Month	Mean Hourly Wind Speed (km/h)	Most Frequent Wind Direction	Maximum Hourly Speed (km/h)
January	17.69	315	80
February	18.27	315	89
March	18.45	360	77
April	18.3	360	71
May	16.51	180	64
June	15.19	180	65
July	14.22	180	79
August	13.17	180	65

Wind Climate Normals (1981-2010)			
Month	Mean Hourly Wind Speed (km/h)	Most Frequent Wind Direction	Maximum Hourly Speed (km/h)
September	14.37	180	85
October	15.95	270	68
November	17.48	315	93
December	18.31	315	85
Year	16.49	180	93

Lake evaporation normals were obtained from the closest Environment Canada monitoring station with long-term evaporation data at the Truro Climate station (**Table A3**). Lake evaporation is negligible during the months of November to April and highest during the summer months of June, July and August.

**Table A3. Lake Evaporation Normals**

Month	Lake Evaporation (mm/day)	Lake Evaporation (mm/month)
January	0	0
February	0	0
March	0	0
April	0	0
May	2.86	88.7
June	3.39	101.7
July	3.75	116.3
August	3.14	97.3
September	2.33	69.9
October	1.33	41.2
November	0	0
December	0	0
	<b>Total mm/year</b>	<b>515.1</b>

## 2.1 Climate Change

The consequences of climate change on river runoff patterns and quantities are not yet fully understood, but a broad outline of climate change effects in Atlantic Canada is reported in FOC (2013) and Richards and Daigle (2011). At a minimum, both spatial and temporal rainfall and evaporation patterns will be modified. It is expected that the variability of extreme events (floods and droughts) will increase, but it is not possible to quantify this change on a subwatershed scale (Pancura and Lines 2005). Analysis of the effect of climate change on water quality in urban streams is further complicated by the usually much stronger signal resulting from direct human activities such as land clearing and urbanization.



The potential impacts of climate change include effects on precipitation and temperature patterns that will influence the runoff to surface water features, groundwater recharge and evaporation. These factors will affect the hydrological cycle of the study area. There are a number of variables that are expected to change as climate change impacts become more pronounced:

1. **Temperature:** temperature can significantly affect the evaporation component of long-term water balance assessments and the evaluation of extreme drought conditions.
2. **Water levels:** hydrological characteristics of a subwatershed can be impacted by changes to initial water levels in lakes and rivers as well as the average and extreme baseflows in watercourses.
3. **Rainfall quantity:** impacts that may be attributed to climate change include departures from long-term mean annual, seasonal, or monthly rainfall amounts, as well as changes to the frequency or severity of rainfall intensities, event volumes and durations, and the time period between rainfall events.

The state-of-the-practice in North America has not yet evolved to a point where there are reliable methodologies for quantifying climate change impacts at the watershed and subwatershed scale. Different components of an urbanized watershed respond to rainfall in different ways: stormwater collection systems (storm sewers, culverts, ditches, creeks, etc.) respond primarily to peak rainfall intensity, whereas storage/treatment facilities (lakes, locks, wetlands, stormwater detention ponds, etc.) respond primarily to total rainfall volume. Given these differences and the lack of applicable methods for assessing effects at the local scale, it can be difficult to predict climate change effects within watersheds.

There are some precedents in Ontario for addressing climate change in stormwater management studies, including:

- Design storm events: A simple approach to climate change adds a contingency to the rainfall intensities already prescribed in municipal design standards. The City of Markham adds a 15-30% safety factor to rainfall intensities for short duration design storm events and this is intended to account for future uncertainties including climate change. A number of other municipalities in the Toronto area require that recently observed high-intensity/short-duration storm events be considered when assessing flood impacts; and,
- Continuous simulation: A number of watershed management authorities in southern Ontario require the use of continuous simulation to assess the impacts of new stormwater infrastructure on wetlands and watercourses. In particular, the Credit Valley Conservation Authority addresses climate change by requiring a range of rainfall/temperature scenarios to be simulated using a minimum 20-year record:
  - Warmer-drier than the 30-year climate normals;
  - Warmer-wetter;
  - Cooler-drier; and
  - Cooler-wetter, which is the key scenario with which to evaluate increased flood risks or long-term water budget imbalance (i.e., high rainfall intensities coupled with low evaporation rates).

In Atlantic Canada, Richards and Daigle (2011) provides an excellent background discussion and useful information on climate change variables in Nova Scotia. The report reinforces the difficulties in climate change predictions and the limitations in current practices. The report appendices include a variety of climate change variables related to temperature, rainfall, and coastal water levels for a wide range of return periods and time horizons for many Nova Scotia municipalities, including Halifax. The report cites a study by Kharin *et al.* (2007) that predicts an increase in average daily rainfall extremes of 16% for North America by the 2080s and applies this value to Halifax

In Nova Scotia, climate projections suggest that climate will become increasingly variable with more frequent and more extreme storm events. There is expected to be increased evaporation due to increasing atmospheric and

ocean temperatures, reduced precipitation in summer and increased precipitation in winter. Generally speaking, there will be changes to the amount, timing and nature of precipitation. The rising ocean temperature is expected to promote cyclonic activity further north than is currently the case, placing Atlantic Canada along the trajectory for more numerous, stronger hurricanes and tropical storms.

In forested watersheds, reports indicate that water quality and quantity are likely to be affected by climate change resulting in reduced snowpack, earlier peak snowmelts, warmer summer temperatures, and flooding (Hodgkins *et al.* 2003). With respect to changes to vegetation cover, both positive and negative outcomes are predicted. On one hand, transitional forest types as found in the Acadian Forest Region are forecasted to support additional stands of temperate broadleaved species with climate change. These species are associated with high water quality. On the other hand, climate change effects such as increased frequency and severity of insect/disease outbreak, windthrow, and forest fires have negative implications for water quality (Jones *et al.* 2009), as does increased erosion and flooding.

In summary, climate change is expected to result in dryer summers, wetter winters and more extreme precipitation events that can lead to flooding. Extreme storm events can flush nutrients from forested and urban areas into the watercourses resulting in rapid but temporary deterioration in water quality as the nutrients are flushed through watershed. These events may also re-suspend and remove phosphorus-laden sediments from ponds, rivers and lakes. Dryer summers suggest forest and aquatic ecosystems will be stressed and vulnerable to unusual weather events, while low stream flow reduces the potential that natural and man-made nutrient inputs can be adequately diluted, leading to an overall lowering of water quality. Finally, flooding liberates nutrients from dry forest soils and in-ground septic systems, leading to water quality impacts.

## 2.2 Acid Rain

The pH of precipitation unaffected by industrial development is typically below 6 making it slightly acidic. From the 1950s to the 1980s Nova Scotia experienced precipitation with reduced pH (<5) due to the emission of sulphur oxides produced locally and in the industrial centers of eastern Canada and the United States (Watt *et al.* 1979). This low pH precipitation is known as acid rain. Deposition of acid rain depleted the buffering capacity of Nova Scotia soils (the ability of soil minerals to neutralize acidity) and resulted in reduced pH in surface waters, which now typically range from 4.5 to 5.5 (Clair *et al.* 2007). Although federal and provincial regulations have since restricted the sulphate concentrations in sulphur oxide emissions, the pH of many water bodies remains acidic and this represents one of the main challenges to restoring healthy fish populations.

Sandy Lake was the subject of an experiment conducted in the early 1980s by DFO to determine whether limestone could be used in to manage lake acidification and improve water quality for sensitive fish species (White *et al.* 1984). In July and August 1981, 135,000 kg of CaCO<sub>3</sub> (limestone) was mixed with water and spread over the lake surface. The authors observed that aluminum, manganese, copper and zinc concentrations were significantly lower following liming and iron concentrations were higher. The study concluded that although it is feasible to maintain pH through the addition of limestone, lime must be added at frequent intervals where lakes are small and the flushing rates are rapid.

## 3. Hydrology

The Sandy Lake watershed extends over 24.2 km<sup>2</sup> and includes all flow from the catchment area upstream of where Peverills Brook flows into the Sackville River. The primary surface water features in the Sandy Lake watershed are Sandy Lake, Marsh Lake, Peverills Brook and Bobs Brook, also called Johnsons Brook (**Figure 1**). The topography of the Sandy Lake watershed consists of an upland area in the northwest, a depression containing Sandy Lake and

Marsh Lake, and a slight rise in topography to the east. The highest elevation in the watershed is 139 meters above sea level (masl).

The greatest flow into Sandy Lake is from Bobs Brook and other tributaries from the western portion of the watershed. Bobs Brook and its tributaries accumulate flow from Lucasville, Uplands Park, Kingswood North and Atlantic Acres Industrial Park. Two small, unnamed streams flow northward into the southern portion of Sandy Lake. Two additional small, unnamed streams, likely fed by spring water, originate near the base of the northwest uplands area and discharge into the northern end of Sandy Lake and the upper reaches of Peverills Brook. Sandy Lake flows into Marsh Lake via Peverills Brook and from Marsh Lake into the Sackville River. Additional stream flow into Marsh Lake originates from the drumlins to the northwest of Marsh Lake and from one small stream flowing north into the southern portion of Marsh Lake.

Sandy Lake (also known as Big Sandy Lake to differentiate it from Sandy Lake/Little Sandy Lake near Glen Arbour Golf Course) has a surface area of 78.5 ha (this study), a volume of approximately 5,100,000 m<sup>3</sup> and has a retention time of 0.34 years (White *et al.* 1984). The deepest part of Sandy Lake is 21.7 m in the northwestern part of the lake. The southwestern portion of Sandy Lake is shallow with depths generally less than 6.0 m. A detailed bathymetric profile of Sandy Lake is presented in Conrad *et al.* 2002, who calculates a lake volume of 6,079,566 m<sup>3</sup>. This study also calculates a mean depth of 8.2 m, and indicates there were 20 dwellings with septic systems located within 300 m of the lake in 2002.

Marsh Lake is a shallow lake surrounded by swamp and bog wetlands (**Figure 3**). The northwest portion is deeper than shallow eastern portion. The surface area of Marsh Lake is approximately 21.8 ha, but this does not account for the wetlands surrounding the lake. Marsh Lake has a short retention time compared to Sandy Lake and is the last lake before discharge into the Sackville River.

The flow from the Sandy Lake watershed is not gauged, so a precise estimate of flow volume and flow patterns is not available. Comparing the relative size of Sandy Lake watershed (24.2 km<sup>2</sup>) to the Sackville River watershed (147 km<sup>2</sup>), the monthly mean flow from the Sandy Lake watershed is estimated at 0.8 m<sup>3</sup>/sec based on the flow of the Sackville River at Bedford, 4.99 m<sup>3</sup>/sec (Environment Canada 2014).

Water quality data from Sandy Lake are available as early as 1971 (Ogden 1972). At that time, the watershed was largely undeveloped with the exception of several cottages. The lake was oligotrophic when sampled in 1972.

## 4. Geology and Hydrogeology

### 4.1 Bedrock Geology

**Figure 4** illustrates the bedrock geology underlying the Sandy Lake watershed, which is composed of Meguma Supergroup metamorphosed sedimentary (“metasedimentary”) rocks (White *et al.* 2008). The Meguma Supergroup has been deformed into a series of folds, which influences the topography and surface drainage network.

In the northwestern portion of the watershed, the bedrock is composed of Curnard Formation Halifax Group rocks with greater proportions of metasilstone and slate. Underlying the remaining area of the watershed is the Beaverbank and Taylors Head Formations rocks of the Goldenville Group consisting of higher proportions of metasandstone (quartzite) than the Halifax Group.

Sulphide minerals in the Meguma bedrock can result in acid rock drainage (ARD) which occurs when the sulphides are oxidized to produce sulphuric acid (Fox *et al.* 1997). The Taylors Head Formation has limited acid generating potential because it is dominated by thick beds of metasandstone with few sulphide minerals (White and Goodwin

2011). The Cunard Formation and Beaverbank Formation rocks have greater ARD generating potential than the Taylors Head Formation because of higher proportions of sulphide rich metasilstone and slate. Analytical testing of a creek that originates in the Cunard and Beaverbank rocks and discharges into Sandy Lake suggests these rocks are generating ARD, resulting in reduced pH of this creek (Conrad *et al.* 2002).

To the west and outside the Sandy Lake watershed, the bedrock is composed of the South Mountain Batholith, a Devonian aged granite, which intruded into the pre-existing sedimentary rocks causing folding, faulting and changes to mineralogy. These effects may influence the permeability of the bedrock in the area west of the Sandy Lake watershed, allowing more rapid infiltration of surface water to groundwater aquifers and possibly making the groundwater more vulnerable to surface contamination.

Several abandoned gold mine shafts are located in the northwest section of the watershed along the Lucasville Road (**Figure 4**). Open mine shafts represent a conduit of potential contamination to the bedrock groundwater of the subwatershed. Historic mine workings may also represent potential sources of pollution within the watershed.

## 4.2 Surficial Geology

**Figure 5** illustrates the surficial geology north of the Bedford Basin, including the Sandy Lake watershed. The term surficial geology refers to the loose deposits of soil, sand, gravel and other material deposited on top of the bedrock. The surficial geology in southern Nova Scotia generally consists of glacial till (a mix of clay, sand, gravel and boulders) combined with alluvial deposits (left by moving water) and lacustrine deposits (deposited as lake sediments) (Utting 2011a).

The Beaver River Till was deposited over bedrock when the glaciers began to melt approximately 12,000 years ago. The till consists of unconsolidated, poorly sorted sediment that contains a wide range of particle sizes and has a sandy matrix. These deposits are mainly found near the western and northwestern limits of the watershed. Thicknesses range from less than 5m (till veneer) to 5-10 m (till blanket). The till was also deposited in an irregular hummocky pattern where thicknesses range from 1 to 10 m.

As noted, drumlin deposits are low, smoothly rounded, elongate mounds of glacial till. Drumlins are common in the watershed and are shown on Figure 5. The source of the sediments making up the drumlins is the bedrock the glacier passed over but the drumlins may also incorporate sediments from distant bedrock formations. This produces sediments in drumlin deposits that may be different than the composition of locally derived tills such as the Beaver River Till. Drumlin deposits often have higher proportions of sand than nearby tills. The higher proportions of sand and the fact that drumlins are elevated above the surrounding landscape contribute to well drained soils associated with these deposits.

Drumlins dominate much of the area surrounding Sandy Lake and are also common to the north and northeast of the watershed. Typically, drumlin deposits are 5-10 m thicker than the height of the drumlin. For instance if the drumlin has relief of 30 m, bedrock is likely to be encountered 35 to 40 m below the ground surface of the drumlin. In the area surrounding Sandy Lake and the drumlin-dominated area to the north and northeast, the surficial sediments are much thicker than the relief of the drumlins (Utting 2011b). The unconsolidated sediments beneath the drumlins are composed of coarse grained material. These sediments are interpreted to result from the burial of a pre-glacial valley in the Beaver Bank area (Kennedy and Utting 2011).

Alluvial and lacustrine deposits are located along water courses within the Sandy Lake watershed. Alluvial deposits consist of gravel, sand, silt and minor clay and organics deposited by streams and rivers in channels and floodplains. These deposits are present along Bobs Brook and sections of Peverills Brook connecting Sandy and Marsh Lakes. Lacustrine deposits, consisting of sand, silt, clay and organics, were deposited from suspension in freshwater lakes, ponds and wetlands. The thickness of these deposits in the Sandy Lake watershed is not known, but the thickness is typically less than 10 m in the region (Utting 2011a).

### 4.3 Hydrogeology

Groundwater is used a domestic source of potable water in the Sandy Lake watershed. **Figure 4** shows the approximate locations of many of the historic and existing groundwater wells recorded in the provincial groundwater wells database (NSE 2013). The wells are primarily clustered along Gatehouse Run and connecting streets hosting residential development. Other wells are noted along Hammonds Plains and Lucasville Roads. Residential and commercial developments along these roads are now supplied with municipal water and so some of these wells may no longer be in service.

The ability of bedrock and surficial aquifers to yield water depends on the inter-connectedness of the pores spaces and fractures within the aquifer. The speed at which the water flows is partly dependent on how big the pore spaces are, how interconnected the pores or fractures are, and how much “head” or water pressure is available to move the water through the aquifer. Primary porosity refers to the porosity associated with water-filled pore spaces between the individual grains, while secondary porosity in bedrock is formed as a result of secondary fractures, joints, bedding planes and faults. Massive crystalline rocks such as granite generally have very little, if any, primary porosity and water typically moves along fractures.

Fractures in the Halifax Group are generally well developed planar features with a higher frequency of fractures than the Goldenville Group. The Goldenville Group has less frequent fractures, but the fractures are cross-cutting creating a more interconnected network of fractures (FracFlow 2004).

The coarse grained surficial deposits underlying the drumlins surrounding Sandy Lake are interpreted to be part of a pre-glacial landscape that hosts a local surficial aquifer (Kennedy and Utting 2011). The extent of the sand deposits is not well defined, but is interpreted to be present along the western side of Sandy Lake and northwest of Sandy Lake. This local surficial aquifer is not generally utilized by residential wells but it represents a possible supply of high quality groundwater (**Figure 5**).

A search of the Nova Scotia Department of Natural Resources (NSDNR) Groundwater Map Viewer (NSDNR 2013) was conducted to collect well construction information for wells within the Sandy Lake watershed and slightly beyond the watershed boundary. The NSDNR contains geo-referenced well information based on the Nova Scotia Environment (NSE) 2013 Well Driller’s Database for wells constructed between 1940 and 2011 (NSE 2013).

There are at least 65 drilled wells in the Goldenville Group quartzite bedrock, 14 in the Halifax Group and 5 wells in the granite within the Sandy Lake watershed (**Figure 4**). Well depth, well yield, static water level and overburden thickness of the wells in the Sandy Lake watershed are summarized in **Table A4**. Generally the wells are between 30 and 130 m deep with water levels typically within 10 m of the ground surface. Well yield interpreted from air lift testing at the time of well installation is generally less than 20 L/min, which is consistent with compiled pumping test data for HRM that indicates bedrock wells average yield ( $Q_{20}$ ) is less than 45 L/min. The groundwater availability of bedrock aquifers in HRM and the Sandy Lake study area is limited, but generally adequate for single dwelling domestic use.



**Table A4. Sandy Lake Study Area Well Log Summary**

Bedrock Aquifer Source	Statistical Summary	Well Depth (m)	Depth to Bedrock (m)	Static Water Level (mbgs)*	Air-Lift Yield (L/min)
<b>Goldenville Group</b>	Minimum	24.4	0.0	1.5	0.2
	Maximum	134.0	23.8	15.2	227.0
	Average (Mean)	85.6	6.8	7.0	19.9
	Number	65	65	36	62
<b>South Mountain Batholith (granite)</b>	Minimum	15.2	2.4	3.0	0.9
	Maximum	91.4	10.7	4.6	227.0
	Average (Mean)	61.0	5.8	4.0	76.5
	Number	5	5	4	5
<b>Halifax Group</b>	Minimum	42.6	0.9	3.0	1.1
	Maximum	99.0	18.9	9.1	22.7
	Average (Mean)	70.5	4.6	4.9	9.6
	Number	14	14	4	14

*mbgs= meters below ground surface*

#### 4.3.1 Groundwater Recharge

Groundwater recharge is the process by which surface water infiltrates through the soil to reach and “recharge” the groundwater aquifer. The permeability or the ability of soils to convey groundwater flow is the most important factor influencing groundwater recharge rates across the watershed. Groundwater recharge rates will be affected by the permeability of underlying sediments, slope and ground cover among other factors.

Groundwater is a critical natural resource since it eventually seeps into lakes, streams and wetlands where cold, clean groundwater is a key factor in maintaining the ecological health of these systems. In addition, groundwater is used as a potable water source by many residents within the watershed who depend on its reliability and high quality.

Deep groundwater recharge occurs via water movement through secondary permeability; that is, through bedrock faults and fractures. Assessing the fracture density and distribution and thus the productivity of the fractures requires detailed information that is not available for the Sandy Lake study area. For the purposes of this study it is assumed that recharge of surficial aquifers to bedrock aquifers is low and the surficial aquifers provide the primary contribution to stream baseflow within the watershed.

In assessing changes to water quality within a watershed, recharge to groundwater is an important consideration since high density residential and commercial development tends to reduce the recharge to groundwater through the construction of impermeable buildings and pavement. This may restrict the groundwater supply to wetlands and streams, causing ecological and water quality changes to important habitats. At the same time, reduction in recharge may result in less availability for residential well users, or changes in water quality due to blasting, excavation and dewatering activities.

Groundwater recharge varies seasonally, with the highest rates occurring in the spring during snow melt and spring rainfall events and the lowest rates occurring in the winter months when most precipitation falls as snow. In Nova Scotia, the climate is moderate in the winter months and precipitation falls as both rain and snow. Under these conditions, the seasonal variation in recharge rates is less pronounced than in areas where winter precipitation accumulates as snow and melts over a short period in the springtime.

A groundwater budget and recharge model is included as Appendix D which defines areas with high recharge potential that may require protection.

#### 4.3.2 Groundwater Quality

There is limited available information regarding groundwater quality within the Sandy Lake watershed. Three groundwater samples are available from NSDNR (2013) in or near Sandy Lake watershed. Analytical results of these samples are summarized in **Table A5**. The sample from the surficial aquifer has higher sodium (Na) and chloride (Cl) concentrations than the bedrock samples, suggesting a greater input from ocean salt spray or the effects of winter road salts. Iron (Fe) and manganese (Mn) concentrations are also elevated in the surficial aquifer compared to the bedrock aquifers. While the one sample is not sufficient to characterize surficial groundwater quality, it highlights the sensitivity of shallow groundwater to contaminant infiltration.

**Table A5. Groundwater Quality**

	<b>Reg485</b>	<b>Ptest407</b>	<b>Ptest376</b>
	11 Jul 2002	03 Apr 1976	03 Jun 1972
<b>Parameter</b>	Surficial Aquifer	Metamorphic Bedrock Aquifer	Metamorphic Bedrock Aquifer
Alkalinity (mg/L)	28	87	96
HCO <sub>3</sub> (mg/L)	28	n/a	92
CO <sub>3</sub> (mg/L)	0.5	n/a	4
Na (mg/L)	94.2	6.9	14
K (mg/L)	3.2	0.8	0.9
Ca (mg/L)	28.8	26	23
Mg (mg/L)	2.9	2.7	7.8
F (mg/L)	0.05	0.2	n/a
SO <sub>4</sub> (mg/L)	34	10	12.6
Cl (mg/L)	170	7.4	6
Hardness (mg/L)	83.8	74	75
TDS (mg/L)	357	133	140
pH	7.2	7.4	8.2
NO <sub>3</sub> - NO <sub>2</sub> N (mg/L)	0.025	0.05	n/a
As (ug/L)	1	n/a	n/a
U (ug/L)	0.05	n/a	n/a
Fe (ug/L)	7300	50	70
Mn (ug/L)	1900	25	350
Easting	443085	444067	439135
Northing	4953116	4952182	4954078

Although not shown in Table A5, naturally occurring water quality issues with wells completed in granite aquifers may include elevated arsenic, uranium, fluoride, iron and manganese. Naturally occurring groundwater quality issues in the Halifax Formation aquifers may include elevated arsenic, iron, manganese and hardness.

## 5. Biological

### 5.1 Fisheries and Aquatic Habitat

As a subwatershed of the Sackville River, the Sandy Lake watershed is an historical spawning ground for Atlantic salmon, as noted in the Debates of the Senate of the Dominion of Canada (1888) and was regularly fished for salmon in the early 1900s (SRA 2013). Salmon spawning habitat has been identified along Peverills Brook between Marsh Lake and the Sackville River and between Marsh Lake and Sandy Lake. The Sackville River Association completed restoration of Peverills Brook by installing eleven (11) digger logs and enhancing a rock sill (ASCF 2013). Atlantic salmon of the Nova Scotia Upland population is designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Sandy Lake is used for sport fishing and contains trout, bass, perch, Atlantic salmon, gaspereaux, American eel, chub, bullnose trout, brown stickleback, shiner, shad, sea trout and catfish (Dalhousie 2002). A comprehensive assessment of the fish species and populations has not been completed for Sandy Lake. However, historical and anecdotal evidence suggests Sandy Lake, Marsh Lake and Peverills Brook support healthy fish populations.

Beavers are reported in the area, along with the Eastern Wood Turtle (Dalhousie 2002). Loons, osprey, eagles and kingfishers have been observed on Sandy Lake.

### 5.2 Wetlands

Wetlands perform a variety of ecological functions. They provide important habitat for flora and fauna, improve water quality, mitigate flooding and are valued for educational and aesthetic purposes by the public. In Nova Scotia, a wetland is defined as

“an area commonly referred to as marsh, swamp, fen or bog that either periodically or permanently has a water table at, near or above the land’s surface or that is saturated with water. Such an area sustains aquatic processes as indicated by the presence of poorly drained soils, hydrophytic vegetation and biological activities adapted to wet conditions” (Government of Nova Scotia 2011).

According to the Nova Scotia Wetland Inventory and municipal GIS data layers, wetlands are found primarily in the southern section of Marsh Lake and the northern and eastern areas of the watershed (**Figure 3**). The wetland area near Marsh Lake is identified as a bog or fen with low shrubs and trees. Swamps and marshes are present in the northern and eastern areas of the watershed (NSDNR 2004a).

The Sandy Lake watershed wet areas (Wet Area Mapping) were assessed in 2010 by the Sackville Rivers Association to evaluate areas for future wetland compensation potential (SRA 2011). Twenty six (26) wet areas were identified using GIS and eight of the 26 sites were further evaluated through field work and were found to be suitable potential locations for wetland restoration.

### 5.3 Vegetation

Uplands within the Sandy Lake watershed are occupied by stands of softwood and mixed-wood forest in the southern portion of the watershed (**Figure 3**). Softwood forests are present in patches throughout the watershed but are concentrated in the western portion where soils are thinner. Softwood forest habitats are dominated by red and black spruce and balsam fir, with minor amounts of red maple (Thompson 2001). Ground cover typically includes a variety of shrub species in open areas, and bunchberry and sphagnum in forested areas. Poorly drained and treed

wetland areas support black spruce and tamarack species, while remnant white pine and hemlock forest stands from the original forest cover remain in ravines (Dillon Consulting 2009).

Mixed woods occur in patches throughout the watershed, typically in areas where soil cover is more extensive than where softwood stands are found (EDM 2006). Mixed woods in the watershed generally include red and black spruce, red maple, red oak and balsam fir.

Hardwood-dominated forests occur on drumlins with medium to coarse grained soils. Forest stands are generally dominated by red maple, white birch and grey birch with minor amounts of red and black spruce and balsam fir. Exposed slopes support limited stands of beech, sugar maple and red oak. Ground cover is generally similar to the mixed woods, and is dominated by shrub species. This habitat is considered second growth generation (about 35-40 years old) and exhibits evidence of both natural and man-made disturbances, such as forest fires and clear-cutting for timber harvest (EDM 2006). Approximately 70% of the Sandy Lake watershed area is covered by forest and the remaining area is covered by deforested areas and residential/industrial (**Figure 3**).

A mature hemlock stand is reported on the peninsula in the southern half of Sandy Lake and may be remnants of older forests in the area (Dalhousie 2002).

Habitat varies along the shorelines of Sandy and Marsh Lakes depending on soil development and drainage. Typical shoreline species include shrubs (steplebush, leatherleaf, sheep laurel, blueberry), herbs characteristic of open areas (asters, goldenrods) and grasses (tickle-grass, deergrass).

Disturbed or developed areas occur in various locations within the watershed and include residential and commercial development located primarily along Lucasville road and Hammonds Plain road. Examples of developed areas include the Atlantic Acres Industrial Park and nearby Farmers Dairy, and the Timber Trails Trailer Park. In August, 2013 Armco Communities logged approximately 80 ha in the Hammonds Plains area, within the Sandy Lake watershed. The approximate extent of recently logged areas is shown on **Figure 3**.

### 5.3.1 Rare Flora

The Atlantic Canada Conservation Data Centre (ACCDC) maintains a database of “occurrence” information regarding species of conservation concern. Although it does not claim to register the presence of all rare species in a given area, it provides a general indication of species that have been observed in the area in the past, and which may be currently present.

Within the Sandy Lake watershed, no plant species of federal conservation concern have been recorded. Seven vascular plants of provincial concern have been recorded within five kilometers of the centre of the watershed; of these seven species, two – the wavy leaved aster (*Symphyotrichum undulatum*) and the Greenland stitchwort (*Minuartia groenlandica*) have been observed in the Marsh Lake area. Both plants are listed as S2 (provincially rare); their general status rank is sensitive.



Wavy Leaved Aster

Habitat: dry woods and clearings

Height: 1 to 3 feet (up to 1 m)

Flowers: August to November



Greenland Stitchwort

Habitat: dry, wind-swept granitic ledges and gravel

Height: low growing

Flowers: June to September

Orchids and ladyslippers have been reported near the shores of Sandy and Marsh Lakes (Dalhousie 2002).

## 5.4 Wildlife and Habitat Management

A comprehensive study of wildlife in the Sandy Lake area has not been undertaken. No species or habitats of conservation concern are identified in the NSDNR significant species and habitats database (NSDNR 2004b).

The Dillon Consulting (2009) EA for proposed Highway 113 provides a description of wildlife that is generally applicable to the Sandy Lake area. The area generally has a low diversity of small mammals and a high concentration of white-tail deer (Washburn and Gillis 2000). Other than deer, which generally avoid barren and wetland habitats, species typical of the forest and lakeshore habitats within the watershed would include coyote, hare, bear, bobcat, bats, fox, porcupine, skunk and raccoon (Dillon Consulting 2009; Porter Dillon 1996). Other small mammals typical of disturbed and second growth habitats include shrews, mice, voles, red squirrels, and chipmunks (Porter Dillon 1996).

Previous studies have identified forest and shoreline birds including black duck, white-throated sparrow, chipping sparrow, song sparrow, yellow-rumped warbler, yellow warbler, common yellow-throat, sharp-shinned hawk, gray jay, American goldfinch, flycatcher, American robin, savannah sparrow, spotted sandpiper, and an active crow population. Bald eagles and great blue heron have also been reported as occasionally feeding immediately south of the watershed (Porter Dillon 1996).

The Atlantic Canada Conservation Data Centre records 25 species of conservation concern within the Sandy Lake watershed. Although the precise locations of the species sightings are not recorded, most of these species appear to have been identified in the Marsh Lake area (Table A6). Although most of these species are birds, there are two amphibians present: the snapping turtle and the wood turtle.



**Table A6. Wildlife Species of Conservation Concern**

Scientific Name	Common Name	COSEWIC	Provincial Legal Status	Provincial Rarity
<i>Gavia immer</i>	Common Loon	Not At Risk		S3B,S4N
<i>Charadrius vociferus</i>	Killdeer			S3S4B
<i>Actitis macularius</i>	Spotted Sandpiper			S3S4B
<i>Gallinago delicata</i>	Wilson's Snipe	Threatened		S3S4B
<i>Chordeiles minor</i>	Common Nighthawk	Threatened	Threatened	S3B
<i>Chaetura pelagica</i>	Chimney Swift	Threatened	Endangered	S2S3B
<i>Contopus cooperi</i>	Olive-sided Flycatcher	Threatened	Threatened	S3B
<i>Contopus virens</i>	Eastern Wood-Pewee	Special Concern	Vulnerable	S3S4B
<i>Empidonax flaviventris</i>	Yellow-bellied Flycatcher			S3S4B
<i>Riparia riparia</i>	Bank Swallow	Threatened		S3B
<i>Hirundo rustica</i>	Barn Swallow	Threatened	Endangered	S3B
<i>Perisoreus canadensis</i>	Gray Jay			S3S4
<i>Poecile hudsonica</i>	Boreal Chickadee			S3
<i>Dumetella carolinensis</i>	Gray Catbird			S3B
<i>Mimus polyglottos</i>	Northern Mockingbird			S3B
<i>Vermivora peregrina</i>	Tennessee Warbler			S3S4B
<i>Dendroica castanea</i>	Bay-breasted Warbler			S3S4B
<i>Wilsonia pusilla</i>	Wilson's Warbler			S3S4B
<i>Wilsonia canadensis</i>	Canada Warbler	Threatened	Endangered	S3B
<i>Piranga olivacea</i>	Scarlet Tanager			S2B
<i>Euphagus carolinus</i>	Rusty Blackbird	Special Concern	Endangered	S2S3B
<i>Carduelis pinus</i>	Pine Siskin			S3S4B,S5N
<i>Chelydra serpentina</i>	Snapping Turtle	Special Concern	Vulnerable	S5
<i>Glyptemys insculpta</i>	Wood Turtle	Threatened	Threatened	S3
<i>Erynnis juvenalis</i>	Juvenal's Duskywing			S2S3
<b>COSEWIC</b>	The Committee on the Status of Endangered Wildlife in Canada			
<b>S1</b>	Extremely rare: May be vulnerable to extirpation (typically 5 or fewer occurrences or very few remaining individuals).			
<b>S2</b>	Rare. May be vulnerable to extirpation due to rarity or other factors (6 to 20 occurrences or few individuals).			
<b>S3</b>	Uncommon or found only in a restricted range, even if abundant at some locations (21 to 100 occurrences).			
<b>S4</b>	Usually widespread, fairly common, and apparently secure with many occurrences, but of longer-term concern (e.g., watch list) (100+ occurrences).			
<b>S5</b>	Widespread, abundant, and secure, under present conditions.			
<b>S#S#</b>	Numeric range rank: A range between two consecutive ranks for a species/community. Denotes uncertainty about the exact rarity (e.g., S1S2).			
<b>B</b>	Breeding (migratory species)			
<b>N</b>	Non-breeding (migratory species)			

# **Appendix B**

## **Water Quality Review**

## Table of Contents

	page
<b>1. Lake Chemistry and Water Quality .....</b>	<b>1</b>
1.1 Lake Chemistry.....	1
1.2 Water Quality.....	3
1.3 Trophic Status and Nutrients.....	4
<b>2. Establishing Water Quality Objectives .....</b>	<b>5</b>
2.1 Introduction.....	5
2.2 Water Quality Indicators.....	5
2.3 Review of Water Quality Guidelines and Objectives from Other Jurisdictions.....	6
2.4 Review of Water Quality Guidelines and Objectives for Total Phosphorus .....	7
2.4.1 Canadian Guidance Framework for Phosphorus.....	8

## List of Figures

Figure B1. Lake Processes .....	2
---------------------------------	---

## List of Tables

Table B1. Trophic Status Based Trigger Ranges for Canadian Waters (CCME, 2004).....	5
Table B2. Changes to Water Quality Parameters from Watershed Development .....	6
Table B3. Water Quality Guidelines and Standards from Canada, USEPA and Vermont.....	7
Table B4. Provincial Water Quality Objectives for Total Phosphorus (µg/L).....	8

# 1. Lake Chemistry and Water Quality

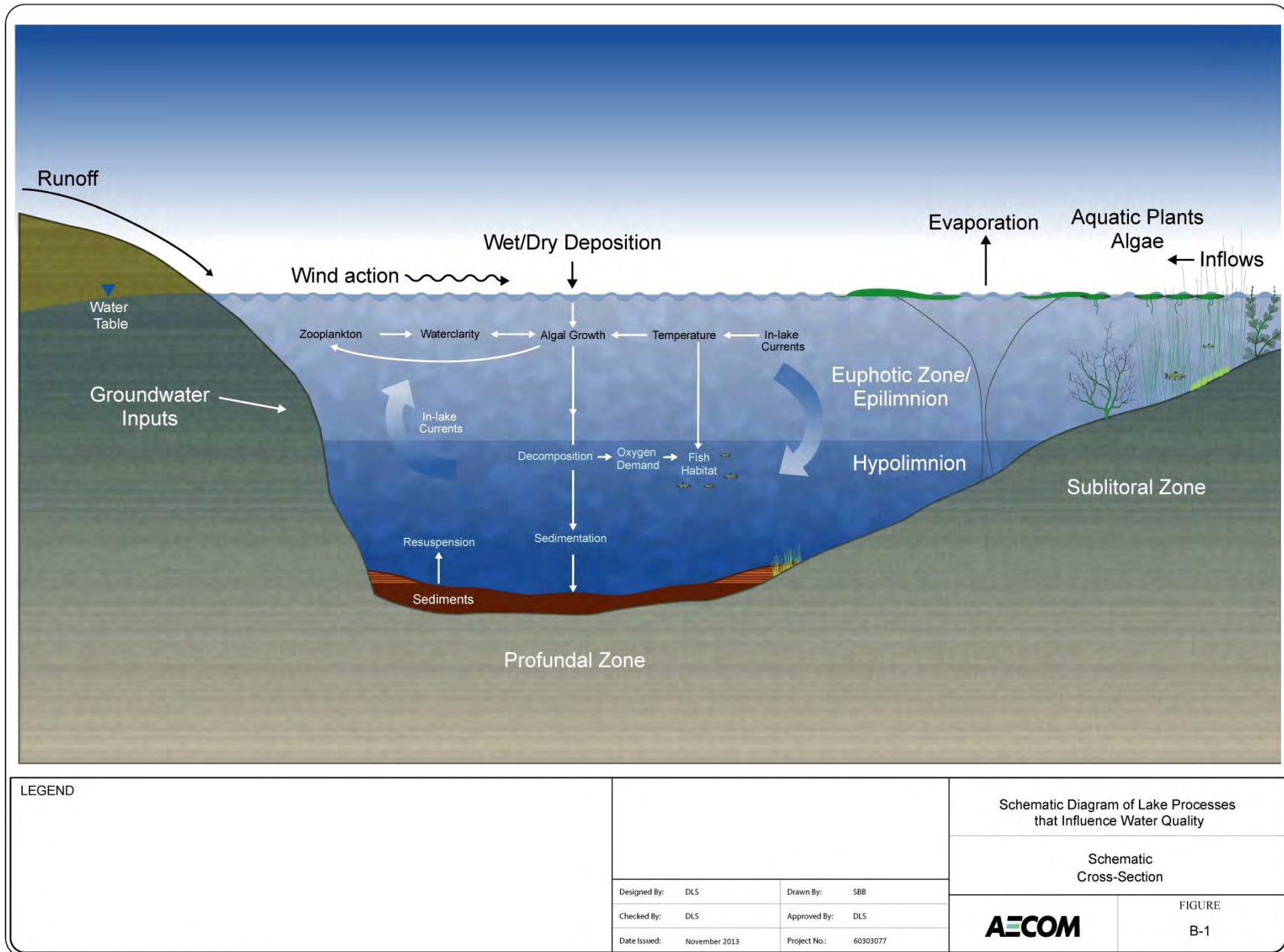
## 1.1 Lake Chemistry

Lakes are central ecological and hydrological components of most watersheds. Lake chemistry is a function of the inflow of surface waters (and hence upstream activities), groundwater discharge to the lake, deposition to the lake surface from the atmosphere, and the deposition and re-suspension of lake bottom sediments. All these processes are modified by the interaction of biological, physical, and chemical activities or processes within the lake. The processes and functions that are important to understanding lake chemistry are illustrated in **Figure B-1**.

Large lakes may have complex water quality patterns due to diverse and chemically distinct inflows from creeks and rivers combined with complex basin shapes. Water circulation through the lake is a core physical process that controls lake water quality. Lake water circulation results from currents generated from inflows, wind, and currents that result when water masses within the lake have different densities. Density currents most commonly occur in response to water masses of different temperatures within a lake.

Deeper lakes in temperate climates undergo a seasonal cycle of thermal stratification, which creates gradients of temperature and dissolved oxygen within the lake. When a lake is of uniform temperature, water is easily circulated throughout its entire depth by wind-driven mixing. This is referred to as “lake overturn” and occurs in the spring and the autumn when lakes warm or cool to approximately 4°C, the temperature at which water is most dense. At this temperature, surface waters sink to the bottom and wind action promotes mixing of the entire water column, exposing the waters to the atmosphere and re-oxygenating the lake. As the lake warms in the summer (or cools in the winter) a density gradient is re-established, with less dense waters at the surface. Throughout much of the year, a deep lake is thermally stratified due to either heating or cooling at the surface. The boundary between warm and cold waters in a lake is called the “thermocline”, and is governed by the water clarity (depth of solar penetration) and the depth to which waters are mixed by the wind. The thermocline isolates water below from the water above such that no further mixing or turnover occurs after stratification. As a result, oxygen concentrations can be depleted, becoming anoxic (< 0.5 mg/L dissolved oxygen) in the deep waters of lakes (hypolimnion) during the summer and winter as decomposition of organic matter consumes the oxygen in the water. This has implications for aquatic life that require oxygen to live, and may also result in the production of toxic compounds, and the release of phosphorus from the sediments to the water overlying the sediments. The reduced oxygen concentrations persist in the hypolimnion until the next period of lake overturn, at which time the entire water column is again mixed. At this time, phosphorus accumulated in the hypolimnion is mixed with the surface waters of the lake.

Lake ice cover is another important physical process. On larger lakes, ice generally forms later than in small lakes due to the greater heat storage of larger water bodies, but will remain in place until spring. Once ice is formed, the lake water is isolated from oxygen exchange with the atmosphere and from mixing by the wind. As a result, no oxygen replenishment occurs and the lake may become anoxic under ice cover. The length of ice cover can significantly influence the water quality of the lake. Within the Sandy Lake watershed, ice cover on lakes is typically of short duration and so winter oxygen depletion is less common than in more continental climates.

**Figure B1. Lake Processes**

N:\Projects\2004\41255\2005\Final\Images\Fig3.2



## 1.2 Water Quality

There is no single or simple measure of water quality. Surface waters naturally contain a wide variety of dissolved and suspended substances, and human activities inevitably add to this mixture. As a result, researchers have developed various approaches to measuring water quality. A single water sample may be tested for a few substances, or for a few hundred, depending on the objectives or concerns at the time of the study. Scientists may also study aquatic organisms and the bottom sediments of lakes and rivers to help assess the overall quality of freshwater systems.

Among the many substances found in water, specific indicators of water quality include:

- a) **Physical Characteristics** such as temperature, dissolved oxygen, colour, Dissolved Organic Carbon (DOC), Total Suspended Solids (TSS) and turbidity. Temperature and dissolved oxygen are largely driven by lake morphometry (shape and structure of the lake basin) and climate but dissolved oxygen can be altered by excessive nutrient load and the introduction of oxygen demanding substances to a lake. Colour and DOC are governed by the organic content of water and result from the decomposition of vegetation in a lake and its watershed. Lakes with a large amount of wetland in their watershed will have high levels of colour and DOC while lakes that are groundwater dominated will have lower concentrations. TSS and turbidity are added by particles of soil or algal cells in the water column that reduce water clarity. They are indicators of urban runoff, algal growth and, indirectly, light transmission through the water column since light stimulates algae populations.
- b) **Chemical Characteristics:**
  1. **General Water Chemistry:**

Alkalinity, pH, total hardness, conductivity, anions (chlorides, sulphide, and iron), and cations (calcium, magnesium, and sodium) help to characterize and differentiate each lake. They generally reflect the characteristics of geology and soils in the watershed of a lake, and the relative importance of groundwater (which is more highly mineralized) and surface water (which is less mineralized). The pH is a measure of the acidity or alkalinity of a water body. Lower alkalinity waters (pH<7) typifies the Sandy Lake watershed lakes. The higher levels of alkalinity “buffer” or protect a water body against changes in pH from the addition of acidic substances such as sulphate from acid rain or sulphide minerals in bedrock. Hardness and conductivity measure the concentration of dissolved minerals while anions and cations indicate the specific ions making up the mineral content. Concentrations of these parameters are generally stable in surface water, and need not be sampled frequently in order to characterize a lake.
  2. **Trace Metals:**

Metal concentrations including lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), and zinc (Zn) reflect the geology of a watershed. At high concentrations metals can impair aquatic life and therefore may be considered pollutants. They can also be added to lakes by industrial processes, urban runoff and land use practices such as landfilling. Concentrations of these parameters in surface water are typically stable over the short to medium term, and need not be sampled frequently. In the urban environment, many trace metals are found to be associated with particulate materials, such as soil and grit particles. As such, they can be partially managed by stormwater management practices that also remove solids. Measurements of TSS therefore help to interpret metals concentrations.
  3. **Nutrients:**

Total phosphorus (TP), total kjeldahl nitrogen (TKN), ammonia (NH<sub>3</sub>), nitrate (NO<sub>3</sub>), and dissolved organic carbon (DOC) describe the nutrient characteristics of a lake. Phosphorus and nitrogen forms of nutrients are critical water quality indicators because of nutrient enrichment in urban lakes and their role in stimulating changes in water clarity and nuisance algae growth, which may include toxic cyanobacteria. Nutrient sources to urban lakes include septic systems, urban runoff that contains organic matter, dog and bird feces, and fertilizer residues. Phosphorus can also be released from the sediments of a lake if the

sediments lack oxygen. The photosynthetic pigment in algae, chlorophyll, is not a nutrient, but is used as an indicator of algal response to lake nutrients.

4. **Bacteria:**

Bacterial counts are good indicators of problems related to urban runoff such as discharges from storm sewers, overflows or by-passes from sanitary sewers and sewage treatment facilities, as well as cross-connections between sanitary and storm sewers and inputs from wildlife and domestic animals. Bacterial counts may increase as a result of urbanization and development and thus they are important indicators of general lake system health.

### 1.3 Trophic Status and Nutrients

The term “trophic status” is used to describe biological productivity within a lake. Trophic status depends on the amount of nutrients available to enhance plant growth, including floating algae called phytoplankton. Algae are important to the overall ecology of the lake because they are the base of the food chain, providing food for zooplankton (microscopic invertebrate animals, which are, in turn, food for other organisms, including fish. Excessive productivity or plant growth is visible as degraded water clarity, algae and weed accumulation on shore and decreased oxygen concentrations in the water column.

In most lakes, phosphorus is the nutrient in shortest supply and its absence acts to limit the production of aquatic life. When present in excess, phosphorus stimulates algal blooms and can result in reduced water clarity and reduced oxygen concentrations in deep lake waters.

Lakes become naturally enriched in nutrients over long periods of time in a process known as eutrophication. Where the amount of phosphorus in a lake is enriched by human activity this process is accelerated and is termed cultural enrichment or cultural eutrophication. Nutrients can come from many sources, such as fertilizers applied to suburban lawns, golf courses, and agricultural fields, deposition from the atmosphere, erosion of soil containing nutrients, urban runoff and sewage treatment plant discharges.

The trophic status of a lake can be determined by measuring nutrient concentrations (phosphorus and nitrogen), algal density (either directly as algal biomass or indirectly as chlorophyll  $\alpha$  and, in some lakes, water clarity. Although water clarity is influenced by soil particles, colour, and dissolved organic carbon, it is also an indication of biological productivity. The more productive a lake is the greater the algal growth and therefore the less clear the water becomes.

Lakes with few nutrients and low productivity are referred to as “oligotrophic”. They are typically clear water lakes with sparse plant life, high oxygen levels in deep waters and low fish production. In contrast, lakes with higher nutrient concentrations and high productivity are referred to as “eutrophic”. They have abundant plant life, including algae. Lakes with an intermediate productivity are called “mesotrophic” and generally combine the qualities of oligotrophic and eutrophic lakes.

Classification of lake trophic status into oligotrophic, mesotrophic or eutrophic, although somewhat subjective, provides a simplified framework for lake management and a point of reference for lake managers. There are many means of classifying lake trophic status but all are based on measurements of trophic status indicators such as phosphorus concentration, algal concentration or water clarity. These indicators are used to assign lakes to a category based on the values measured. Environment Canada (CCME 2004) provided the following classification (**Table B1**) of trophic status for lakes and rivers, as taken from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

**Table B1. Trophic Status Based Trigger Ranges for Canadian Waters (CCME, 2004)**

Trophic Status	Trigger Ranges for Total Phosphorus (µg/L)	
	Lakes	Rivers and Streams
Ultra-oligotrophic	<4	-
Oligotrophic	4-10	<25
Mesotrophic	10-20	25-75
Meso-eutrophic	20-35	-
Eutrophic	35-100	>75
Hypereutrophic	>100	-

## 2. Establishing Water Quality Objectives

### 2.1 Introduction

One of the principal objectives of the watershed study is to evaluate existing water quality conditions and recommend water quality objectives for the main lakes within the watershed. The water quality objectives are based upon a scientific understanding of the Sandy Lake watershed and widely accepted standards of water quality. These recommended water quality objectives will be used by HRM to establish the acceptable standards that HRM and the public agree will achieve the long term management goals for the Sandy Lake Area.

### 2.2 Water Quality Indicators

Suburban development within the Sandy Lake watershed may require removal and transformation of forested and natural areas for residential and commercial developments. Given this, a short list of critical parameters or water quality indicators used to establish water quality objectives was derived based on those parameters most likely to be negatively affected by development within the watershed. Deterioration of these parameters will negatively affect recreational use, aquatic life and passive enjoyment or aesthetics of these lakes.

The parameters most likely to be negatively influenced as a result of these land use changes are: **total phosphorus, nitrate, ammonia, total suspended solids, chloride and *E. coli***. Given their sensitivity to development, these parameters were selected as “indicators” upon which to base water quality objectives. Other parameters such as metals, oil and grease, chlorophyll  $\alpha$ , and nitrogen, may also increase due to development in the watershed; however, watershed management and implementation of mitigation measures to reduce development impacts to the “indicator parameters” will also limit the changes to all of these parameters. For example, metals concentrations may increase in the watershed but it is likely that the metals will be associated with the transport of suspended solids to the lake as a result of clearing and construction activities in the watershed and increased runoff as a result in increased surface hardening. Consequently, management of suspended sediment within the lake will not only help reduce phosphorus concentrations but also metals. Nevertheless, to avoid a large number of water quality objectives that need to be monitored through expensive water quality monitoring programs, we have restricted setting water quality objectives to the few variables that we think will provide protection of the watershed while focusing the monitoring efforts. There may be, at some time in the future, a need to undertake more specialized monitoring programs and to set specific water quality objectives to individual lakes or even parts of lakes. An example of this might be in relation to impacts from specific developments or land use changes that may warrant targeted investigation such as a new quarry development, forestry operations or housing development. However, at

the present time it is essential to implement focussed and effective water quality management program based on these selected water quality indicators using their associated objectives and early warning values.

**Table B2. Changes to Water Quality Parameters from Watershed Development**

Water Quality Parameter	Effect of Development	Rationale for inclusion as Indicator Parameter
TP	Increase from fertilizer runoff, stormwater runoff, waste water treatment plant (WWTP) by-passes and overflows, septic systems	Increases in phosphorus can increase growth of algae and aquatic plants which can in turn reduce water clarity and dissolved oxygen
NO <sub>3</sub>	Increase from fertilizer runoff, WWTP by-passes and overflows, septic systems, urban runoff, stormwater discharge.	Increases in nitrate can increase growth of algae and aquatic plants which can in turn reduce water clarity and dissolved oxygen
Ammonia	Increase from fertilizer runoff, WWTP by-passes and overflows, urban runoff, effluents from some industrial and commercial activities	Un-ionized ammonia is a portion of ammonia that can be toxic to aquatic life at elevated concentrations
TSS	Increase from deforestation, construction activities, gravel operations, WWTP bypasses and overflows, and stormwater runoff from urban areas/hard surfaces	Increases in suspended solids can reduce water clarity, alter habitat, and interfere with feeding, physiological and behavioural in fish and affect benthic production and periphyton communities.
Chloride	Increase due to spray from road salting practices, stormwater runoff, WWTP bypass overflows, and long-range transport	Increases chloride results in increased salinity, thereby affecting the ability of some organisms to osmoregulate (affecting endocrine balance, oxygen consumption, and physiological processes)
<i>E. coli</i>	Increase due to septic systems, WWTP bypass overflows, and stormwater runoff	An indicator of fecal contamination in recreational water

## 2.3 Review of Water Quality Guidelines and Objectives from Other Jurisdictions

The province of Nova Scotia has not yet developed comprehensive water quality objectives (WQOs) for the lakes and rivers in the province although WQOs have been recommended for specific lakes. When developing water quality objectives for the Sandy Lake watershed, the guidelines and objectives from other jurisdictions were consulted for direction. The Canadian Water Quality Guidelines (CWQG) provides a benchmark for a consistent level of protection across Canada. The CWQG are derived according to a nationally endorsed scientific protocol, in which all components of the aquatic ecosystem are considered using the available scientific data in association with reviews and guidelines developed in other jurisdictions (e.g., United States Environmental Protection Agency (USEPA), Netherlands, and European Union). The CWQG “are set at such values to as to protect all forms of aquatic life and all aspects of the aquatic life cycles”. They are conservative values, set at levels to protect the most sensitive forms of aquatic life.

National standards for parameters in surface waters in the USA have been developed by the USEPA. The USEPA standards are widely used benchmarks based on leading edge scientific research. The USEPA has developed a strategy to address nutrient enrichment of waterbodies that includes the use of regional and waterbody– type approach to set nutrient criteria. The state of Vermont, which has developed comprehensive water quality objectives in association with USEPA guidelines, was selected for comparison as it has similarities with Nova Scotia with respect to latitude, climate and geology. **Table B3** summarizes the CWQG, USEPA, and Vermont water quality guidelines and standards for the key indicator parameters identified for the Sandy Lake watershed.

**Table B3. Water Quality Guidelines and Standards from Canada, USEPA and Vermont**

Parameter	CWQG	USEPA	Vermont
TP	Trophic Status Approach	• Ecoregion Based Approach	• Lake specific – maximum increase of 1 mg/L
NO <sub>3</sub>	• 13 mg NO <sub>3</sub> /L	• n/a	• 5.0 mg/L as NO <sub>3</sub> -N
Un-ionized Ammonia	• 0.019 mg/L	• Temperature/pH dependent	• EPA values
TSS	• Short term exposure: 25 mg/L increase • Long term exposure: 5 mg/L increase	• <10 % of the seasonal value	• Water Class dependent
Chloride	• 120 mg/L (chronic toxicity guideline) • 640 mg/L (acute toxicity guideline)	• 230 mg/L chronic concentration (CC) • 860 mg/L maximum concentration (MC)	• n/a
<i>E. coli</i>	• 2000 <i>E. coli</i> /L <sup>1</sup> (geometric mean of 5 samples)	• 126 <i>E. coli</i> /100 mL (geometric mean of 5 samples)	• Water Class dependent

Note: 1. Health Canada Guidelines for Recreational Water Quality

All indicator parameters, with the exception of total phosphorus, have definitive CWQG limits. The concentrations of these parameters are unlikely to be affected by local geology, but are responsive to land use within the watershed.

## 2.4 Review of Water Quality Guidelines and Objectives for Total Phosphorus

Currently there are no national guidelines for phosphorus, although several provinces have developed their own guidelines or objectives. The development of national guidelines has been hindered by the need to consider the following factors that affect the nature of phosphorus as a pollutant:

- It is non-toxic and is a required and limiting nutrient in fresh water, such that small increases stimulate aquatic productivity;
- The natural or baseline water quality and trophic status for lakes varies extensively across Canada;
- The detrimental effects of phosphorus are indirect, resulting from algal growth and oxygen depletion, and so there is a lot of variation in phosphorus concentrations associated with observed effects;
- The effects of phosphorus on primary biological production are modified by natural factors that attenuate light (i.e., Dissolved Organic Carbon or turbidity). These factors can mask the effects of increased phosphorus by reducing the biological response normally associated with elevated phosphorus concentrations;
- The effects of phosphorus on surface water are partially aesthetic (i.e., decreased water clarity), and so determination of thresholds of effect is somewhat subjective; and
- Phosphorus concentrations can vary substantially in surface water, as a result of season, differences between river and lake systems and as a result of natural factors in the landscape such as geology, soils and wetlands.

These factors have been accommodated in the guidelines developed by several provinces. Provincial total phosphorus water quality guidelines vary from 5-15 µg/L in British Columbia to 50 µg/L in Alberta (**Table B4**) and reflect, in part, the differences in natural water quality across Canada.



**Table B4. Provincial Water Quality Objectives for Total Phosphorus (µg/L)**

	Lakes	Rivers
British Columbia	5-15	
Alberta	50	
Manitoba	25	50
Ontario	10, 20	30
Quebec	Background + 50% increase (upper limits of 10 and 20 µg/L)	

#### 2.4.1 Canadian Guidance Framework for Phosphorus

Environment Canada (CCME 2004) developed a framework for the management of phosphorus. The framework offers a tiered approach where phosphorus concentrations should i) not exceed predefined “trigger ranges”; and ii) not increase more than 50% from the baseline or reference condition. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site. If the defined range is met or exceeded then management action is “triggered”, to assess the problem, determine its causes and implement solutions. For lakes and rivers, trophic status classifications have been developed as ranges of phosphorus concentrations which reflect the fact that not all lakes respond in a clear and precise manner. Environment Canada (CCME 2004) provided a classification of trophic status for lakes and rivers (**Table B4**) as adapted from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

# Appendix C

## Water Quality Data Summary Tables

[illegible]

Sample Name				Sandy Lake									Sandy Lake Outlet									Sandy Lake Outlet									Sandy Lake Outlet 2			Sandy Lake			Sandy Lake			Marsh-Lake		Marsh Lake Outlet			
Lake Name	CCME Guideline (RWQ)	CCME Guidelines (FWAL)	Units	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Sandy Lake	Marsh Lake	Marsh Lake	Marsh Lake	Marsh Lake							
Easting	-	-	-	444550	444550	444550	444550	444550	444550	444550	444550	444550	444018	444018	444018	444018	444018	444018	444018	444018	444018	444018	444018	444014	444014	444014	unknown	unknown	unknown	444574	444574	444574	unknown	unknown	unknown	444590	445640	445640	445640						
Northing	-	-	-	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4953619	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954358	4954340	4954340	4954340	unknown	unknown	unknown	4953566	4953566	4953566	unknown	unknown	unknown	4955417	4955193	4955193	4955193							
Sampling Date	-	-	dd-mm-yy	3-Sep-08	21-Oct-08	2-Jun-09	12-Aug-09	18-Nov-09	21-May-10	24-May-10	9-Nov-10	19-Aug-11	23-May-07	1-Nov-07	28-May-08	3-Sep-08	21-Oct-08	2-Jun-09	18-Nov-09	21-May-10	24-May-10	9-Nov-10	19-Aug-11	27-Aug-13	15-Nov-13	20-May-14	1/1/1980	1/1/1991	1/1/1991	2-Sep-98	2-Sep-98	2-Sep-98	1/1/2000	1/1/2000	25-Jul-07	27-Aug-13	15-Nov-13	20-May-14							
Sampled By / Data Source	-	-	-	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	HRM	AECOM	AECOM	AECOM	DFO	DFO	DFO	NSE	NSE	NSE	DFO	DFO	NSE	AECOM	AECOM	AECOM							
FIELD DATA																																													
Secchi Depth	1.20	-	Meters	2.0	2.4	2.7	N/A	1.8	3.2	2.6	1.7	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.05	3.05	3.05	-	-	-	-	-								
Temp	-	-	Celsius	19.58	12.20	15.53	24.90	7.48	14.16	22.99	11.40	22.67	-	-	-	-	-	-	-	-	-	-	-	-	21.60	7.70	-	4	6	22	22	22	5.1	5.7	-	19.20	5.60	-							
Dissolved Oxygen	-	5.5-9.5	mg/L	9.64	10.15	10.71	8.81	13.41	11.91	8.74	12.13	9.27	-	-	-	-	-	-	-	-	-	-	-	-	4.28	4.09	-	-	-	3	3	3	-	-	-	4.10	4.18	-							
pH	5.0-9.0	6.5-9	pH	6.42	7.08	7.36	6.45	6.76	7.55	6.91	6.29	6.8	-	-	-	-	-	-	-	-	-	-	-	-	6.08	6.31	-	4.9	5.3	-	5.70	6.20	5.90	5.81	5.65	6.40	6.10	6.10	-						
Specific Conductance	-	-	uS/cm	167	165	178	159	135	167	156	128	119	-	-	-	-	-	-	-	-	-	-	-	-	128	116	-	58.9	113.7	-	146	125	130	132.1	133	119	111	94	-						
TDS	-	-	g/L	0.11	0.11	0.12	0.10	0.09	0.11	0.10	0.08	0.077	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.08	-	-	-	-	0.069	-	-	-	-	0.073	0.07	0.06	-						
Salinity	-	-	ppt	0.08	0.08	0.08	0.07	0.06	0.08	0.07	0.06	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
INORGANICS																																													
Total Alkalinity (as CaCO3)	-	-	mg/L	6	6	<5	<5	<5	<5	<5	<5	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.1	-	2	3	2.8	0.21	0.42	3.8	-	-						
Dissolved Chloride (Cl)	-	-	mg/L	40	41	45	39	32	42	37	29	24	-	-	-	-	-	-	-	-	-	-	-	-	34	28	47	-	-	-	-	-	-	-	-	30	28	44							
Colour	-	-	TCU	39	45	26	54	66	19	15	26	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.5	-	-	-	8	12	-	-								
Nitrite + Nitrate	-	-	mg/L	<0.05	0.07	0.13	0.14	<0.05	0.11	<0.05	0.06	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	0.07	-	-	-	0.09	<0.01	0.05	-	-	<0.01	<0.05	<0.05	<0.05						
Nitrite (N)	-	60.00	mg/L	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05						
Nitrogen (Ammonia Nitrogen)	-	19.00	mg/L	<0.05	<0.05	<0.05	<0.05	0.08	0.07	0.06	0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	0.02	0.023	-	-	-	0.01	0.03	0.021	0.019	0.02	<0.05	<0.05	<0.05					
Nitrogen TKN - water (as N)	-	-	mg/L	0.4	0.4	<0.4	1	1.2	0.5	0.7	0.4	3.6	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	1.4	0.9	-	-	-	-	-	-	-	-	0.7	0.7	0.9	-						
Total Nitrogen	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24	0.25	-	0.32	0.2	0.22	0.1	0.17	0.2	-						
Total Organic Carbon	-	-	mg/L	5.3	5.7	4.6	10.5	8.6	5.9	6.8	8.4	10.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	4.4	4.4	-	-	5.8	-	-							
Orthophosphate (as P)	-	-	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	0.002	0.02	-	0.004	<0.001	<0.001	-	-	<0.005	<0.01	<0.01	<0.01						
pH (Lab)	5.0-9.0	6.5-9	pH	6.52	6.66	6.8	7.2	7.0	6.8	7.0	6.6	7.1	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	7.0	4.9	5.29	-	-	-	-	-	-	-	-	-							
Total Calcium (Ca)	-	-	mg/L	4.8	4.4	4.1	5	4.6	5.5	17.2	4.1	3.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	3.3	-	3.92	3.9	3.92	4	3.9	3.5	-					
Total Magnesium (Mg)	-	-	mg/L	1.0	0.9	0.9	1	1.0	1	1.7	1.0	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0.9	-	0.96	0.93	0.92	0.99	0.97	0.8	-					
Total Phosphorus	-	-	mg/L	0.1	0.1	-	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.019	0.009	0.023	0.007	0.019	-	0.012	0.001	0.005	0.008	0.008	0.012	0.010	0.022	
Total Phosphorus (1M depth)	-	-	mg/L	0.011	0.021	0.008	0.012	0.025	0.043	0.010	0.019	0.006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
Total Phosphorus (Deep)	-	-	mg/L	0.015	-	-	N/A	-	-	0.026	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
Total Potassium (K)	-	-	mg/L	1.2	1.0	0.9	1	1.1	1	1.2	1.2	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.7	-	0.7	0.8	0.9	0.66	0.67	0.8	-					
Total Sodium (Na)	-	-	mg/L	25	23	22.6	22.9	19.1	30.3	27.7	17.6	18.1	-	-	-	-	-	-	-																										



Sample Name				Uplands Park WWTF																																	
Lake Name	CCME Guideline (RWQ)	CCME Guidelines (FWAL)	Units	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA			
Easting	-	-	-	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown			
Northing	-	-	-	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown			
Sampling Date	-	-	dd-mm-yy	10-Jan-12	26-Jan-12	10-Feb-12	7-Mar-12	29-Mar-12	11-Apr-12	25-Apr-12	28-May-12	12-Jun-12	26-Jun-12	6-Jul-12	10-Jul-12	17-Jul-12	9-Aug-12	11-Sep-12	5-Oct-12	30-Oct-12	14-Nov-12	27-Nov-12	11-Dec-12	7-Jan-13	21-Jan-13	14-Feb-13	4-Mar-13	19-Mar-13	8-Apr-13	23-Apr-13	14-May-13	4-Jun-13	18-Jun-13	3-Jul-13	23-Jul-13		
Sampled By / Data Source	-	-	-	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water	Halifax Water			
FIELD DATA																																					
Secchi Depth	1.20	-	Meters	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Temp	-	-	Celsius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Dissolved Oxygen	-	5.5-9.5	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
pH	5.0-9.0	6.5-9	pH	6.77	7.05	7.07	6.85	6.82	6.61	6.50	6.37	6.33	7.02	6.51	6.59	6.51	6.62	6.52	6.49	6.35	6.39	6.76	6.53	6.64	6.51	6.30	6.54	6.66	6.71	6.14	6.23	6.35	6.66	6.06	6.28		
Specific Conductance	-	-	uS/cm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
TDS	-	-	g/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Salinity	-	-	ppt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
INORGANICS																																					
Total Alkalinity (as CaCO3)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Dissolved Chloride (Cl)	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Colour	-	-	TCU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Nitrite + Nitrate	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Nitrite (N)	-	60.00	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Nitrogen (Ammonia Nitrogen)	-	19.00	mg/L	2.20	3.30	9.60	6.20	6.80	8.40	5.10	5.80	4.40	17.00	3.30	7.20	5.30	12.00	2.10	3.70	5.10	5.90	13.00	2.10	7.00	3.60	4.00	5.00	3.60	6.90	2.00	1.10	3.70	2.60	2.00	-		
Nitrogen TKN - water (as N)	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Nitrogen	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Organic Carbon	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Orthophosphate (as P)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
pH (Lab)	5.0-9.0	6.5-9	pH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Calcium (Ca)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Magnesium (Mg)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Phosphorus	-	-	mg/L	1.20	1.50	3.20	1.90	2.80	4.20	2.70	3.90	3.90	4.40	3.20	3.60	4.70	3.60	1.70	2.40	3.20	2.00	2.80	0.94	2.80	1.30	2.20	2.40	1.90	2.30	3.60	1.50	4.40	2.40	1.70	-		
Total Phosphorus (1M depth)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Phosphorus (Deep)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Potassium (K)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Sodium (Na)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Reactive Silica (SiO2)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Total Suspended Solids	-	-	mg/L	14.00	16.00	31.00	10.00	15.00	11.00	35.00	57.00	15.00	13.00	12.00	12.00	16.00	11.00	37.00	10.00	7.20	44.00	9.30	13.00	5.80	13.00	5.00	4.80	5.00	4.40	5.20	12.00	26.00	19.00	9.20	-		
Dissolved Sulphate (SO4)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Lab Turbidity (NTU)	50.00	-	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Conductivity (uS/cm)	-	-	µS/cm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Calculated Parameteres																																					
Anion Sum	-	-	me/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Bicarb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Calculated TDS	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Carb. Alkalinity (calc. as CaCO3)	-	-	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-													

# **Appendix D**

## **Groundwater Recharge Model**

Table of Contents

	page
1. Introduction .....	1
2. Baseflow .....	1
3. Water Budget.....	1
4. Groundwater Recharge Model .....	2
5. Discussion .....	4
6. Conclusions .....	5

List of Tables and Figures

Table D1: Sandy Lake Watershed Water Surplus.....	2
Table D2: Soil Infiltration Factors .....	2
Table D3: Summary of Groundwater Contributions and Total Flow .....	3

## 1. Introduction

Precipitation falling within a watershed may flow overland as runoff or infiltrate into the soil. Groundwater recharge is the portion of precipitation that infiltrates into soil and reaches the groundwater system. Groundwater discharging to watercourses provides “baseflow” to streams throughout the year. Baseflow is essential to maintaining stream flow for aquatic ecosystems during periods with limited precipitation. The baseflow contribution to the Sackville River is estimated to be 11% of the mean annual flow (Caissie and Robichaud 2009). This estimate of baseflow is assumed to be the same for the Sandy Lake watershed and is used as a calibration target for the groundwater recharge model.

Groundwater recharge potential was defined for the Sandy Lake watershed using a Geographic Information System (GIS) based recharge model. The groundwater recharge model partitions **surplus water** into groundwater **recharge** and overland **runoff** using slope, vegetation cover and soil infiltration rates as deterministic factors. The results of the model identify areas of high recharge potential that in turn are potentially subject to protective recommendations as required by Regional Plan Policy E-17.

The groundwater contribution to Sandy Lake is an important contributor lake water quality because it adds phosphorus dilute groundwater to the lakes. However, groundwater contributions are not integrated to the Lakeshore Capacity Model (LCM). Quantifying groundwater contributions to Sandy Lake can be used to estimate the phosphorus dilution in the lake by groundwater inflows.

## 2. Baseflow

Baseflow is the groundwater contribution to stream flow. A baseflow estimate for the Sackville River based on hydrometric data is used to derive a calibration target for the Sandy Lake watershed groundwater recharge model. Annual flow in the Sackville River is monitored by Environment Canada with data available from hydrometric data (HYDAT) electronic databases (Environment Canada 2014). Using these data, a study of natural flow regimes in the Maritime Provinces completed by Fisheries and Oceans Canada estimated baseflow for the Sackville River to be 0.11 of mean annual flow (Caissie and Robichaud 2009). Similarly, Kennedy et al (2010) estimated baseflow from the Sackville River to be 0.12 of mean annual flow. The mean annual flow of the Sackville River during the time period 1981-2010 is  $152.7 \times 10^6 \text{ m}^3$  of water and the baseflow contribution (0.11) is  $16.8 \times 10^6 \text{ m}^3$ . The Sandy Lake watershed ( $24.2 \text{ km}^2$ ) is a sub-watershed of the Sackville River ( $146 \text{ km}^2$ ). Assuming the proportional baseflow contribution to the Sackville River (0.11) is the same for the Sandy Lake watershed, the baseflow volume to the Sandy Lake watershed is  $2.8 \times 10^6 \text{ m}^3$ .

## 3. Water Budget

A water budget is used in the groundwater recharge model to calculate the surplus water available for groundwater recharge. The surplus water is the total precipitation falling as rain and snow minus losses to the atmosphere from evapotranspiration (a combination of evaporation and transpiration of moisture through plant foliage). Precipitation (mm/year) is the yearly average from climate normal data averaged over the 30 year period from 1981 to 2010 at Environment Canada's Halifax Stanfield International Airport climate station (Station ID 8202250). Evapotranspiration is estimated using the methods of Thornthwaite and Mather (1957).

The surplus water calculations assume that changes in soil moisture storage are negligible and there is no change in groundwater storage in the watershed. The water surplus – that is, water available for both surface runoff and infiltration - is presented in Table D1.



**Table D1: Sandy Lake Watershed Water Surplus**

Meteorological Station	Total Annual Precipitation (mm)	Actual Annual Evapotranspiration (mm)	Annual Water Surplus (mm)
Halifax Stanfield International Airport	1,396	543	853

Notes: 1. Data obtained from the 1981 – 2010 average at Halifax Stanfield International Airport (Environment Canada) weather station.  
 2. Actual Evapotranspiration calculated using the Thornthwaite and Mather (1957) method.

## 4. Groundwater Recharge Model

The groundwater recharge model uses three factors to partition the surplus water between groundwater recharge and overland runoff:

1. Slope;
2. Vegetative cover; and
3. Permeability of the earth materials (surficial geology).

This model design is based on the concept that more water will infiltrate to groundwater under conditions of low grade slope, thick vegetation canopy and high permeability (loose) soils rather than when slopes are steep, vegetation cover is minimal and the soils are impermeable.

The three factors separating recharge and runoff were represented for the Sandy Lake watershed using a GIS based analytical model (Figure D1). This model assumes that volumes of domestic and municipal groundwater taking for consumption and irrigation are negligible compared to flow through the system, and that groundwater and/or surface water inflow from outside the watershed is also negligible.

The first step of the Sandy Lake groundwater recharge model is to define the slope factor using a GIS-derived digital elevation model (DEM). The raster DEM is transformed into polygons based on the slope factor. The smallest polygon unit is 100 m<sup>2</sup>. The second step is to designate a vegetative cover value for each polygon created for the slope factor. The vegetative cover value is derived from data files obtained from the Nova Scotia Forest Inventory (NSDNR 2013). Values range from 0.07 to 0.2 with higher values representing more recharge and lower values representing less recharge.

The third step is to define the soil infiltration factor. Surficial geology mapping (**Figure 5** - in the main report) was used to define the areas of differing soil infiltration factors. The values assigned to each surficial geology type (Table D2) are based on soil infiltration factors developed for Ontario surficial sediments. Higher values indicate more permeable, less compact soils.

**Table D2: Soil Infiltration Factors**

Surficial Geology Deposit	Ontario Soil Infiltration Factors	Nova Scotia Adjusted Soil Infiltration Factors
Alluvial	1.20	1.20
Anthropogenic	0.05	0.05
Bedrock	0.10	0.10
Drumlins	0.40	0.60

Surficial Geology Deposit	Ontario Soil Infiltration Factors	Nova Scotia Adjusted Soil Infiltration Factors
Glaciofluvial outwash	1.30	1.30
Hummocky till	0.60	0.40
Lacustrine	0.50	0.50
Lacustrine (lake)	0.75	0.75
Organic Deposits	0.60	0.60
Till blanket	0.40	0.35
Till veneer	0.10	0.15

The slope and vegetation GIS layers for each factor were added together and then multiplied by the soil infiltration factor to estimate an overall infiltration factor for each polygon. The infiltration factors for the polygons ranged from <0.05 in areas with exposed bedrock to >0.30 where mature forest cover and permeable soils dominate. To determine how much water infiltrates to groundwater compared with how much remains as surface runoff, the infiltration factors for each polygon were multiplied by the surplus water value (853 mm). Using the Ontario soil infiltration factors, the total groundwater recharge was estimated to be  $1.9 \times 10^6 \text{ m}^3$  or 9% of the total annual flow. This estimate of groundwater contributions is lower than the hydrometric baseflow estimate. Soil infiltration factors were adjusted (Table D3) by increasing the infiltration of drumlins and till veneer and decreasing the infiltration of the till blanket and hummocky till. These adjustments are consistent with the surficial geology of Nova Scotia where drumlins have a higher proportion of course grained materials derived from bedrock along the flow path of the Laurentide ice sheet resulting in higher permeability of drumlins compared to the till deposits between the drumlins, which are primarily derived from local bedrock resulting in lower permeability.

**Table D3: Summary of Groundwater Contributions and Total Flow**

Method of Assessment	Proportion of Groundwater Contribution to Total Flow	Groundwater Contribution ( $\times 10^6 \text{ m}^3$ )	Total Annual Flow ( $\times 10^6 \text{ m}^3$ )
Baseflow from Hydrometric Data	0.11	2.77	25.20
Ontario Soil Infiltration Factors	0.09	1.89	20.64
Nova Scotia Adjusted Soil Infiltration Factors	0.11	2.36	20.64

The model was completed with the adjusted soil infiltration factors. The total annual groundwater recharge estimated for Sandy Lake is  $2.36 \times 10^6 \text{ m}^3/\text{yr}$  and surface runoff  $18.28 \times 10^6 \text{ m}^3/\text{yr}$ . Added together to make total flow, recharge plus runoff is  $20.64 \times 10^6 \text{ m}^3/\text{yr}$ . The proportion of recharge to total flow predicted by the recharge model is 0.11 or 11%, that is, 11% of the surplus water within the watershed infiltrates into the soil while 89% remains as surface runoff. The groundwater recharge predicted using the adjusted soil infiltration factors is consistent with the proportion of baseflow estimated using the hydrometric data.

The results of the groundwater recharge model are represented as recharge in **Figure 6** of the main report. The purpose of this map is to highlight areas where there is greater infiltration and hence a greater estimated potential for groundwater recharge, which in turn correspond to more productive hydrostratigraphic units. The sum of the recharge from all the polygons provides an estimate of total annual recharge or baseflow to streams and lakes in the watershed.

## 5. Discussion

The map of groundwater recharge potential identifies several areas with elevated recharge potential. The drumlins surrounding Sandy Lake and Marsh Lake provide areas of high recharge that supply groundwater (in the form of baseflow) to the lakes and wetlands. Residential or other development in areas of high recharge would likely reduce the recharge potential and thus baseflow by changing the vegetation cover and reducing the soil permeability. Given this, future development in the areas of high recharge should include design features that maintain groundwater recharge so that cool, clean baseflow to Sandy and Marsh Lakes is sustained.

A comparison of the total watershed flows (**Table D3**) generated by the groundwater recharge model ( $20.6 \times 10^6 \text{ m}^3/\text{year}$ ) and the hydrometric data ( $25.2 \times 10^6 \text{ m}^3/\text{year}$ ), indicates a difference of approximately  $4.6 \times 10^6 \text{ m}^3/\text{year}$ . The factors that may contribute to the difference between the two estimates of total stream flow include:

- Underestimation of precipitation for Sandy Lake using the climate normal data from the Stanfield Airport located approximately 30 km from Sandy Lake. Collection of precipitation data at the nearby Citadel station in Halifax stopped in 2001, but a review of the data indicates that Halifax receives approximately 5% more precipitation than the airport. A portion of this additional precipitation would contribute to groundwater recharge and might account for some of the missing  $4.6 \times 10^6 \text{ m}^3/\text{year}$ ; and,
- Differences in the land cover between the Sandy Lake and Sackville watersheds. The Sackville River watershed is considerably more urbanized than the Sandy Lake watershed. The impermeable roofs, roads, sidewalks and parking lots associated with urban development would produce a larger proportion of surface runoff in the Sackville watershed compared to the Sandy Lake watershed, and a corresponding lesser volume of infiltration as groundwater recharge.

It should also be underlined that if data from the Stanfield Airport climate station underestimates the annual precipitation for Sandy Lake, then the precipitation data used in the LCM may also be erroneous. The effect of modeling less-than-actual precipitation is to overestimate phosphorus concentrations, since more precipitation entering Sandy Lake dilutes and thus lowers the concentration of this nutrient. This consideration is further discussed in the main report.

It is also important to point out the LCM was initially developed to model nutrient inputs to lakes on the Canadian Shield in central Ontario. In these areas, soil cover is very thin and so the model does not (and cannot) account for groundwater inputs (baseflow) to lakes. As described above, we estimate that at least 11% of the water flowing through the Sandy Lake watershed is groundwater. Studies demonstrate that groundwater in undeveloped areas contains much lower concentrations of phosphorus than surface water in similar areas (US Geological Survey 1999). This suggests that in areas of thick soil cover where groundwater baseflow to streams is common, low-nutrient groundwater inputs may serve to dilute surface water features, resulting in lower phosphorus concentration than those predicted by the LCM. Lakeshore Capacity Modeling of existing conditions conducted for this study consistently predicted higher phosphorus concentrations than were measured in the lake. These results suggest that groundwater plays a more important role in maintaining the lake trophic status in the Sandy Lake watershed than, for example the Birch Cove Lakes watershed where soil cover is thin to non-existent (AECOM 2012).

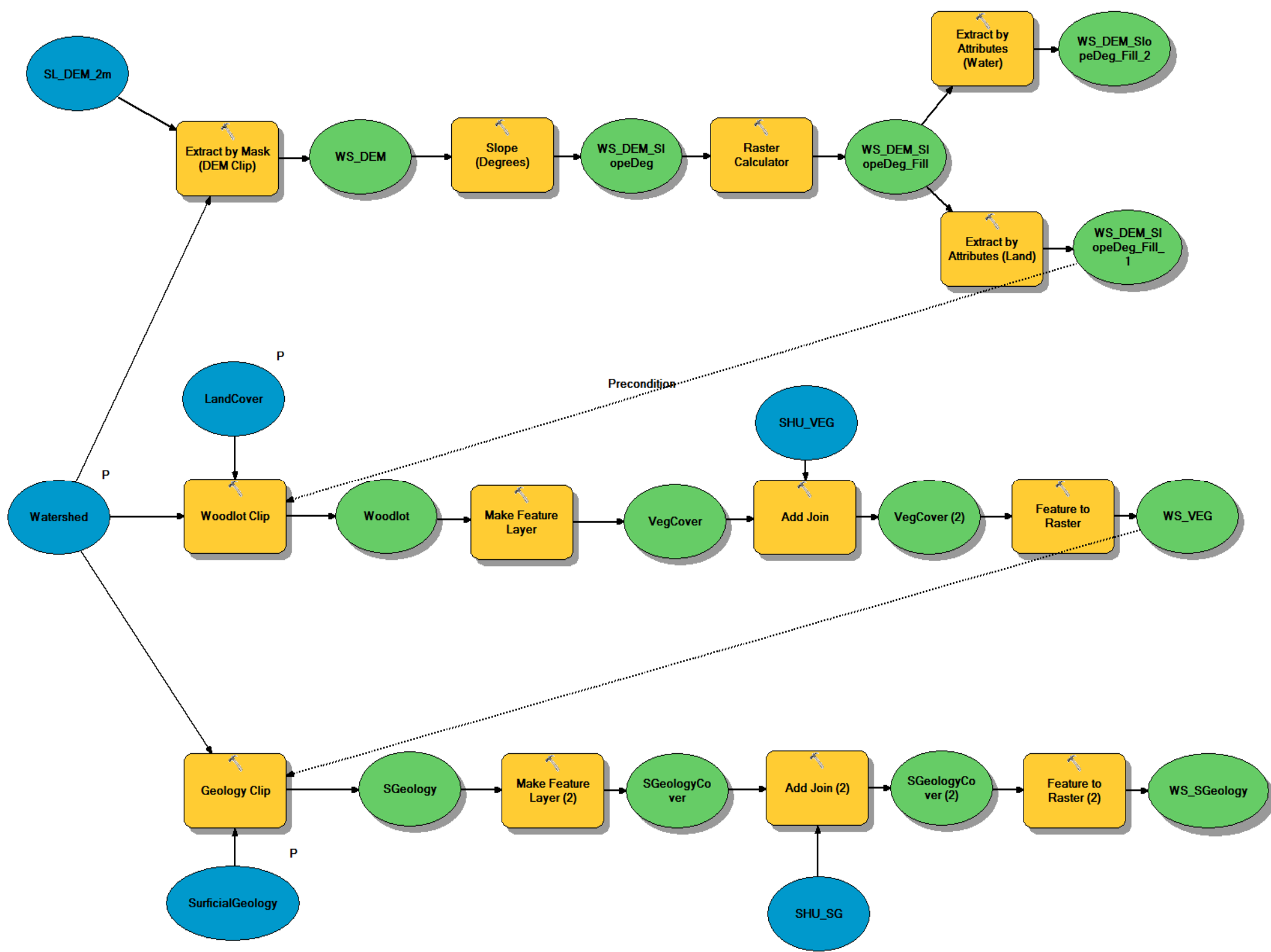
## 6. Conclusions

The results of the groundwater recharge model produce two conclusions useful for the Sandy Lake watershed study:

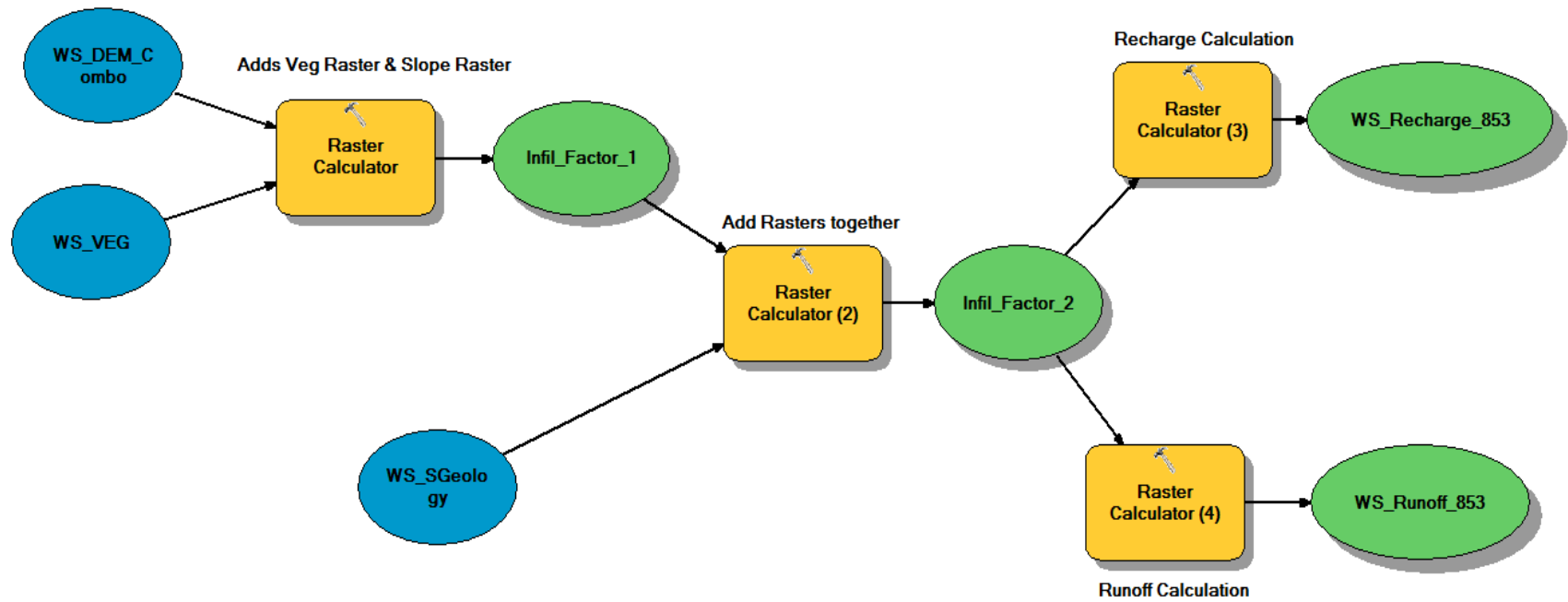
1. High groundwater recharge rates are calculated for the drumlin-rich areas north and east of Sandy and Marsh Lakes extending toward the Sackville River. Areas with high groundwater recharge rates are ecologically valuable since they produce cool, clean baseflow to streams, lakes and wetlands during low-flow periods. The protection of these areas is a priority identified in Regional Plan Policy E-17; and,
2. The Sandy Lake watershed receives significant contributions of groundwater (11%) and the precipitation data used for Sandy Lake may in fact underestimate actual precipitation for the area and thus underestimate contributions from groundwater. Both of these factors have implications for the hydraulic budget of the LCM because they are unaccounted inputs of water that may result in an over-prediction of phosphorus concentrations in the lakes.



Water Balance Model



Infiltration Model



Sandy Lake Area Watershed Study		
Sandy Lake Water Balance & Infiltration Model		
March 2014		Datum: ATS 1977 MTM 5 Nova Scotia Source: HRM & Hal. Water
		Figure D1
This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.		

# **Appendix E**

## **Lakeshore Capacity Model**

## Table of Contents

	page
<b>1. Introduction .....</b>	<b>1</b>
1.1 Objective and Modeling Scenarios .....	1
<b>2. Model Input Parameters.....</b>	<b>2</b>
2.1 Catchment and Lake Areas.....	3
2.2 Land Use .....	3
2.3 Phosphorus Export Coefficient Selection.....	5
2.3.1 Phosphorus Export from Undeveloped Lands .....	5
2.3.2 Phosphorus Export from Developed Lands .....	6
2.4 Phosphorus Inputs from Residential Septic Systems.....	7
2.5 Point Source Inputs .....	7
2.6 Lake Phosphorus Retention Coefficient.....	8
2.7 Hydraulic Inputs.....	8
<b>3. Model Assumptions and Uncertainty .....</b>	<b>10</b>
<b>4. Results.....</b>	<b>12</b>
4.1 Sandy Lake .....	12
4.1.1 Scenario 1: Existing Conditions .....	12
4.1.2 Scenario 2: Future Land Use – Full Build-Out.....	13
4.1.3 Scenario 3: Future Land Use with Removal of Point Sources.....	15
4.1.4 Scenario 4: Future Land Use with Advanced Wastewater Management.....	15
4.1.5 Summary of Sandy Lake Scenarios.....	15
4.2 Marsh Lake.....	15
4.2.1 Scenario 1: Existing Conditions .....	15
4.2.2 Scenarios 2, 3 and 4: Future Land Use.....	16
<b>5. Summary .....</b>	<b>16</b>

## List of Tables

Table E1: Morphology of Lakes in the Sandy Lake Watershed .....	3
Table E2: Sandy Lake Subwatershed Land Use Areas for Modeling Scenarios .....	4
Table E3: Marsh Lake Land Use Areas for Modeling Scenarios .....	4
Table E4: Export Coefficients by Land Use (g/ha/yr) .....	5
Table E5: Climate Data used in the Lakeshore Capacity Model.....	9
Table E6: Uncertainty in the LCM Model .....	11
Table E7: Comparison of Phosphorus Contributions in Scenarios .....	14

## List of Figures

Figure E1: Schematic Representation of the LCM Inputs and Outputs (From Brylinsky 2004).....	3
Figure E2: Phosphorus Contributions from Land Use Categories and Point Sources .....	12
Figure E3: Phosphorus Inputs from Land Use Types in the Four Scenarios.....	14

# 1. Introduction

A refined version of Ontario's Lakeshore Capacity Model (LCM) was used to assess potential changes in water quality from proposed development within the Sandy Lake watershed. The model, developed by Dillon and Rigler (1975) was calibrated on Canadian Shield lakes in Ontario (Dillon *et al.* 1986; Hutchinson *et al.* 1991) and has since been applied to lakes in Nova Scotia (e.g. Brylinsky 2004, Jacques Whitford 2004; Soliman 2008; AECOM 2013). The LCM is a mass balance, steady state model that quantifies the natural and human phosphorus inputs to a watershed and estimates the resulting phosphorus concentrations of the watershed's lakes (MOE 2010). The model is also used to predict how future land developments may impact the lake phosphorus concentrations.

Inputs to the model include:

1. Surface areas for each land use (e.g. forest, meadow, residential, etc.);
2. Phosphorus export coefficient for each land use;
3. Hydraulic inputs; and,
4. Point sources of phosphorus (e.g., septic systems, waste water treatment plant discharge and sanitary sewer overflows).

Using this information the model calculates:

- Hydraulic budget;
- Phosphorus loads from all land uses, point sources and septic systems; and,
- Predicted lake total phosphorus concentrations.

The model version used for the Sandy Lake watershed was based on the version developed by Brylinsky (2004) for Nova Scotia lakes.

## 1.1 Objective and Modeling Scenarios

The objective of the modeling was to evaluate the long-term impact of development in the Sandy Lake watershed on Sandy and Marsh Lake phosphorus concentrations. To complete this, the Sandy Lake watershed was delineated into two catchments or subwatersheds (Sandy Lake and Marsh Lake subwatersheds) and phosphorus concentrations were modeled for the lake in each subwatershed. Four land use scenarios were modeled and displayed in **Figures 12 to 15** of the main report. The modeling scenarios include existing conditions and three future development scenarios:

1. Modeling Scenario 1: Existing Conditions;
2. Modeling Scenario 2: Future Developments;
3. Modeling Scenario 3: Future Developments plus (a) Removal of Upland Waste Water Treatment Facility and (b) Sandy Lake Cottages converted to small lot residential supplied with waste water services; and
4. Modeling Scenario 4: Future Developments (Scenario 3) with Advanced Stormwater Management.

Scenario 1 represents the existing land use conditions in the Sandy Lake watershed (**Figure 12**). The surface areas occupied by the different land uses in each subwatershed were interpreted through analysis of aerial photographs, parcel fabric GIS layers obtained from HRM, and subdivision development plans. The approach used in this application of the LCM is to calibrate the Existing Conditions land use scenario to the measured phosphorus concentration of the lakes as defined in **Section 5** of the main report.



Scenario 2 land use is based on the Existing Conditions Scenario with modifications to represent possible future developments that have been identified in the watershed (**Figure 13**). The possible developments included in the Future Developments scenario(s) were defined in consultation with HRM and include:

- Possible development identified in a municipal servicing study completed by the engineering firm CBCL (CBCL 2009);
- Planned development of Kingswood North;
- Planned development of the Thistle Grove (formerly Peerless) subdivision;
- Planned developments of the Bedford West project in the Sandy Lake watershed; and
- Possible development in the Jack Lake Lands.

Scenario 2 assumes the Uplands WWTF will remain in operation with phosphorus discharges remaining the same as in the Existing Conditions. The scenario also assumes that all septic systems in the Existing Conditions will remain in place and discharge phosphorus the same as in the Existing Conditions.

Scenario 3 (**Figure 14**) is similar to Scenario 2 and includes that the conversion of all cottages along the western shore of Sandy Lake are developed and provided with water and wastewater services (septic systems removed). The scenario also includes the removal of the Uplands WWTF and that Uplands Park is provided with wastewater services.

Scenario 4 (**Figure 15**) is the same as Scenario 3, but also includes Advanced Stormwater Management for all the possible development areas.

Details of the modeling scenarios are provided in Section 4 – Results. The results from the future scenarios are compared to the existing conditions to evaluate how development may impact water quality.

## 2. Model Input Parameters

The Lake Capacity Model parameters that are used to estimate the average annual phosphorus concentrations of lake water include:

- Catchment and lake areas;
- Land use areas;
- Phosphorus export coefficients;
- Phosphorus point sources;
- Phosphorus retention coefficients; and
- Hydraulic inputs.

Each of these parameters are discussed in more detail in the following sections.

The LCM is a mass balance, steady state model that is essentially an accounting system that sums phosphorus contributions, phosphorus retention and the hydraulic inputs to estimate the average phosphorus concentrations in lake water on a yearly basis (Brylinksy 2004). The model calculates the phosphorus contribution from land use activities using land use areas and phosphorus export coefficients for each land use area. It also includes phosphorus inputs from point sources such as septic systems or wastewater treatment facilities (WWTF). Phosphorus retention (removal) is represented by the phosphorus retention coefficient. The total phosphorus load to the lake is calculated as the inputs from land use and point source minus the phosphorus retained in the lake.

The phosphorus load is combined with an estimate of the yearly hydraulic load (volume) to calculate an average annual phosphorus concentration for each subwatershed (Figure E1). The hydraulic inputs (inflow) include precipitation infiltration and groundwater contributions.

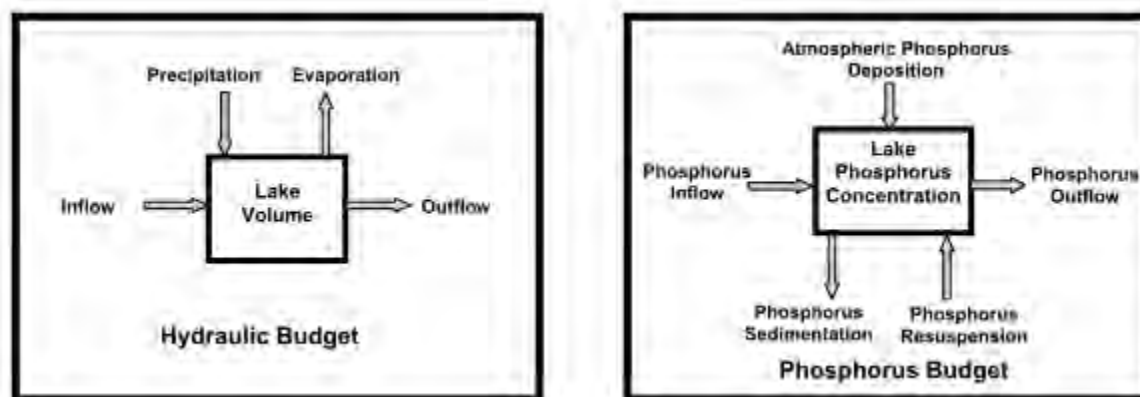


Figure E1: Schematic Representation of the LCM Inputs and Outputs (From Brylinsky 2004)

## 2.1 Catchment and Lake Areas

For each lake, the total subwatershed area and lake surface area was calculated in a Geographic Information System (GIS) environment using LiDAR derived Digital Elevation Model (DEM). The drainage area for the Sandy Lake subwatershed was calculated by subtracting lake surface area from the lake's total subwatershed area. The surface area of Marsh Lake was taken to be the open water not including wetlands. Results are provided in **Table E1**.

Table E1: Morphology of Lakes in the Sandy Lake Watershed

Lake	Subcatchment Surface Area (ha)	Surface Area (ha)	Maximum Depth (m)	Average Depth (m)	Volume <sup>1</sup> (m <sup>3</sup> )
Sandy Lake	1791.1	78.5	21*	12.9*	6.08 x 10 <sup>6</sup> *
Marsh Lake	631.3	11.3	N/A	N/A	N/A

Notes: \* from Conrad 2002.

Bathymetric and lake volume information is available for Sandy Lake only (Conrad 2002). Mean depth and volume were used in the LCM model for Sandy Lake to calculate flushing rate, turnover time, and response time.

## 2.2 Land Use

Phosphorus contributions from land use areas depend on the type of vegetative covering in undeveloped areas and the amount of impervious surfaces in developed areas. With these considerations in mind, the Sandy Lake watershed was grouped into categories with similar phosphorus export capacities. The surface areas occupied by the different land uses in each subwatershed were interpreted through analysis of aerial photographs, parcel fabric GIS layers obtained from HRM, and subdivision development plans. Eleven different land use categories were identified for Scenarios 1, 2 and 3. An additional land use category was used for Scenario 4 to represent future developments with Advanced Stormwater Management (ASM). For each subwatershed, the total area for each land use category was calculated using GIS.

The areas occupied by each land use category are presented in **Tables E2** and **E3** and displayed in **Figures 12 to 15** in the main body of the report.

**Table E2: Sandy Lake Subwatershed Land Use Areas for Modeling Scenarios**

Land Use Category	Interpretation	Scenario 1 (ha)	Scenario 2 (ha)	Scenario 3 (ha)	Scenario 4 (ha)
Forest	>70% forest cover	786.89	495.95	495.95	495.95
Deforested	From aerial photos	182.48	85.65	85.65	85.65
Wetland and wetland buffer	Wetlands database	52.26	113.63	113.63	113.63
Water	Ponds and lakes	81.43	81.43	81.43	81.43
Industrial	Disturbed ground, no parking lots, large buildings	107.73	105.41	105.41	105.41
Institutional	School	8.32	6.18	6.18	6.18
Commercial	Buildings and parking area	40.90	76.57	76.57	76.57
Roadway	From parcel fabric	71.32	87.34	87.34	87.34
Small Lot Residential	<0.5 ha	105.10	377.38	386.45	90.35
Small Lot Residential with ASM	<0.5 ha	n/a	n/a	n/a	296.09
Large Lot Residential	>0.5 ha	313.05	320.01	310.95	310.95
Park	As designated	41.58	41.58	41.58	41.58

**Table E3: Marsh Lake Land Use Areas for Modeling Scenarios**

Land Use Category	Interpretation	Scenario 1 (ha)	Scenario 2 (ha)	Scenario 3 (ha)	Scenario 4 (ha)
Forest	>70% Forest cover	386.15	353.74	353.74	353.74
Deforested	From aerial photos	137.08	129.76	129.76	129.76
Wetland	Wetlands database	34.18	34.18	34.18	34.18
Water	Ponds and Lakes	16.46	16.46	16.46	16.46
Industrial	Disturbed ground, no parking lots, large buildings	6.48	6.48	6.48	6.48
Institutional	School	0	0	0	0
Commercial	Buildings and parking area	2.49	2.49	2.49	2.49
Roadway	From parcel fabric	6.75	7.93	7.93	7.93
Small Lot Residential	<0.5 ha	7.97	18.22	18.22	7.96
Small Lot Residential with ASM	<0.5 ha	n/a	n/a	n/a	10.19
Large Lot Residential	>0.5 ha	26.56	53.88	53.88	53.88
Park	As designated	7.20	8.13	8.13	8.13

## 2.3 Phosphorus Export Coefficient Selection

In the LCM, each land use category is assigned a phosphorus export coefficient, which varies depending primarily upon the type of vegetative cover and the proportion of impermeable surfaces. The export coefficient is expressed as the mass of phosphorus exported from a given surface area over a specified time period (mass/area/time). A review of phosphorus export coefficients used in other studies, combined with site specific information within the Sandy Lake watershed were used to assign appropriate phosphorus export coefficients for this study.

Phosphorus export coefficients have been used extensively in Nova Scotia to evaluate lake phosphorus loading (Scott and Hart 2004; Brylinsky 2004; Watt 2009; AECOM 2013). The values used in these studies were evaluated and supplemented by information from other jurisdictions (HESL and MOE 2011) to provide the framework for the phosphorus export coefficients used for the Sandy Lake watershed. **Table E4** presents the export coefficients used for the modeling.

**Table E4: Export Coefficients by Land Use (g/ha/yr)**

Land Use Classification	Export Coefficient	Primary Source
Forest	88	Scott <i>et al.</i> (2000) <sup>1</sup>
Deforested	115	Scott <i>et al.</i> (2000) <sup>1</sup>
Wetland	115	Scott <i>et al.</i> (2000) <sup>1</sup>
Water	250	Watt 2009
Industrial	400	Waller and Hart (1986) <sup>1</sup>
Institutional	400	Waller and Hart (1986) <sup>1</sup>
Commercial	600	Waller and Hart (1986) <sup>1</sup>
Roadway	1000	Scott <i>et al.</i> 2004a
Small Lot Residential	600	HESL & MOE, 2011
Small Lot Residential with ASM	300	This Study
Large Lot Residential	200	HESL & MOE, 2011
Park	500	HESL & MOE, 2011

1- As referenced in Brylinsky 2004.

### 2.3.1 Phosphorus Export from Undeveloped Lands

The phosphorus export from forests, cleared land (deforested), and wetlands as well as phosphorus arriving as atmospheric deposition have been characterized in Nova Scotia (Scott *et al.* 2000). The phosphorus export coefficients for forested areas underlain by sedimentary rocks defined by Scott *et al.* (2000) (88 g/ha/year) is adopted for the forested areas in Sandy Lake. The Scott *et al.* (2000) value for cleared/wetland (115 g/ha/year) is adopted for deforested and wetland areas in Sandy Lake. The phosphorus flux for water covered areas is approximated from the concentration of phosphorus in atmospheric deposition. For ponds and rivers located in the subwatershed, the atmospheric export coefficient of 250 g/ha/yr was selected. This is the export coefficient value examined and justified for Paper Mill Lake in Watt (2009). An export coefficient of 500 g/ha/yr was used for the “parks” land use category. This export coefficient represents parks that may have areas of undisturbed forest, but also includes phosphorus contributions from landscaped and dog walking areas. Golf courses occupy a small area



of land within the Sandy Lake watershed and were included in the park designation. In general, the phosphorus export values from undeveloped areas are consistent with values used in previous studies in Nova Scotia.

### 2.3.2 Phosphorus Export from Developed Lands

In developed and urban environments, phosphorus is adsorbed to particulate matter and transported by stormwater runoff to ditches, streams and lakes. This nutrient input contributes significantly to lake phosphorus budgets. Selection of appropriate phosphorus export coefficients for developed lands in large part depends on the proportion of impervious surfaces in each land use category. Impervious surfaces such as asphalt roads and building roofs provide a direct pathway for particulates to be washed into watercourses, bypassing potential retention that can be achieved through filtration, sedimentation and infiltration.

A wide range of phosphorus export coefficients for urban development is available from a variety of geographies. Reckhow *et al.* (1980) provide a range from 19 to 623 g/ha/year and Waller and Hart (1986) estimate urban runoff in Ontario to be 1100 g/ha/year. Within Ontario's Lake Simcoe watershed, high intensity residential development including single and semi-detached homes are estimated to have a phosphorus export coefficient of 1320 g/ha/year compared to 130 g/ha/year for low intensity or rural development. Waller and Hart (1986) estimated phosphorus export coefficients for Halifax urban areas to be 1860 g/ha/year for residential, 2020 g/ha/year for commercial, and 420 g/ha/year for institutional.

In the Sandy Lake LCM, "roads" are the land use category that have the greatest proportion of impervious surfaces and are assigned the greatest phosphorus export coefficient (1000 g/ha/year). The value of 2020 g/ha/year commonly used in Nova Scotia is considered an overestimate for Sandy Lake watershed because the land parcels used to define the road are approximately 25 m wide and include (in addition to the road surface) ditches, deforested and forested areas adjacent to the paved roads. These features are expected to promote filtration and infiltration, lowering the amount of phosphorus reaching the watercourses. The lower value of 1000 g/ha/year accounts for this variability in the land type within the roads category.

The areas identified as "commercial" in the Sandy Lake watershed have paved parking areas and buildings that occupy a large proportion of the land parcel and less than half the area occupied by permeable surfaces such as grass and tree cover. A phosphorus export coefficient of 600 g/ha/yr is assigned to the commercial land use category.

"Industrial" land use areas were identified as properties with smaller proportions of impermeable surfaces compared to commercial land uses, and include areas with large gravel parking lots or disturbed, deforested areas.

"Institutional" land use is applied to schools and is similar to commercial land use but tends to have higher proportions of green areas. Both industrial and institutional land uses are assigned a phosphorus export coefficient of 400 g/ha/year.

Residential developments were divided into two groups based on the parcel lot size. Different export coefficients were assigned to "large lots" versus "small lots", given the observation that large lots tend to have proportionally more unpaved, permeable surfaces relative to small lots. That is, paved and impermeable surfaces (which facilitate phosphorus export) occupy proportionally more surface area of a small lot compared to a large lot, and so the phosphorus export coefficient is correspondingly higher for small lots. "Large lot residential" is defined as residential land parcels that are > 0.5 ha in surface area. This includes the large lots in the Kingswood North subdivision. A relatively low phosphorus export coefficient of 200 g/ha/year is used for large lot residential to account for the high proportion of pervious surfaces. "Small lot residential" is defined as < 0.5 ha and includes higher density developments such as the Peerless subdivision (also known as Thistle Grove) as well as the currently undeveloped

land slated for municipal services and residential development in the future. These developments have more impervious surface than the large lot residential and are assigned a correspondingly higher phosphorus export coefficient of 600 g/ha/year.

An additional land use was created for Scenario 4 to estimate the potential reduction of phosphorus using Advanced Stormwater Management. This land use is an adaptation of the “Small lot residential” in future developments and assumes that all new developments will require Advanced Stormwater Management (ASM) that will remove 50% of the phosphorus from stormwater runoff. Therefore the corresponding phosphorus export coefficient for “Small lot residential with ASM” is 300 g/ha/year.

## 2.4 Phosphorus Inputs from Residential Septic Systems

Discharges from private, residential septic systems are a potential source of phosphorus to groundwater and lakes; these discharges are accounted for in the LCM. The west side of Sandy Lake hosts approximately 20 residences with septic systems. There are also approximately 200 residences with septic systems within 300 m of watercourses that drain into Sandy Lake. The model requires the following information to calculate the phosphorus input from these nutrient sources:

1.  $N_d$  – the number of dwelling units within 300 m of the shoreline of the lake and any tributaries that enter the lake;
2.  $N_u$  – the average number of people occupying the dwellings;
3.  $N_{pc}$  – the average fraction of the year each dwelling is occupied;
4.  $S_i$  – the amount of phosphorus produced per capita; and
5.  $R_{sp}$  – the adsorption capacity of the soils.

The average number of persons per dwelling was estimated to be 2.6; with an average fraction of year each dwelling is occupied as 1 (i.e., they are occupied year-round). These values were also used for residences in the Birch Cove Lakes watershed (AECOM 2013) and are assumed to be representative of the Sandy Lake population. A phosphorus load of 660 g/person/yr was used as the amount of phosphorus produced per capita (Paterson *et al.* 2006).

The adsorption capacity is used to infer phosphorus attenuation in the soils. The adsorption capacity is dependent on the type of soils, the depth of the soils, topographic relief, age of the septic system and distance from the shoreline. A study in the Annapolis Valley, NS suggests 0.2 (20% of phosphorus is retained in soils) is a reasonable value to represent phosphorus retention for an individual household over more than 30 years (Sinclair 2014). This value is reasonable for the residences on the western shore of Sandy Lake because many of these homes and their septic systems are likely close to 30 years old. The residences within 300 m of water courses are expected to contribute less phosphorus to Sandy Lake because they are typically newer homes and the discharge has a greater distance to travel before reaching Sandy Lake. The 200 residences within 300 of water courses are assigned a value of 0.7 for the adsorption of capacity of soils.

## 2.5 Point Source Inputs

In this study, point source inputs of phosphorus to lakes consist of discharges from sewage treatment plants. Two waste water treatment systems are located in the Sandy Lake watershed and are represented in the LCM. The Uplands Waste Water Treatment Facility (WWTF) services approximately 170 people. The facility is owned and operated by Halifax Water, who monitors discharge flow rate and phosphorus concentrations, among other parameters. The average flow rate (40 m<sup>3</sup>/day) and the mean phosphorus concentration (2.7 mg/L) in 2013 are used to calculate a yearly phosphorus flux of 39,420 g/year. The calculated total phosphorus discharge corresponds to a

per capita yearly discharge of 231 g/person/year which is comparable to the phosphorus discharges from primary (387 g/person/year) and secondary (212 g/person/year) treatment systems (Chambers 2001).

The Timber Trails mobile home park used a communal septic system to service approximately 230 people until 2014. Much of the phosphorus from this system is expected to be retained by soils long before it reaches Sandy Lake because the septic system is approximately 500 m from the nearest watercourse and several kilometers from Sandy Lake. However, septic system failures in the past may have contributed to the phosphorus load to Sandy Lake. A per capita flux of 660 g/year and a phosphorus retention factor of 0.8 results in an estimated phosphorus flux of 30,360 g/year from this system for the existing conditions scenario. A new primary waste water treatment system for Timber Trails has been designed to replace the septic system and is anticipated to be on line in 2014. The waste water treatment system is designed for a 500 person capacity and is anticipated to remove more phosphorus from the discharge than the septic system. Phosphorus discharge from the new waste water treatment system is 387 g/person/year for 500 people with a retention factor of 0.8 for a total of 38,700 g/year. In summary, a discharge of 30,360 g/year is estimated for the existing conditions scenario and 38,700 g/year is estimated for all future scenarios.

## 2.6 Lake Phosphorus Retention Coefficient

Phosphorus is exported from the different land types by overland flow and stormwater runoff to streams and into lakes. A portion of the phosphorus entering a lake is “sedimented out” and retained within the lake sediments. This portion is represented by the lake phosphorus retention factor. The lake phosphorus retention factor is derived from the flushing rate of the lake in combination with the particle settling rate. The flushing rate is approximated from the yearly hydraulic output and the lake volume. In situations where the lake volume cannot be accurately estimated, the flushing rate is replaced by the areal loading rate which uses the lake area instead of volume. The areal loading rate is combined with a phosphorus retention coefficient or ‘settling rate’. In their study Dillon *et al.* (1992) present average settling rates for oxygenated lakes as 12.4 m/year and 7.2 m/year for lakes where the hypolimnion become anoxic. The value for lakes with anoxic lake bottom is lower because the anoxic conditions release phosphorus adsorbed to sediments back into the water column. The value 12.4 m/year was selected for Sandy Lake and Marsh Lake because both lakes are expected to be fully oxygenated for the majority of the year.

The lake phosphorus retention factor can be varied during the model validation/calibration process to ensure the measured and predicted phosphorus concentrations are comparable. If measured values are lower than predicted values, the retention factor can be increased to represent phosphorus that was removed from runoff by stormwater management methods or through higher sedimentation rates inferred from lake morphology.

## 2.7 Hydraulic Inputs

The *phosphorus inputs* to the watersheds define the mass of phosphorus introduced to the system while the *hydraulic inputs* define the volume of water carrying the phosphorus load. The concentration of phosphorus predicted by the LCM is sensitive to changes in the hydraulic inputs. Therefore, an accurate hydraulic budget is required to increase confidence in the LCM phosphorus predictions.

Factors in the hydraulic budget include precipitation, evapotranspiration, lake evaporation, surface runoff for vegetated and urban areas, and groundwater inputs.

The precipitation and evaporation rates are used to estimate the hydraulic flux for each subwatershed. The Annual Unit Precipitation onto the lake was estimated at 1.396 m/yr based on Environment Canada's “climate normals” (**Table E5**) from the Stanfield Airport (Station 8202250) for the most recent meteorological record (1981-2010).

Lake Evaporation of 515 mm/year was estimated from the Environment Canada Station 8205990, located in Truro (**Table E5**). Lake evaporation is used in the LCM to account for water removed from the watershed from evaporation off the lake surfaces. Evapotranspiration is estimated from climate normal monthly average temperatures and precipitation, a sunlight correction factor for latitude and monthly soil moisture changes (Thornthwaite and Mather 1957).

**Table E5: Climate Data used in the Lakeshore Capacity Model**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
<b>Daily Average Temperature (°C)</b> <sup>1</sup>	-5.9	-5.2	-1.3	4.4	10.0	15.1	18.8	18.7	14.6	8.7	3.5	-2.4	6.6
<b>Precipitation (mm)</b> <sup>1</sup>	134	106	121	115	112	96	95	93	102	125	154	143	1396
<b>Lake Evaporation (mm)</b> <sup>2</sup>	0	0	0	0	89	102	116	97	70	41	0	0	515
<b>Evapotranspiration (mm)</b> <sup>3</sup>	0	0	0	25	65	96	114	108	78	42	14	0	543

<sup>1</sup> Environment Canada Climate Normals (1981-2010) for Stanfield Airport (8202250). <sup>2</sup> Truro Station (8205990). <sup>3</sup> Calculated using Thornthwaite and Mather 1957.

The precipitation falling in the study area is partitioned to runoff for two generalized surface coverage types: urban coverage and vegetated coverage. Precipitation falling on urban areas loses a portion of the water to evaporation. The runoff in urban areas (1.26 m/year) is estimated to be 80% of the total precipitation. The urban runoff value is applied to commercial, industrial, institutional, residential and road land uses. Precipitation falling on vegetated areas loses water through evapotranspiration. Runoff from vegetated areas (0.853 m/year) is estimated as total precipitation minus evapotranspiration. The vegetated surface runoff value is applied to forest, deforested, wetlands and park land use areas. The hydraulic input from precipitation falling directly on lakes and watercourses (0.881 m/yr) is estimated from total precipitation minus lake evaporation.

It is notable that the LCM was developed for lakes located on the Canadian Shield in Ontario, where soil is thin and groundwater contribution to lakes and streams is negligible. The Sandy Lake watershed has areas with thick sediments and so is expected to have significant groundwater contributions to the hydraulic budget. The baseflow or groundwater contribution to Sandy Lake is estimated to be 11% of the hydraulic load of the watershed (Appendix D). In the LCM this baseflow contribution is included as an input to the hydraulic budget of subwatersheds.

The hydraulic budget of the Sandy Lake watershed estimated using the hydraulic inputs of the LCM is  $25.7 \times 10^6$  m<sup>3</sup>/yr. The LCM hydraulic budget is similar to the estimated annual flow from the Sandy Lake watershed. The Sandy Lake watershed (24.2 km<sup>2</sup>) is a subwatershed of the Sackville River watershed (146 km<sup>2</sup>). The gauged annual average flow from the Sackville River is  $152.7 \times 10^6$  m<sup>3</sup>/yr and by association the annual average flow from the Sandy Lake watershed is expected to be  $25.3 \times 10^6$  m<sup>3</sup>/yr. The hydraulic budget used in the LCM is comparable to the gauged flow of Sandy Lake, suggesting the LCM hydraulic budget is accurate.



### 3. Model Assumptions and Uncertainty

As described in Brylinsky (2004), phosphorus runoff coefficient models such as the LCM rely on several assumptions. Understanding these assumptions allows for more informed interpretation of the results and adjustment of model variables so the model is optimized for the conditions within the target watershed.

A key assumption used in this application of LCM is that the existing measured lake water quality conditions are the result of the land use conditions represented Scenario 1 – Existing Conditions. Using this assumption the model parameters were adjusted to calibrate the model so the predicted water quality conditions were in close agreement with the measured water quality conditions. While there is uncertainty and variability in the lake water quality conditions as described in Section 5, this data set is considered the most reliable source of quantitative data available. Therefore the modelled phosphorus export from land use and point sources inherently have a similar level of uncertainty as the existing measured lake water quality.

A major assumption in the model is that the amount of phosphorus transported overland by surface runoff to the lake is independent of the transport distance. This means that a land use far from the lake will contribute the same phosphorus per unit of area to the lake as the same land use much closer to the lake. This assumption simplifies the model's use, but is likely not an accurate representation of phosphorus transport. It is logical to presume that more phosphorus will be removed from stormwater the greater the overland distance travelled. This is because there is a higher probability that phosphorus will be immobilized or consumed by plants over increasing distances. A related assumption is that no phosphorus is assimilated or retained in watercourses en route to the lake. However, retention of phosphorus can result from sedimentation, sorption to stream sediments and uptake by organisms (Wagner *et al.* 1996). Behredt and Opitz (2000) indicated as much as 20 – 40% of phosphorus load is retained in some streams before reaching the lake. The retention of phosphorus from water as it travels through the watershed can be approximated in the LCM by varying the phosphorus export coefficient as needed.

The model also assumes that all residences on septic systems within 300 m of the lake shore or a tributary contribute equally to the phosphorus load within the lake. This assumption has not been validated and so different retention factors have been proposed depending on septic system distance from tributaries (Hutchinson 2002). Phosphorus soil retention factors used to approximate phosphorus fluxes from septic systems can be adjusted for groupings of septic systems to account for differences in distance from water bodies. However, this approach was not adopted for this study.

As noted above, the model was developed for lakes in the Canadian Shield region of Ontario where the soils are thin and there is limited groundwater contribution to lakes. The model assumes groundwater does not contribute to the hydraulic load or flow through the watershed. Adding groundwater to the hydraulic load of a watershed would have the effect of diluting the phosphorus load and decreasing the lake phosphorus concentration. In Sandy Lake, the groundwater contribution is 11% of the total hydraulic load (Appendix D). Considering the hydraulic budget of the LCM in this study is within 2% of the gauged flow from the watershed, the addition of groundwater to the hydraulic budget is considered valid for this application of the LCM.

In summary, the assumptions used in the LCM do not account for phosphorus retention within the watershed and do not account for a dilution factor from groundwater. This means that observed phosphorus concentrations will likely differ from those predicted by the model. To help calibrate and match modeled concentrations to observed concentrations, the lake phosphorus retention factor (a variable that approximates the amount of phosphorus removed through sedimentation within a lake) can be used to approximate both phosphorus retention during transport and dilution by groundwater.

The model inputs carry varying degrees of uncertainty. A quantification of uncertainty for the model is not completed; however, the generalized uncertainty for the model input parameters are described (**Table E6**). The key model inputs are the phosphorus export coefficients, the point sources of phosphorus (septic and WWTF), the hydraulic budget and the measured concentration of phosphorus in lake water.

The phosphorus export coefficients used in this study are adapted from previous studies which calculated values from measured fluxes of phosphorus from the various land use types. The measurement of phosphorus fluxes provides good control of phosphorus export coefficient for those land areas measured. Adapting the values to other land use types that are assumed to be similar introduces uncertainty. Therefore the level of uncertainty related to the phosphorus export coefficients in this study is moderate. The phosphorus export from the two WWTF and the septic systems is estimated based on generalized mean values (Uplands WWTF) and assumed soil retention factors for the septic systems. The generalized mean value is based on measure concentrations and flow, so the uncertainty should be low over when the time period of a year is considered. The phosphorus flux from septic systems is based on generalizations of usage and on soil retention. The generalized usage has not been verified for this area so may have low to moderate uncertainty. The phosphorus soil retention used to represent the septic systems assumes a high level of retention for new systems (80%) and low retention (20%) for older systems. The phosphorus retention by soils in the long term may not be as high as assumed because the soils will eventually reach a point of saturation where there is little retention. Therefore the uncertainty related to septic system fluxes is moderate.

The hydraulic budget of the model is based on precipitation, evapotranspiration, infiltration and groundwater. The estimates of each of these carries low to moderate uncertainty. However, the total hydraulic budget is close to the expected hydraulic budget based on the gauged flow of the Sackville River. Considering the mean annual flow of the Sackville River has low uncertainty, the overall hydraulic budget of the Sandy Lake watershed also has low uncertainty. While there may be higher levels of uncertainty regarding the breakdown of the hydraulic budget (precipitation, etc) the overall uncertainty is low.

The modeled phosphorus concentration of the existing conditions is calibrated to the measured mean value of the lakes. The measured mean value has uncertainty based on the variability of the concentrations and the upward trend of the phosphorus concentrations observed (**Figure 8**). The phosphorus concentrations in Sandy Lake have a wide range of values. Taking the mean from the range introduces uncertainty, but considering the data set has 17 samples to draw the mean from, the uncertainty is low to moderate. Taking the mean value from a data set with a trend of increasing concentrations over a period of 8 years indicates the mean value selected to calibrate the model is likely an under estimation of the mean concentration of current conditions. This introduces a moderate level of uncertainty.

**Table E6: Uncertainty in the LCM Model**

Model input	Relative level of uncertainty
Phosphorus export coefficient	Moderate
Phosphorus flux from Uplands WWTF	Low
Phosphorus flux from septic systems	Moderate
Hydraulic budget	Low
Median lake phosphorus concentration	Moderate
Overall uncertainty	Moderate

The overall uncertainty in the values produced by the LCM for the Sandy Lake watershed is moderate. The uncertainty is described prior to the results section to indicate that the absolute values produced by the model should be viewed with an understanding of the moderate confidence in the values. While the absolute values produced by the study are uncertain, the model's primary function in this case it to describe the general impacts of development

in the watershed and to display how various mitigation measures will affect the impact and the degree of mitigation the measures will affect the impacts from development.

## 4. Results

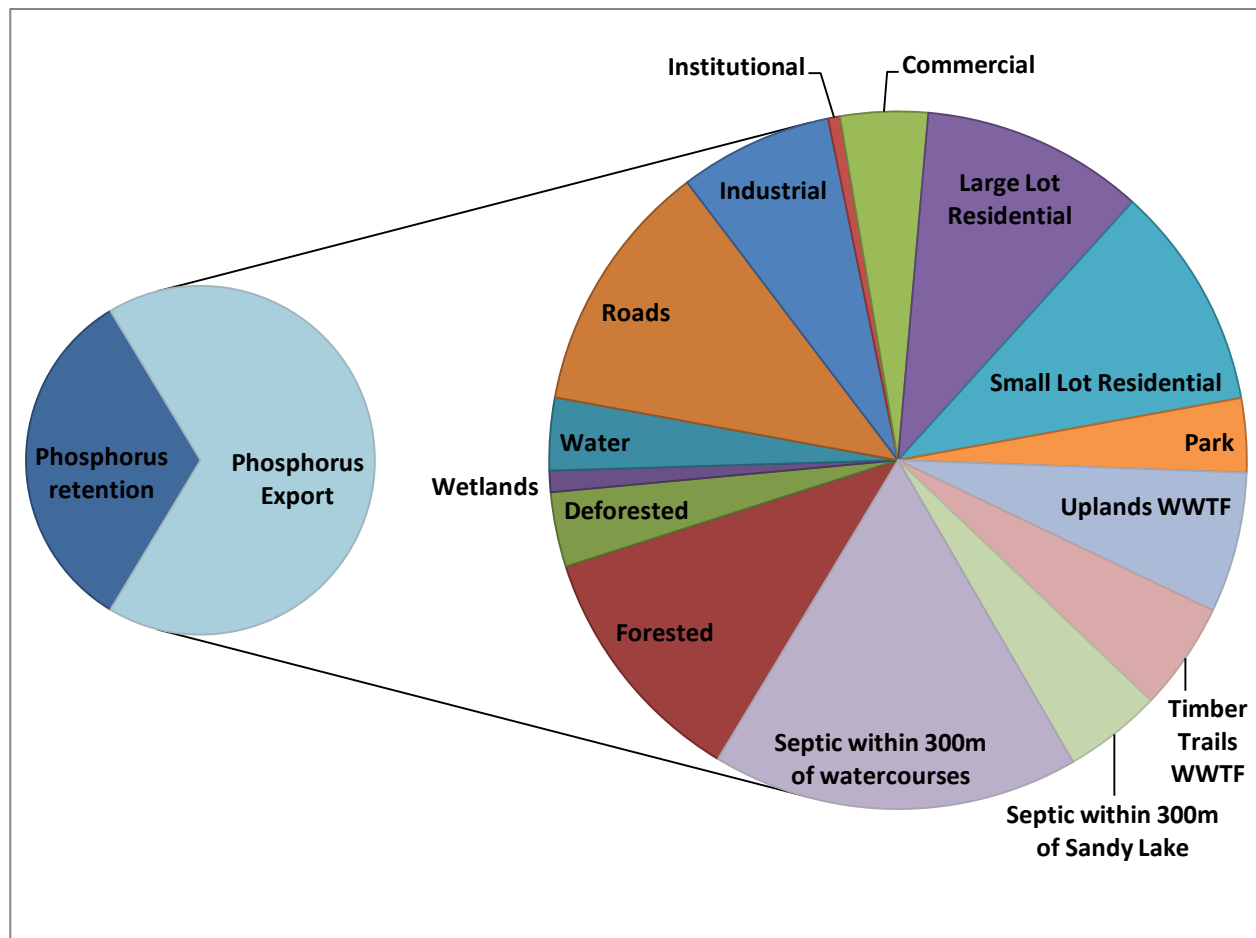
### 4.1 Sandy Lake

#### 4.1.1 Scenario 1: Existing Conditions

Lake modeling was completed using the existing land use (**Table E2**) and the phosphorus export coefficients described in Section 2.3 and **Table E4**. The proportional phosphorus contributions from each source are displayed in **Figure E2**. The smaller pie chart represents the proportions of phosphorus outflow from Sandy Lake and the phosphorus retained by sedimentation.

The undeveloped portions of the watershed (forest, deforested, wetlands, park and water) contribute 23% of the phosphorus input to Sandy Lake. Developed land use (institutional, industrial, commercial, residential, parks and roads) contribute 44% of the phosphorus into Sandy Lake and wastewater systems (Uplands WWTF, Timber Trails WWTF and septic systems) contribute 33% of the phosphorus budget.

The phosphorus retention coefficient estimated from the areal load and settling rate (12.4 m/year) for oxygenated hypolimnion predict one third (33%) of the phosphorus entering the lake will be sequestered in the lake sediments.



**Figure E2: Phosphorus Contributions from Land Use Categories and Point Sources**

The predicted phosphorus concentration in Sandy Lake **under current conditions** is 20 µg/L. This predicted value is significantly greater than the median measured phosphorus concentration of 12 µg/L. Brylinsky (2004) and MOE (2010) indicate that a model is not valid if the modeled phosphorus concentrations differ by more than 20% of the measured concentrations, as is the case with the Sandy Lake results.

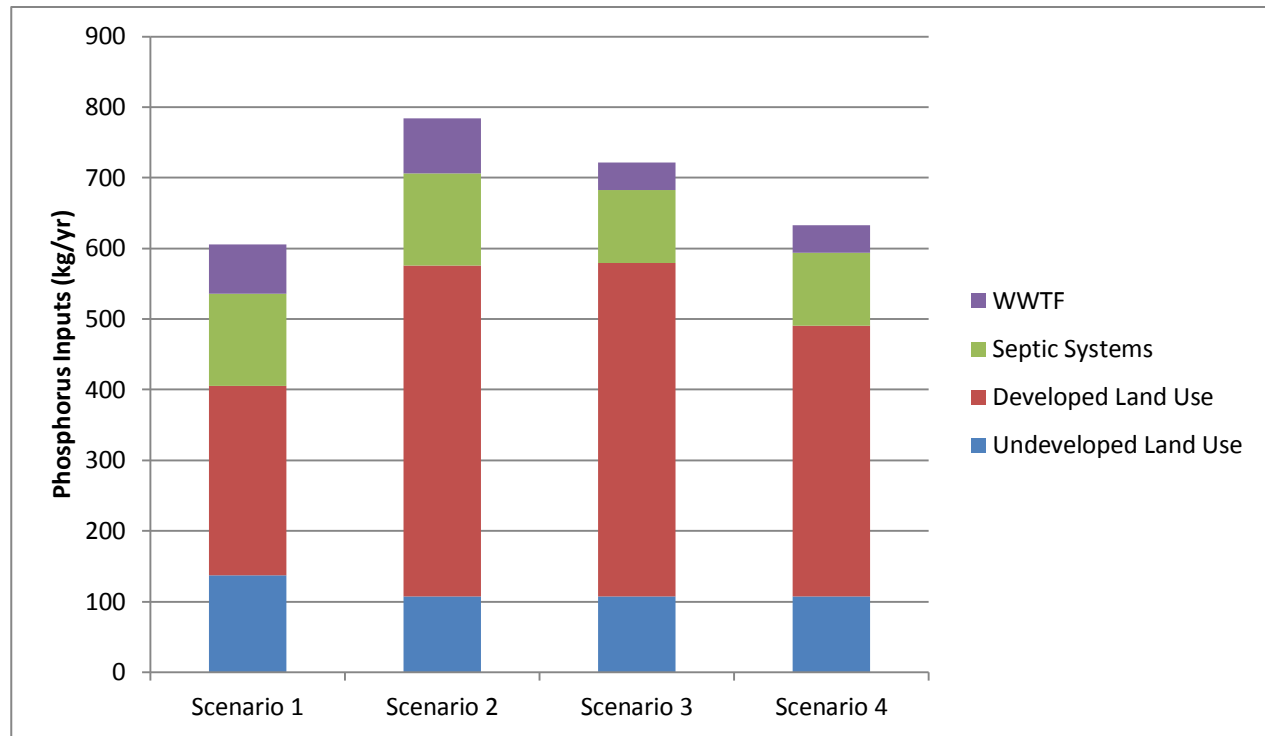
As discussed in Section 3, the model assumptions may over-predict phosphorus concentrations by not factoring in phosphorus retention as water travels within the watershed before it reaches the lakes. Predicted phosphorus inputs to the lakes can be reduced by adjusting the lake phosphorus retention coefficient, which in turn reduces the predicted lake phosphorus concentration.

In this study, the phosphorus retention coefficient was adjusted from 0.33 to 0.6 in the LCM to reduce the predicted phosphorus concentration to match the measured phosphorus. The value of 0.6 is within the range of values used in the Birch Cove Lakes LCM (AECOM 2013) and comparable to the values used for adjustment in the Paper Mill Lake watershed (Watt 2009). The adjusted LCM is the model version that in turn is used to predict Marsh Lake phosphorus concentrations and future land use scenarios. The phosphorus retention factor (0.6) used to validate the existing land use model was also used for Scenarios 2 and 3.

#### 4.1.2 Scenario 2: Future Land Use – Full Build-Out

The land use areas for Scenario 2 (Future Land Use) are summarized in **Table E2** and displayed on **Figure 11**. As noted, this scenario models full development of the area identified in CBCL 2009, Kingswood North, Peerless subdivision, Jack Lake Lands, as well as the replacement of the Timber Trails septic system with a wastewater treatment system. **The predicted Sandy Lake phosphorus concentration in Scenario 2 is 15.8 µg/L, which represents an increase of 3.8 µg/L or 32% over current concentrations (12 µg/L) due to future development.** This value (15.8 µg/L) is below the recommended water quality objective of 18 µg/L. However, it is greater than the early warning value (15 µg/L)

The change in phosphorus concentrations in Scenario 2 comes primarily from the development of forested and deforested land to small lot residential (**Figure E3**). The small lot residential land use category contains more paved and impermeable surfaces resulting in greater phosphorus export than undeveloped land. In the existing land use Scenario 1, forested, roads, large lot residential, small lot residential and septic systems within 300 m of watercourses are the dominant contributors to the phosphorus budget with each contribute more than 10% of the total phosphorus. In Scenario 2 the contribution from small lot residential increases by a factor of 3 and is the dominant source of phosphorus at 25% of the total load in Scenario 2.



**Figure E3: Phosphorus Inputs from Land Use Types in the Four Scenarios**

**Table E7: Comparison of Phosphorus Contributions in Scenarios**

	Scenario 1: Existing Land Use	Scenario 2: Future Land Use 1	Scenario 3: Future Land Use 2	Scenario 4: Future Land Use 3
Phosphorus Source	% of TP	% of TP	% of TP	% of TP
Forested	11.4	5.8	6.3	6.9
Deforested	3.5	1.2	1.3	1.5
Wetlands	1.0	0.7	0.8	2.0
Water	3.4	2.5	2.8	3.2
Roads	11.8	10.9	11.9	13.8
Industrial	7.1	5.3	5.7	6.6
Institutional	0.6	0.3	0.3	0.3
Commercial	4.1	6.1	6.6	7.2
Large Lot Residential	10.3	8.1	8.4	9.8
Small Lot Residential with ASM	n/a	n/a	n/a	14.0
Small Lot Residential	10.4	30.4	33.9	8.5
Park	3.4	2.6	2.8	3.2
Uplands WWTF	6.5	4.9	0.0	0.0
Timber Trails WWTF	5.0	4.8	5.3	6.1
Septic within 300m of Sandy Lake	4.5	3.4	0.0	0
Septic within 300m of watercourses	17.0	12.9	14.0	16.2



#### 4.1.3 Scenario 3: Future Land Use with Removal of Point Sources

Scenario 3 also includes conversion of forested and deforested land to small lot residential (like Scenario 2) but Scenario 3 includes three additional modifications to Scenario 2:

- Cottages along Sandy Lake are converted from large lot residential to serviced small lot residential;
- Septic systems at the Sandy Lake cottages are removed as phosphorus inputs; and
- Uplands WWTF is removed as a phosphorus input.

The changes to land use and phosphorus inputs in Scenario 3 predict Sandy Lake phosphorus concentration to be **14.5 µg/L, which is 2.5 µg/L greater than existing conditions and 1.3 µg/L less than Scenario 2**. The conversion of the large lot residential to small lot residential land use results in an increase in phosphorus of 4.68 kg/year (<1% of total phosphorus). The removal of the septic systems results in a decrease of 27.46 kg/year (4% of total phosphorus) and the removal of the Uplands WWTF results in a decrease of 39.42 kg/year (5% of total phosphorus).

#### 4.1.4 Scenario 4: Future Land Use with Advanced Wastewater Management

Scenario 4 builds on the phosphorus reductions used in Scenario 3 and includes further phosphorus reductions from the implementation of Advanced Stormwater Management (ASM) in all new development areas. ASM in this application assumes stormwater management methods will be effective in reducing 50% of the phosphorus load over a year period. This is represented in the model by a 50% reduction in the phosphorus export coefficient of the small lot residential land use.

The application of ASM in Scenario results in a predicted phosphorus concentration of **12.8 µg/L, which is 0.8 µg/L greater than existing conditions and 1.7 µg/L less than Scenario 3**.

#### 4.1.5 Summary of Sandy Lake Scenarios

Existing water quality conditions are in the lower end of the mesotrophic range and display a general increase in phosphorus concentrations (Section 5). Development in the Sandy Lake watershed as represented by the modeling scenarios predict further increase in phosphorus concentrations. The LCM Scenario 2 full build out is predicted to increase the phosphorus concentrations to the middle of the mesotrophic range. The change in the land use from undeveloped to developed accounts for the increase in phosphorus load. Scenario 3 includes full development in the watershed but considers a reduction of phosphorus inputs by removing the Uplands WWTF and removing the septic systems within 300 m of Sandy Lake. Further achievable reductions in phosphorus inputs are represented in Scenario 4 by implementation of Advanced Stormwater Management in all new development areas. The phosphorus load predicted by Scenario 4 is slightly greater than Existing Conditions, but the make-up of the phosphorus contributions is different. In Scenario 4 there is greater input from developed land use than Existing Conditions, but there is a reduction in the phosphorus inputs from the septic systems and WWTF.

### 4.2 Marsh Lake

#### 4.2.1 Scenario 1: Existing Conditions

The phosphorus concentration of Marsh Lake under the existing land use conditions was calculated with the land use areas in **Table E3** and the phosphorus export coefficients in **Table E4**. The predicted phosphorus concentration

is 12 µg/L which is < 20% greater than the observed value for Marsh Lake (11 µg/L) indicating the phosphorus retention coefficient (0.05) does not need to be adjusted.

#### 4.2.2 Scenarios 2, 3 and 4: Future Land Use

The predicted phosphorus concentration Marsh Lake in Scenario 2 is 14.9 µg/L which is a 24% increase from existing conditions. The predicted phosphorus concentration Marsh Lake in Scenario 3 is 14 µg/L which is a 17% increase from existing conditions. Scenario 4 predicted phosphorus concentration is 12.6 µg/L representing a 5% increase in phosphorus compared to existing conditions.

The land use changes in Scenarios 2 and 3 do not directly affect much of the land use in the Marsh Lake subwatershed (**Table E3**) but does include an increase in land use as small lot residential and large lot residential in the northern portion of the subwatershed. Marsh Lake receives water flowing from Sandy Lake resulting in changes to the Sandy Lake subwatershed also impacting the water quality in Marsh Lake.

## 5. Summary

The LCM in this study is used to predict how future developments in the Sandy Lake watershed will affect lake water quality in the future. The LCM is a simple model with several assumptions that contribute to uncertainty in the precision of the modeled values. This application of the LCM has attempted to reduce the uncertainty in the model by adjusting parameters in the model to reflect the local conditions of the watershed. However, given the inherent uncertainty in the model, the values should be viewed in the context of a narrative describing how activities in the watershed will affect the lake water quality.

The results of the model predict that development in the watershed without phosphorus reduction offsets will increase the phosphorus concentration in the lakes and push the lake water quality closer to the upper mesotrophic range. Reductions in phosphorus load to the lakes can be achieved through two general approaches; reduce the wastewater effluent to the watershed and utilize stormwater management. While development in the Sandy Lake watershed would increase the phosphorus load from impermeable surfaces, the development would also provide an opportunity to reduce the phosphorus load from septic systems near the lake and WWTF effluent by directing wastewater away from watercourse and into waste water services. The meaning of the term Advance Stormwater Management does not reflect any specific methods of stormwater management, but represents any methods that could reduce phosphorus discharge to lakes by 50%. Adoption of ASM systems would help offset the phosphorus load produced by changes in land use from undeveloped to developed.

The application of the LCM for the Sandy Lake watershed illustrates how phosphorus concentrations would be affected by development. The results suggest that changes in lake phosphorus concentrations from development can be mitigated by reducing the phosphorus load from wastewater effluent and Advanced Stormwater Management.

AECOM Canada Ltd  
1701 Hollis Street (SH400)  
(PO Box 576 CRO)  
Halifax, Nova Scotia, B3J 3M8  
[www.aecom.com](http://www.aecom.com)