Halifax Regional Municipality

Birch Cove Lakes Watershed Study – Preliminary Report

Halifax Regional Municipality

Birch Cove Lakes Watershed Study – Preliminary Report

Prepared by:

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Project Number:

60221657

Date:

June 2012

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June 13, 2012

Mr. Paul Morgan
HRM Steering Committee
P.O. Box 1749
Halifax, NS B3J 3A5

Dear Mr. Morgan:

Project No: 6021657
Regarding: Birch Cove Lakes Watershed Study – Preliminary Report

AECOM is pleased to submit the attached Preliminary Report for the Birch Cove Lakes Watershed Study. As required by HRM's Terms of Reference, the report recommends preliminary water quality objectives for key lakes in the watershed, and will be the subject of a public presentation on June 20th, 2012.

Please do not hesitate to telephone the undersigned should you have any questions or require additional details.

Sincerely,
AECOM Canada Ltd.

Russell Dmytriw, P. Geo.
Senior Project Manager, Environment
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Distribution List

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	DJG	June 10. 2012	Address comments received from HRM

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Executive Summary

The 2006 Halifax Regional Municipal Planning Strategy requires that watershed studies are undertaken before a Community Vision exercise and in advance of community design work undertaken through the secondary planning process. In response to requests by property owners of the “Highway 102 West Corridor Lands” to begin planning for new serviced communities, Regional Council has directed that a watershed study be completed for the Birch Cove Lakes watershed.

AECOM was contracted by HRM in August 2011 to complete the Birch Cove Lakes Watershed Study in two phases:

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

This preliminary report presents the water quality objectives for comment by the public and HRM so that questions and clarifications can be addressed in the Final Report. The Final Report will identify areas that are suitable and not suitable for development, determine the amount of development that can be accommodated while maintaining water quality objectives, recommend measures to protect and manage quantity and quality of surface and groundwater and recommend regulatory controls and management strategies to achieve the desired water quality objectives.

The following tasks were completed to arrive at the water quality objectives presented below:

- Existing water quality data were reviewed and a supplementary sampling program was undertaken to establish a baseline of the water quality in key water courses;

- Other jurisdictional approaches to setting water quality objectives for lakes were reviewed and an approach was developed to recommend water quality objectives for the Birch Cove Lakes watershed.

- Water quality objectives were set for each lake for total phosphorus and for the watershed as a whole for nitrate, un-ionized ammonia, total suspended solids, chloride and the bacteria *Escherichia coli*, commonly called *E. coli*;

- A limited flow monitoring program was initiated to help calibrate the nutrient and stormwater loading models used to evaluate water quality objectives; and

- Using HRM’s LiDAR data, spatial modeling was completed to delineate watershed and sub-watershed boundaries and to identify vernal ponds, wetlands and intermittent streams.

The Birch Cove Lakes watershed is situated on the southern edge of the Nova Scotia Southern Upland physiographic region and has a surface area of approximately 34.6 km^2. Surface water flow within the watershed is generally south to north in the larger lakes, although the smaller lakes in the upper watershed actually flow to the southeast. Existing dams are located at Quarrie Lake outlet, Kearney Lake outlet and Paper Mill Lake outlet.

Approximately 68% of the watershed is undeveloped. In total, approximately 10% consists of waterbodies (lakes, ponds, streams), 3% is wetland, 53% is soil-covered forested uplands, 4% is industrial and commercial, 12% is residential, 8% is roads and 3% is exposed bedrock.

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 re-suspension of lake bottom sediments. 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 and is a critical measure of lake water quality. The trophic status can be determined by measuring nutrient concentrations (phosphorus and nitrogen), algal density and, in some lakes, water clarity.

Lakes with few nutrients and low biological productivity are referred to as “oligotrophic”. Lakes with higher nutrient concentrations and high productivity are referred to as “eutrophic”. Eutrophic lakes are characterised by abundant plant life, including algae, and consequent low water clarity. 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 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 and assigning lakes to a category based on the values measured.

Existing Water Quality

In order to establish water quality objectives and prevent any further deterioration in water quality, water quality data collected in the past six years was used to assess current conditions, prior to any further development in the watershed. Historical data (collected prior to 2006) was used for comparison purposes, when appropriate. The year 2006 was selected as starting year since this is the first year of the on-going, comprehensive data set collected by or on behalf of HRM. In addition, AECOM is undertaking additional limited water quality sampling at five locations on a quarterly basis over the course of this project.

Current water quality conditions are summarized as follows:

Kearney Lake

Surface phosphorus concentrations ranged from <2 μg/L to 13 μg/L with a median concentration of 8 μg/L. Concentrations are generally in the mesotrophic range, with some samples in the oligotrophic range and one sample in the eutrophic range. The concentrations of nitrogen compounds were low. Metal concentrations were low, mostly below analytical detection limits.

Paper Mill Lake

At all three sampling locations in Paper Mill Lake, median total suspended solid, nitrate, nitrite, ammonia, and orthophosphate concentrations were low. The inflow from Kearney Lake is of high quality. At the outflow representing the whole lake concentrations, the total phosphorus concentrations ranged from <2 μg/L to 18 μg/L with no seasonal variations in concentrations. Concentrations fluctuate in the mesotrophic range, with selected values in the oligotrophic range. The TP concentration at the outflow has been relatively stable. The median total phosphorus concentration is 7 μg/L, which is in the mesotrophic range.

Washmill Lake

Total phosphorus ranged from <2 μg/L to 12 μg/L with a median concentration of 8 μg/L. Concentrations are generally in the mesotrophic range. Orthophosphate concentrations were below the detection limit and the concentrations of nitrogen compounds were low.

Black Duck Brook

The total phosphorus concentrations ranged from 8 to 40 μg/L with a median concentration of 8 μg/L. Again, concentrations are generally in the mesotrophic range, bordering on oligotrophic. Nitrate and nitrite, and ammonia concentrations were low.

Quarrie Lake, Big Horseshoe Lake and McQuade Lake

Quarrie, Big Horseshoe, and McQuade Lake have been sampled by AECOM on two occasions and two more sampling events are scheduled. Preliminary data analysis indicates that Big Horseshoe Lake has higher total phosphorus and total kjeldahl nitrogen than the other lakes. Dissolved chloride is low in the lakes, indicating their relatively undeveloped watersheds. In McQuade Lake, which is surrounded by development, total phosphorus concentrations were in the mesotrophic range. The total phosphorus concentrations in Quarrie and Big Horseshoe Lakes were in the oligotrophic range.

Headwater Lakes

Undeveloped headwater lakes (Hobsons, Charlies, Ash, Fox, Crane, Three Finger, Flat, and Cranberry Lakes) have not been tested since 1994. At the time of sample collection, the trophic status of Ash, Charlies, Crane, and Fox was ultra-oligotrophic, and Charlies, Big Cranberry, Hobsons, Flat, and Three Finger were oligotrophic. All these lakes had low phosphorus concentrations.

<u>Water Quality Objectives</u>

The water quality objectives are based upon a scientific understanding of the Birch Cove Lakes 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 Birch Cove Lakes watershed.

The parameters most likely to be negatively influenced as a result of 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.

All indicator parameters, with the exception of total phosphorus, have definitive Canadian Water Quality Guideline (CWQG) limits. Because the CWQGs are set to protect the most sensitive species, and because water quality in the Birch Cove lakes is currently better than these objectives, AECOM recommends that the CWQGs for nitrate, un-ionized ammonia, total suspended solids, and chloride be adopted for the Birch Cove Lakes 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. AECOM suggests this value is appropriate for the *E. coli* parameter.

With respect to phosphorus, Environment Canada (CCME 2004) provided a classification of trophic status for lakes and rivers. For the Birch Cove Lakes watershed we recommend building on this classification with each water body categorized into one trophic status based on existing conditions either measured or predicted based on model results. As a result, the management objective would be to meet or maintain the trophic status of a water body so the water quality objective for total phosphorus becomes <u>the upper limit of the TP range</u> indicated in Table 19 for each trophic state. This approach is consistent with the objectives of the Regional Plan, which seeks “to maintain the existing trophic status of our lakes and waterways to the extent possible.”

Table 19. Water Quality Objectives, Early Warning Alert Value and Proposed Evaluation Methodology for Alert Values for Total Phosphorus (µg/L) in Birch Cove Lakes Watershed

Parameter	Derivation of Objective	Birch Cove Objective or Lake Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
TP - Ash Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Charlies Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Cranberry Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Crane Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Flat Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Fox Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Hobsons Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Horseshoe Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - McQuade Lake	Mesotrophic	≤20	15	3 year running mean of Black Duck Brook measurements
TP - Susies Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Quarrie Lake[2]	Oligotrophic	≤10	8	3 year running mean at outfall
TP – Three Finger Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Washmill Lake	Oligotrophic	≤10	8	3 year running mean of data
TP - Kearney Lake	Oligotrophic	≤10	8	3 year running mean of data
TP - Paper Mill Lake	Oligotrophic	≤10	8	3 year running mean of data

[1]No recent water quality data to verify model predicted water quality results. Data should be collected to validate objective and proposed alert value. Until additional data are available, the evaluation is dependent upon modeling and the early warning alert value is based on the upper TP limit of the oligotrophic state due to uncertainty in the model.
[2]Only two samples to date, Objective needs to be validated with additional analytical data and proposed alert value confirmed.

Additional work will be completed to meet the remaining objectives of Policy E-17 for presentation in the Final Report. The potential effects of future land use changes on the trophic state and phosphorus concentrations in the primary lakes will be assessed using a Lake Capacity Model (LCM) that has been employed previously in the Halifax region. While the LCM deals with this in a steady state manner by accounting for changes in land use, it does not address the dynamic nature of pollutant delivery nor the benefits of stormwater management best practices in an adequate and time dependent manner. Consequently, AECOM will also adapt the U.S. Environmental Protection Agency's StormWater Management Model management model to predict phosphorus loads within the Birch Cove Lakes watershed. These models will also be used to assess the benefits that could be achieved from mitigation measures to reduce the impacts of development, reduce or maintain phosphorus loadings and maintain or improve lake trophic state. The final report will also recommend a cost effective water quality monitoring program in the light of existing data and water bodies that need to be assessed as a result of planned development.

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1 Introduction

Halifax Regional Municipality (HRM) in 2002 adopted the HRM Water Resources Management Study (Dillon Consulting Ltd. 2002) as a basis for developing watershed planning policies. Following from this study, HRM uses the watershed as the basic unit of land use planning, since the critical environmental functions and features within a watershed are linked together, and all may be affected by land use decisions within the watershed. 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).

The 2006 Halifax Regional Municipal Planning Strategy (also called the Regional Plan) requires that watershed studies are undertaken before a Community Vision exercise and in advance of community design work undertaken through the secondary planning process. In response to requests by property owners of the “Highway 102 West Corridor Lands” to begin planning for new serviced communities through HRM’s secondary planning process, Regional Council has directed that a watershed study be completed for the Birch Cove Lakes watershed.

AECOM was contracted by HRM in August 2011 to complete the Birch Cove Lakes Watershed Study in two phases:

3. present a series of recommended water quality objectives for key receiving water bodies within the watershed in a Preliminary Report; and,
4. address the remaining objectives of Regional Plan Policy E-17 in a Final Report.

The water quality objectives contained in the Preliminary Report will be presented to the public and to Regional Council for comment so that questions and clarifications can be addressed in the Final Report.

1.1 Watershed Study Planning Context

As noted, the Regional Plan requires that watershed studies are undertaken in advance of community design work undertaken through the secondary planning process. In response to requests by developers of the “Highway 102 West Corridor Lands” to begin the secondary planning processes, Regional Council has directed that a watershed study be completed for the Birch Cove Lakes watershed.

At the same time, a significant portion of the lands within the watershed have been identified in the Regional Plan for inclusion within the conceptual Blue Mountain – Birch Coves Lakes Park. As noted by the HRM’s Regional Plan Advisory Committee, the information provided by the watershed study will be valuable in determining how much of this area can be developed while maintaining desired water quality standards and which lands might be most important to preserve (HRM Staff Report 2010).

Policy E-17 of the Regional Plan requires watershed studies are carried out as part of a comprehensive secondary planning process in recognition that water quality and ecosystem health are vulnerable to the effects of urban and suburban development. Section 2.3 of the Regional Plan states:

> “Although it is not the intention of this Plan to achieve pristine conditions for every watershed, there is a desire to achieve public health standards for body contact recreation and to maintain the existing trophic status of our lakes and waterways to the extent possible. Our lakes, waterways and coastal waters should not be further degraded.”

The Final Report of the watershed study will identify areas that are suitable and not suitable for development within the watershed, determine the amount of development that can be accommodated while maintaining water quality objectives in the receiving watercourses, recommend measures to protect and manage quantity and quality of surface and groundwater and recommend regulatory controls and management strategies to achieve the desired water quality objectives.

This watershed study complements the Halifax Regional Wastewater Management Functional Plan, currently underway, which will provide Halifax Water with a management plan for the existing wastewater system and identify upgrades required to comply with new performance guidelines adopted by the Canadian Council of Ministers of the Environment (CCME 2009). Based on these guidelines, the Federal Government has published draft Wastewater System Effluent Regulations, which are expected to be finalized in 2012. The watershed study also incorporates and builds upon information presented in the Water Quality Monitoring Functional Plan, mandated by the Regional Plan's Policy E-18 and completed in 2009 (Stantec 2009, updated 2010).

1.2 Study Objectives

The primary objective of the Birch Cove 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 pollutant sources without experiencing a significant decline in water quality and ecological function.

The ultimate 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 the water quality from further degradation. More specifically, the objectives of watershed study are listed in Policy E-17 of the Regional Plan:

1. Recommend measures to protect and manage quantity and quality of groundwater resources;
2. Recommend water quality objectives for key receiving watercourses in the watershed;
3. 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;
4. Determine the parameters to be attained or retained to achieve marine water quality objectives;
5. Identify sources of contamination within the watershed;
6. Identify remedial measures to improve fresh and marine water quality;
7. Recommend strategies to adapt HRM's stormwater management guidelines to achieve the water quality objectives set out under the watershed study;
8. 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;
9. Identify and recommend measures to protect and manage natural corridors and critical habitats for terrestrial and aquatic species, including species at risk;
10. Identify appropriate riparian buffers for the watershed;

11. Identify areas that are suitable and not suitable for development within the watershed;
12. Recommend potential regulatory controls and management strategies to achieve the desired objectives; and
13. Recommend a monitoring plan to assess if the specific water quality objectives for the watershed are being met.

1.3 Scope of the Preliminary Report

In order to achieve the Preliminary Report objectives, the following tasks were completed:

- The study scope was presented to the Bedford Watershed Advisory Board in October 2011 to explain the work to be undertaken and to hear any concerns or issues;
- Existing water quality data were reviewed and a supplementary sampling program was undertaken to establish a baseline of the water quality in key water courses;
- A review of other jurisdictional approaches to setting water quality objectives for lakes was undertaken. Based on this information, an approach was developed for recommending water quality objectives for the Birch Cove Lakes watershed. Water quality objectives were set for each lake for total phosphorus and for the watershed as a whole for nitrate, un-ionized ammonia, total suspended solids, chloride and the bacteria *Escherichia coli*, commonly called *E. coli*;
- In order to address an information gap of past monitoring within the Birch Cove Lakes watershed, a limited flow monitoring program was initiated to help calibrate the nutrient and stormwater loading models used to evaluate water quality objectives; and
- Using HRM's LiDAR data, spatial modeling was completed for the watershed. The LiDAR data were used to delineate watershed and sub-watershed boundaries and to identify vernal ponds, wetlands and intermittent streams. The LiDAR data were also critical to the pre- and post-development analysis of land uses and impervious surfaces for use in the nutrient modeling.

1.4 Scope of the Watershed Study (Final Report)

Upon completion of the Preliminary Report, additional work will be undertaken to meet the remaining objectives of Policy E-17 for presentation in the Final Report, including:

- Previous steady state nutrient loading models used within the watershed will be reviewed in order to identify any required changes to the assumptions and model variables on which the models were based in order to re-run these models;
- A steady state nutrient loading model (Lake Capacity Model [LCM]) will be used to determine predicted in-lake phosphorus concentrations and thus predicted lake trophic state. These models will be calibrated against current measured total phosphorus (TP) in-lake concentrations;
- A standard dynamic 1-dimensional flow model (Stormwater Management Model [SWMM]) will be developed for the watershed and calibrated to the current measured TP in-lake concentrations;

- Land use within the watershed will be spatially modeled to provide details on current landuse within each sub-watershed and to project landuse forward for three scenarios: "approved developments" for areas where development agreements have been approved or are in the process of being approved; "planned development" where Secondary Planning Strategies have been adopted by HRM but development agreements have yet to be approved; and "Proposed Development" encompassing the Highway 102 West Corridor Lands, which are designated by the Regional Plan for potential future development;

- The steady state and dynamic models will be used to evaluate total phosphorus loadings to the lakes within the watersheds under the current, near term and longer term development scenarios in order to predict the impacts on the lakes when compared to the recommended water quality objectives. This step will include assessing the opportunities for remedial actions to protect or recover lake water quality such that water quality objectives are met;

- The opportunities for land exchanges and alternative development scenarios will be assessed to better protect the water resources;

- The opportunities for the application of stormwater management tools to reduce loadings of sediment and phosphorus to the water bodies both within new developments and as options for retrofitting built areas will be evaluated;

- A cost effective and environmentally sound water quality monitoring program for the watershed in the light of existing data and water bodies that need to be assessed as a result of planned development will be recommended;

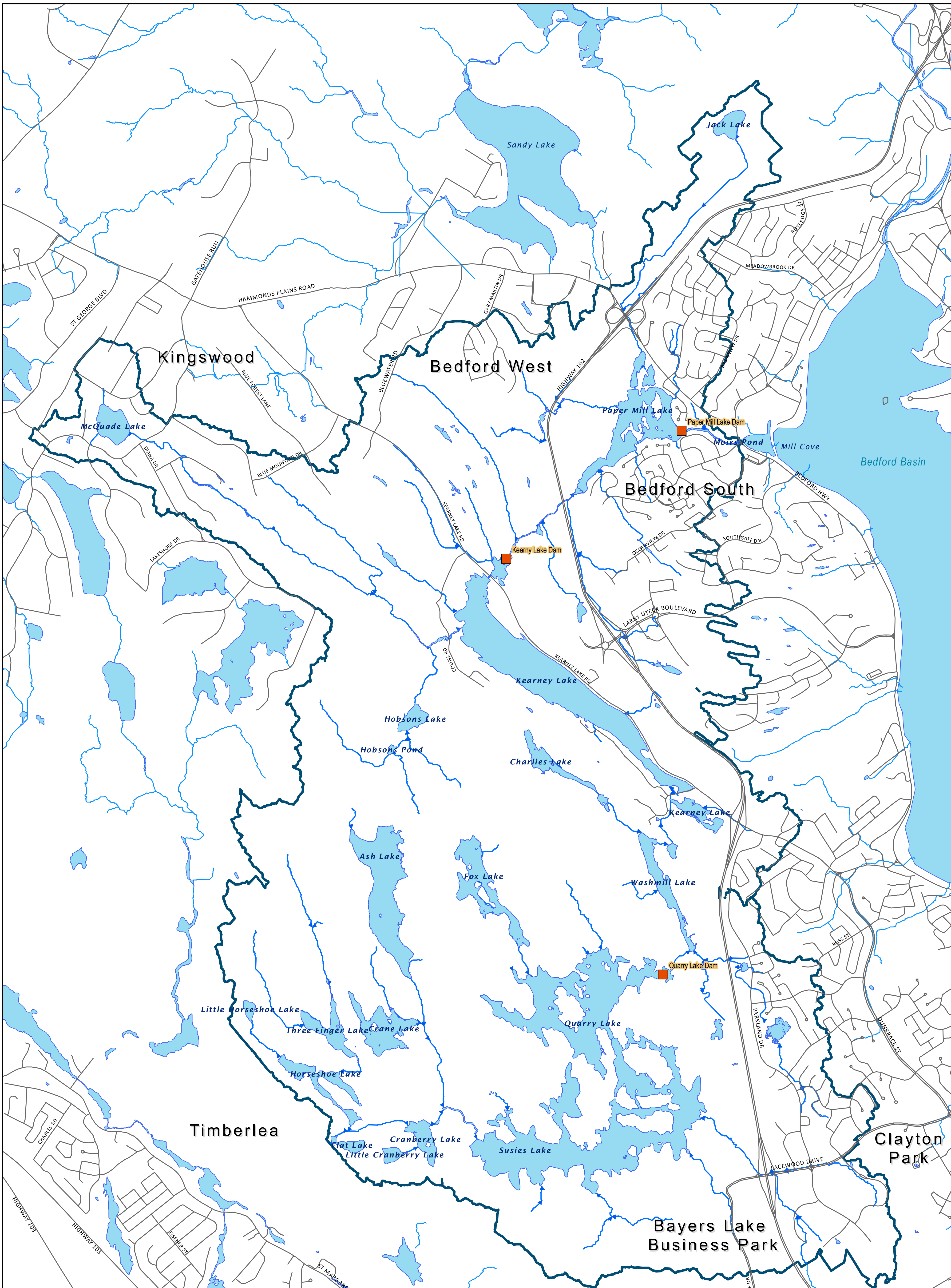
- A water quantity monitoring program to better calibrate the stormwater model and to confirm the predicted impacts of development on flow and pollutant loading will be recommended; and,

- The potential for existing control structures to affect water quantity and quality in downstream watercourses will be evaluated. The evaluation will provide a quantitative assessment of the impact on water quality measures and a qualitative assessment of the sophistication of management needed to be effective.

The draft Final Report and the Final Report will also incorporate the changes to the Preliminary Report based on discussions with the Bedford Watershed Advisory Board, the project Steering Committee and responses from public reviews.

1.5 General Description of the Birch Cove Lakes Watershed

The Birch Cove Lakes watershed is located within the boundaries of HRM, north of Timberlea and the Bayers Lake Business Park and west of peninsular Halifax (Figure 1). With a surface area of approximately 34.6 km^2, the Birch Cove Lakes watershed is an ecologically diverse area containing 17 lakes greater than 1.0 ha in surface area and numerous ponds, streams and wetlands. The highest elevation is 149 m metres (m) above mean sea level (amsl) at Geizer Hill in the southeast end of the watershed, while the lowest elevation is essentially sea level where the watershed outlets into Bedford Basin through Paper Mill run at Mill Cove.



Dam Locations
Watercourse
Birch Cove Flow Direction
Roads
Birch Cove Lakes Watershed
Water

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Birch Cove Lakes Watershed

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	

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Figure 1

The watershed is situated on the southern edge of the Nova Scotia Southern Upland physiographic region. The rugged terrain is dominated by rolling granite bedrock that has undergone repeated cycles of glaciation. As in other parts of Canada where resistant rocks have been scoured by glaciers, the watershed has been left with little or no mineral soils resulting in significant amounts of exposed bedrock and irregular drainage patterns. Many of the low-lying basins between bedrock outcrops are occupied by lakes and wetlands. In general terms, approximately 10% of the watershed consists of waterbodies (lakes, ponds, streams), 3% is wetland, 53% is soil-covered forested uplands, 4% is industrial and commercial, 12% is residential, 8% is roads and 3% is exposed bedrock.

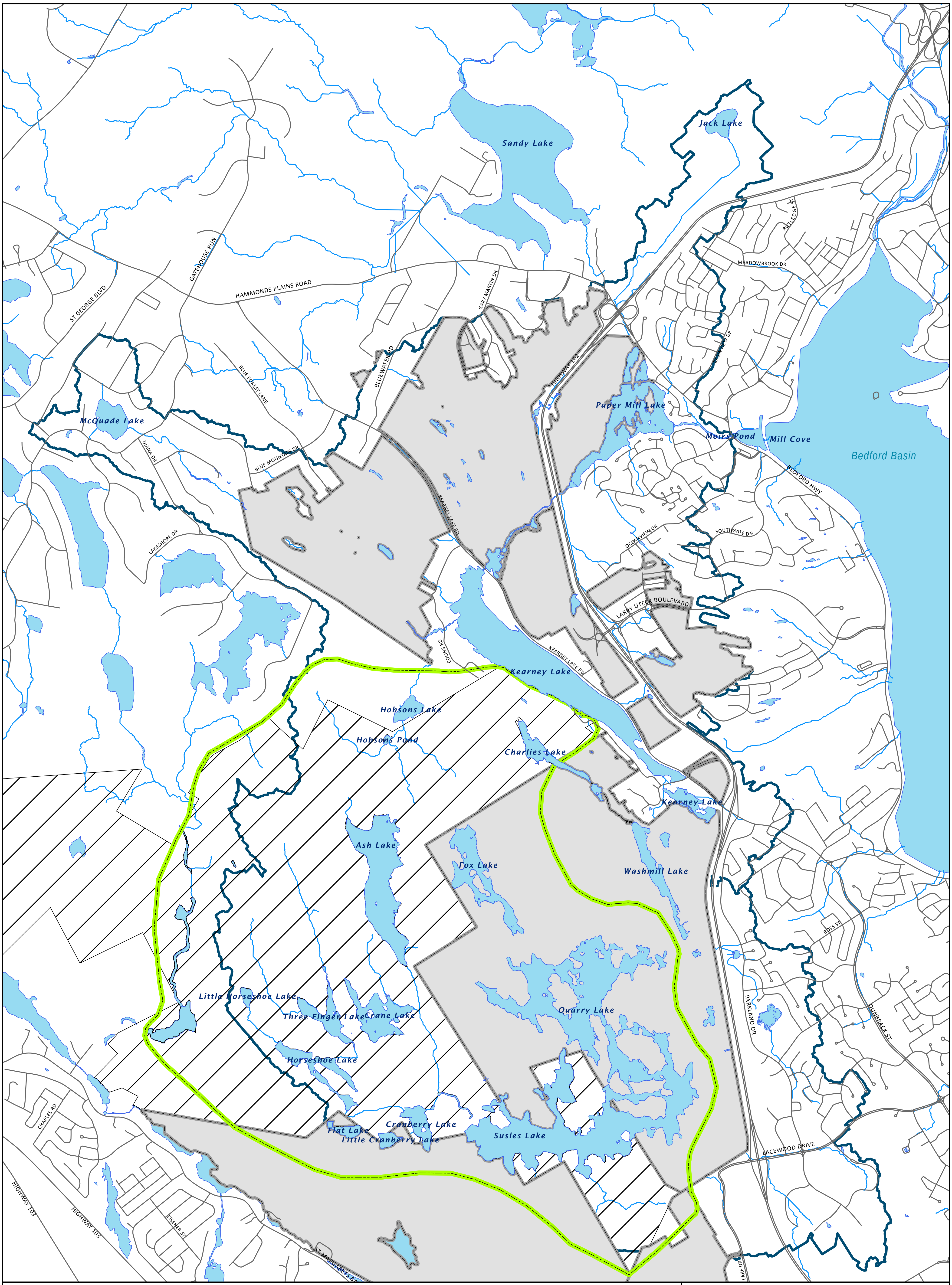
Surface water flow within the watershed is generally south to north in the larger lakes, from Susies Lake through Quarrie Lake, Washmill Lake, Kearney Lake, Paper Mill Lake, and ultimately to Moirs Pond and the Bedford Basin. In the upper watershed, the smaller lakes that feed Susies Lake actually flow to the southeast: Ash Lake, Little Horseshoe and Horseshoes Lakes, Three Finger Lake, Crane Lake, Flat Lake, Little Cranberry and Cranberry Lakes all contribute flow to Susies Lake.

Existing dams are located at Quarrie Lake outlet, Kearney Lake outlet and Paper Mill Lake outlet. The Quarrie and Kearney Lake dams were rebuilt in 2005 and 2006, respectively, while the Paper Mill dam is scheduled for reconstruction in 2012. At this time, none of the dams are used to adjust water levels within the watershed.

The watershed supports a wide range of land uses from urban and commercial developments to rural settlements and open space or natural environments. Approximately 68% of the watershed is undeveloped. Portions of the Bayers Lake Business Park, Clayton Park residential area, the Kingswood subdivision, Bedford West and Bedford South developments and residential areas between Highway 102 and the Bedford Highway are within the watershed (Figure 1). Residences range from older homes and cottages to modern suburban homes and low rise apartment buildings. Commercial development areas are concentrated along the perimeter of the watershed. Commercial properties include small businesses, offices, mini-strip malls, grocery stores, restaurants, and medical facilities. Schools, community and recreation centres and places of worship are also present within the developed areas.

In April 2009, approximately 1,312 ha of provincially-owned Crown land, of which 704 ha is located within the Birch Cove Lakes watershed, was designated the Blue Mountain-Birch Coves Lakes Wilderness Area under section 11 of the provincial Wilderness Areas Protection Act (Figure 2). The Wilderness Area makes up 20% of the watershed. Following HRM's endorsement of the Blue Mountain/Birch Cove Assessment Study (EDM 2006), a portion of the Wilderness Area was nominated in the 2006 HRM Regional Plan to form the Blue Mountain Birch Coves Lakes Regional Park. Portions of nearby privately owned land within the conceptual Regional Park boundaries, commonly referred to as the "Highway 102 West Corridor Lands" were identified for potential addition to the Regional Park.

The park objectives are to provide a near urban wilderness experience in perpetuity for the citizens of HRM. The park will contribute to the preservation of undeveloped lakes within the watershed and to the maintenance of water quality within Washmill, Kearney and Paper Mill Lakes, which have been impacted by past development. The Regional Park lands are also part of a wilderness network connecting across the Chebucto Peninsula providing wildlife corridors and habitat (HRM Staff Report 2011).



- Watercourse
- Roads
- Crown Lands Designated Wilderness Area
- Privately Owned Lands
- Conceptual Regional Park Boundary
- Birch Cove Lakes Watershed
- Water

Halifax Regional Municipality Birch Cove Lakes Watershed Study		
Designated Wilderness Area & Conceptual Regional Park		
June 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 2
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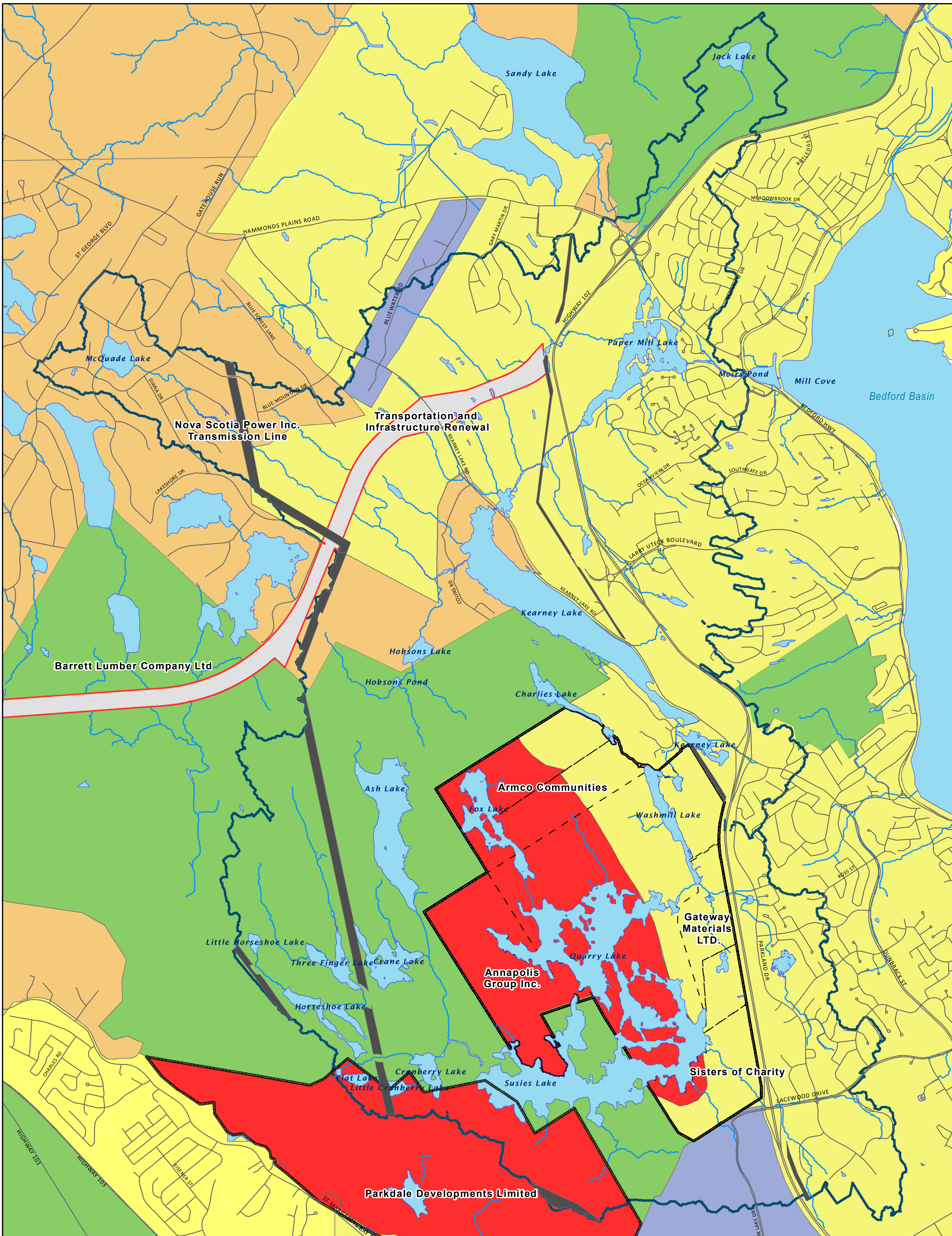
Privately held land within the watershed is owned by a number of different landowners (Figure 3). Other than urban and suburban development, which is largely confined to the northern, southern and eastern peripheries of the watershed, both logging and quarrying have been undertaken in the area. The 76 ha Gateway Quarry property located west of the 102 Highway near Kearney Lake is a significant terrain feature in the watershed. Nova Scotia Power maintains two intersecting transmission lines within the watershed while Barrett Lumber Company harvests timber near Blue Mountain (EDM 2006). A portion of the proposed Highway 113 corridor also transects the watershed, connecting Highway 102 in the east with Highway 103 in the southwest. While there are no immediate plans to build the Highway 113, construction can be expected over the longer term (P. Morgan, pers. comm. 2012).

As noted above, HRM commissioned the Birch Coves Lakes Watershed Study following a request by landowners of Highway 102 West Corridor Lands to initiate the secondary planning process for new serviced developments on the property. The Highway 102 West Corridor Lands are located west of Highway 102 and south of Kearney Lake and include property around Washmill Lake, Fox Lake, and Quarrie Lake (Figure 3).

According to the Regional Plan, privately held land within the watershed is designated as **Urban Settlement** (along the Bedford Highway, Highway 102, and the eastern end of Hammonds Plains Road), **Urban Reserve** (around Susies and Quarrie Lakes and the southern end of the watershed), **Rural Commuter** (south of Hammonds Plains Road, and **Open Space and Natural Resource** (in the centre of the watershed). There are also two areas designated as **Business / Industrial Park** which correspond to the Bayers Lake Business Park and the Atlantic Acres Industrial Park in Hammonds Plains. The Highway 102 West Corridor Lands are designated as Urban Settlement and Urban Reserve.

The Urban Settlement designation defines areas where urban forms of development will occur over the life of the Regional Plan (ending in 2026). The Regional Plan supports growth in a series of mixed use transit-oriented centres in strategic areas throughout this designation. Development will include water and wastewater services in these areas (Policy S-1). The Urban Reserve designation is used to identify and ensure there is a continuous supply of land that can be developed and serviced after 2026 (Policy S-4).



Roads
Watercourse
Business and Industrial Parks
Open Space and Natural Resource
Rural Commuter
Urban Reserve
Urban Settlement

Privately Owned Land
Land Owner Blocks
Proposed Highway 113 Corridor
Nova Scotia Power Inc. Transmission Line
Water
Birch Cove Lakes Watershed

Halifax Regional Municipality Birch Cove Lakes Watershed Study		
Future Land Use Designations and Land Ownership		
June 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 3
AECOM		

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Meters

1.6 Structure of the Preliminary Report

This watershed study report is organized into the following principal sections:

1. Section 1: Introduction. This section of the report introduces the study and provides the overall context, scope and approach to the work.
2. Section 2: Existing Environmental Conditions. This section describes climate, geology, groundwater, terrestrial and aquatic ecological resources and surface water resources and includes a brief discussion of the water quality data available for the analysis of these resources.
3. Section 3: Spatial Data Processing. Section 3.0 describes spatial data acquisition and processing (GIS and mapping) that form the foundation for the analysis of future development on the natural water resources of the watershed. Included here are discussions of the existing landuse and an overview of the development scenarios used in the modeling of future impacts. This section also includes a discussion of the physical and biophysical constraints associated with development in the watershed area (e.g., areas that are suitable and not suitable for development).
4. Section 4: Receiving Water Quality Objectives. This section reviews various jurisdictional approaches and their water quality objectives. Key parameters are selected for analysis and objective setting based on the fact that they are known to be strongly influenced by urbanization. The recommended water quality objectives are set based on the recent water quality data from the watershed in conjunction with guidance from these sources of information.

2 Existing Environmental Conditions

2.1 Climate

The Birch Cove Lakes watershed is strongly influenced by the Atlantic Ocean and is one of the most humid parts of the Maritime provinces. The area is characterized by warm summers and mild, snowy winters. Within this region, the mean annual temperature is approximately 6.5°C, while the mean summer temperature is 14°C and the mean winter temperature is -2°C. The mean annual precipitation ranges 1300-1600 mm. This region is classified as having an Atlantic high cool temperature ecoclimate (Webb and Marshall 1999).

As inputs to the numerical models, climate and precipitation normals between 1971 and 2000 were obtained from Environment Canada’s Halifax Citadel meteorological station. These data are presented in Table 1.

Table 1. Temperature and Precipitation Climate Normals

Air Temperature Climate Normals (1971-2000)				Precipitation Climate Normals (1971-2000)			
Month	**Daily Maximum (^{0}C)**	**Daily Minimum (^{0}C)**	**Daily Average (^{0}C)**	**Month**	**Rainfall (mm)**	**Snowfall (mm)**	**Precipitation (mm)**
January	-0.2	-8.6	-4.4	January	112.3	38.4	150.7
February	-0.1	-8.1	-4.1	February	76.2	37.7	113.4
March	3.5	-4.2	-0.3	March	106.0	28.4	134.4
April	8.4	0.8	4.6	April	111.3	9.8	121.1
May	14.1	5.5	9.8	May	118.1	1.2	119.4
June	19.4	10.5	15.0	June	108.0	0.0	108.0
July	22.9	14.2	18.6	July	105.9	0.0	105.9
August	23.0	14.8	18.9	August	98.3	0.0	98.3
September	19.0	11.4	15.2	September	107.1	0.0	107.1
October	13.1	5.9	9.6	October	134.4	1.0	135.4
November	7.9	1.2	4.5	November	146.8	6.9	153.7
December	2.6	-5.1	-1.3	December	131.7	28.5	160.2
Year	11.2	3.2	7.2	Year	1356.1	151.8	1508

Wind normals over the same period were obtained from Environment Canada's Shearwater Airport meteorological station (Table 2). The Halifax Citadel station was not selected to represent wind data in the area, as maximum hourly wind speed (km/h) is the only information available from this station.

Table 2. Wind Speed and Direction Normals

Wind Climate Normals (1971-2000)			
Month	**Speed (km/h)**	**Most Frequent Direction**	**Maximum Hourly Speed (km/h)**
January	18.1	W	83.0
February	17.7	NW	97.0
March	17.8	NW	78.0
April	16.9	N	85.0
May	14.0	S	72.0
June	12.8	S	77.0
July	11.3	S	87.0
August	11.1	SW	60.0
September	12.8	SW	97.0
October	14.8	W	80.0
November	16.5	NW	89.0
December	17.7	W	89.0
Year	15.1	W	

Lake evaporation normals were obtained from Environment Canada's Truro Climate station (Table 3). This was the closest Environment Canada monitoring station with long-term evaporation data that could be related to the lakes.

Table 3. Evaporation Normals

Month	Lake Evaporation (mm)
January	0
February	0
March	0
April	0
May	2.9
June	3.4
July	3.6
August	3.2
September	2.3
October	1.3
November	0
December	0
Year	0
Total	16.70

2.1.1 Climate Change

Since the planning horizon for this study extends over 20 years it is appropriate to consider the potential impacts of climate change on water quality and water quantity within the watershed. Although this time frame may be too short to expect significant changes to the water budget of the area, it is worth considering climate change trends and probable future effects to precipitation patterns in this analysis.

The emission of atmospheric greenhouse gases (GHG) is inducing a series of climatic changes, most notably an increase in global mean temperatures and an intensification of the global hydrological cycle (Meehl et al. 2007a). To assess the magnitude of these changes and understand their impact on climate, modelling teams around the world have created numerical models that couple atmospheric circulation, the ocean and surface climatological processes. Given an initial climatic state and the evolution of GHG concentrations, these Global Climate Models (GCM) simulate the Earth's climate over hundreds, if not thousands of years.

Typically, models contributing to the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report have a horizontal resolution of about 250 km, meaning that changes to local weather patterns cannot be adequately described by GCMs. Rather, GCMs strive to accurately reproduce climate statistics, the large scale mean state and seasonal cycle of climatic variables, rather than local weather conditions (Randall et al. 2007).

In general, a gradual increase in the temperature of the planet has been observed over the past century, and is expected to continue into the future, at least for some decades. The direct effects of temperature change, however, are far from clear. While the extremes seem to be most apparent in the northern polar regions, it is more difficult to understand the changes in temperate regions where hydrologic and water quality records usually extend only a few decades. The consequences of temperature change on river runoff patterns and quantities are not yet clearly determined. Rainfall and evaporation patterns (spatial and temporal) will be modified and it is expected that the variability of extreme events (floods and droughts) will increase, but it is not possible to quantify this change (Pancura and Lines 2005). Analysis of the effect of climate change on hydrologic and water quality in temperate urban streams is further complicated by the usually much stronger signal resulting from direct human activities such as land clearing and urbanization.

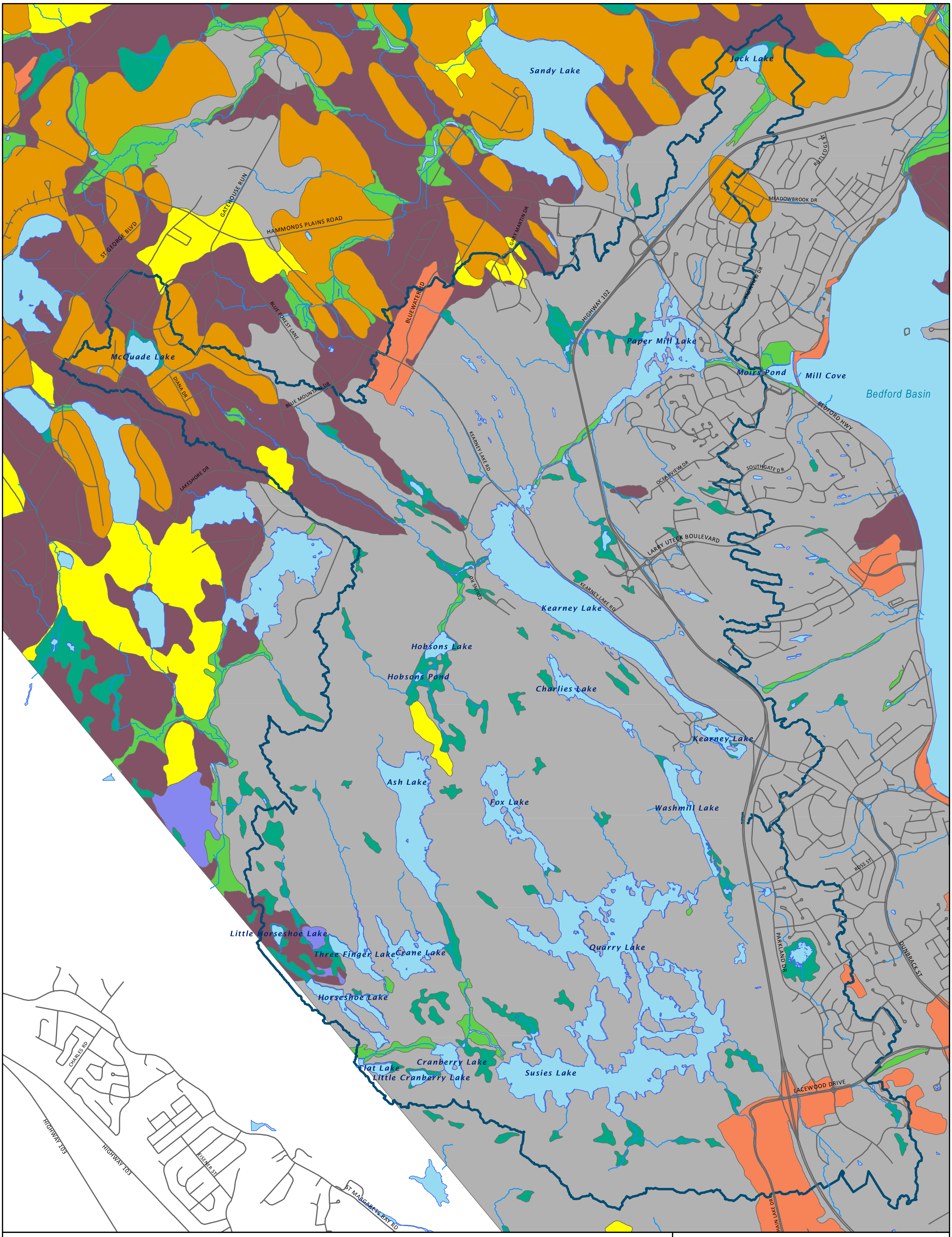
Although HRM is taking a risk management approach to managing the effects of climate change anticipated within the municipality over the next 100 years (HRM 2007), any measurement of a hydrologic response of the Birch Cove Lakes watershed is for all intents and purposes impossible due to the absence of historical flow measurements within the watercourses. Consequently, for the 20 year time horizon of this project, impacts from climate change are assumed to be masked by anthropogenic changes directly within the watershed and no attempt has been made to analyse the effects of climate change in this study.

2.2 Geology and Hydrogeology

2.2.1 Surficial Geology

Figure 4 illustrates the surficial geology of the Birch Cove Lakes watershed. The term surficial geology refers to the loose deposits of soil, sand, gravel and other material deposited on top of the bedrock. These materials generally consist 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 2011).

Within the watershed, bedrock exposed at surface and bedrock beneath shallow soil cover occupies approximately 75% of the land surface area. Exposed surfaces in some areas are glacially scoured and exhibit furrows gouged by boulders embedded in the underside of moving ice sheets.



- Roads
- Watercourse
- Lakes
- Birch Cove Lakes Watershed

Surficial Geology

- Alluvial
- Anthropogenic
- Bedrock
- Drumlins
- Hummocky till
- Lacustrine
- Till blanket
- Till veneer
- Organic Deposits

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Surficial Geology

May 2012	1:30,000	Datum: NAD83 Zone 17 Source: HRM
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Figure 4

0 495 990 1,980
Meters

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The Beaver River Till, deposited as a blanket or veneer over bedrock when the glaciers began to melt approximately 12,000 years ago, covers approximately 6% of the Birch Cove Lakes watershed. The Beaver River Till is 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 5-10 m (till blanket) and < 5m (till veneer). The till was also deposited in an irregular hummocky pattern where thicknesses range from 1 to 10 m.

Drumlin deposits (low, smoothly rounded, elongate oval mounds of glacial till) occupy approximately 2.25% of the watershed are found almost exclusively along its northern perimeter, in the vicinity of the Kingswood subdivision in the McQuade Lake area. Numerous drumlins are found north of the watershed boundary, both east and west of Sandy Lake.

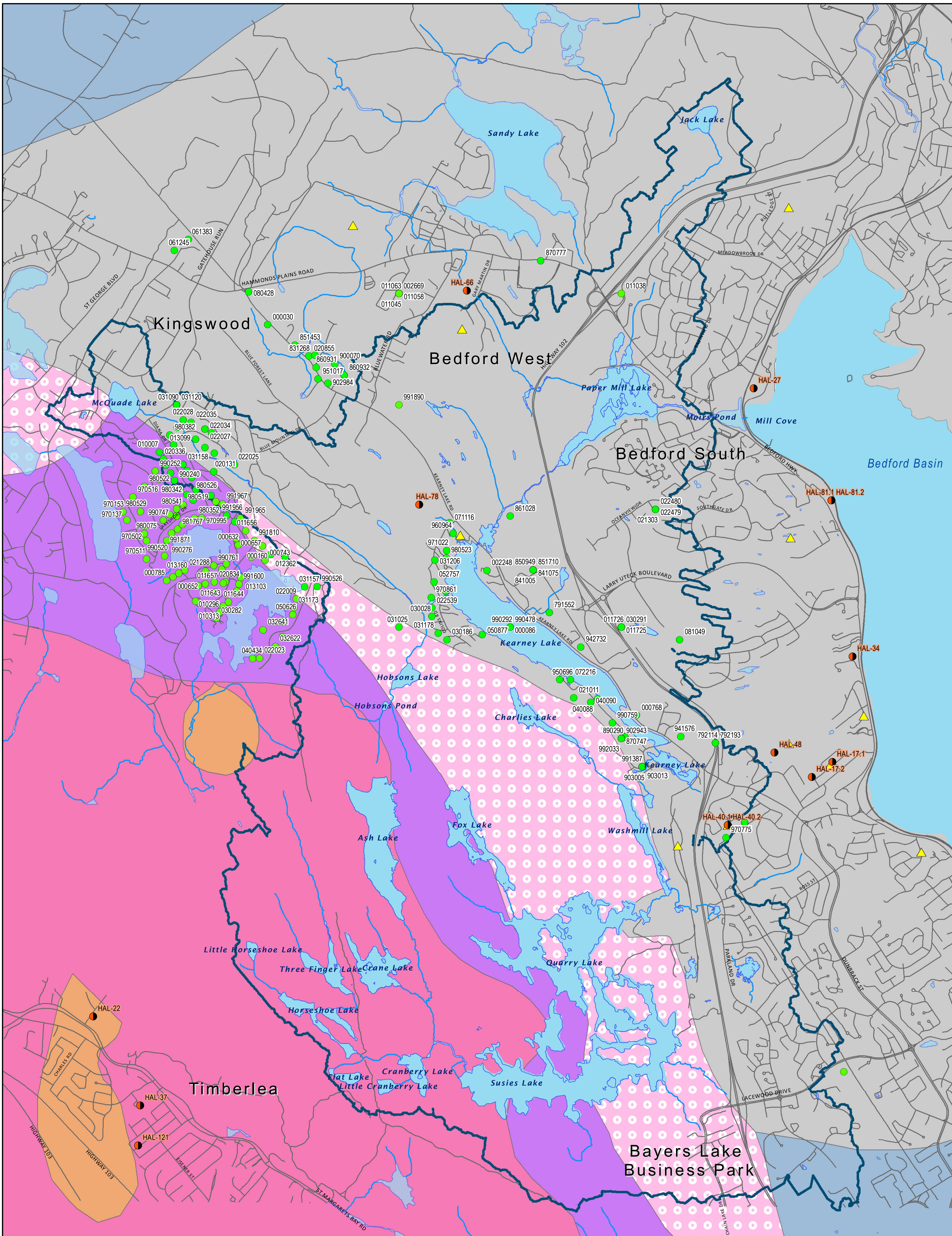
Alluvial and lacustrine deposits represent 1% and 4% of the land cover within the Birch Cove Lakes watershed, respectively. Alluvial deposits consist of gravel, sand, silt and minor clay and organics and were deposited by streams and rivers in channels and floodplains. These deposits are visible between Ash Lake and Kearney Lake and between Kearney and Paper Mill Lakes. Lacustrine deposits, consisting of sand, silt, clay and organics, were deposited from suspension in freshwater lakes, ponds and wetlands. Lacustrine deposits are typically found around existing lakes, indicating these lakes were larger in the past as the glaciers were melting. Within the watershed, the thickness of alluvial deposits ranges from 1 to 10 m, while lacustrine deposits have estimated thicknesses ranging 1 to 5 m (Utting 2011).

Surficial deposits disturbed by human activity cover approximately 3% of the watershed, although this is difficult to estimate, given the changes that development can have on the landscape

.

Bedrock Geology

Figure 5 illustrates the bedrock geology underlying the Birch Cove Lakes watershed. The metamorphosed sedimentary rocks of the Goldenville and Halifax Formations form the Meguma Group of rocks, which hosts most of the groundwater wells within the watershed. Older Goldenville Formation quartzite (metamorphosed sandstone) occupies the northern portion of the watershed while younger acid-forming slate (metamorphosed shale) of the Halifax Formation are present in the extreme southeast portion of the watershed, within and near the Bayers Lake Business Park (MacDonald 1994). Igneous Devonian-age granite of the South Mountain Batholith occupies the southern portion of the watershed. The granite intruded into the sedimentary rocks at much later date and caused extensive folding and fracturing of the older Meguma Group rocks through heat and pressure (MacDonald 1994). This pressure caused the formation of a series of northwest-southeast trending folds parallel to the granite/sedimentary rock contact, which is roughly parallel to Kearney Lake. In addition, two major joint sets (fractures) are present, running both parallel and perpendicular to the axis of the folds (Cross and Woodlock 1976). The folds, fractures and joint sets are the most likely pathways for groundwater movement within these sedimentary rocks. In contrast, the granitic rocks are typically not fractured (MacDonald 1994) and are not exploited for groundwater within the watershed.



Yellow triangle	Groundwater Chemistry
Half-filled circle	HAL### Pumping Test (Nova Scotia Environment Reference No.)
Green circle	###### Drilled Well (Nova Scotia Well Log No.)
Blue line	Watercourses
Grey line	Roads
Light blue fill	Water
Dark blue outline	Birch Cove Lakes Watershed

Devonian Granite
- Tantallon Leucomonzogranite
- Halifax Peninsula Leucomonzogranite
- Sandy Lake Monzogranite
- Granodiorite

Meguma Group
- Goldenville Formation
- Halifax Formation

Geology Ref: MacDonald and Horne (1987)

Note: The wells shown on this figure represent the wells included in the groundwater resources discussion of the report, and do not necesarily represent all of the wells in the map area.

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Bedrock Geology & Wells within Birch Cove Lakes Watershed

May 2012	1:32,000	Datum: NAD83 Zone 17 Source: HRM
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Figure 5

0 500 1,000 2,000
Meters

The slates of the Halifax Formation host sulphide minerals in the form of pyrite and pyrrhotite (Fox *et al.* 1997). Excavation of these sulphide-bearing rocks can result in acid rock drainage (ARD) which occurs when sulphide minerals exposed to the air oxidize to produce sulphuric acid. ARD can cause serious direct ecological impacts to aquatic habitats and may enter the ground water flow regime, eventually contaminating wells (HRM 2011). While newly exposed slates will oxidize rapidly, acid generation decreases as the iron sulphide minerals are transformed to iron oxide (Fox *et al.* 1997). Within the Birch Cove Lakes watershed, almost no terrain underlain by ARD-generating rock remains undeveloped and so future ARD is unlikely to be a significant concern with additional development.

Groundwater Quantity

The ability of a rock formation 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 energy (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.

In the Birch Cove Lakes area, groundwater flow generally follows the topography, which in turn is a function of bedrock structure. The groundwater flow systems are reported to be very local and shallow, and springs or seeps are numerous (Cross and Woodlock 1976).

Municipal water supply services do not extend across the entire Birch Cove Lakes watershed. In general, municipal water supply services extend to most of the developed areas along the periphery of the watershed, except for certain streets bordering Kearney Lake, such as Saskatoon Drive and Hamshaw Drive located along the southeast side of the lake and Belle Street and Collins Road located along the northwest side of the lake. Within the Kingswood subdivision (in the northwest extremity of the watershed), there are houses along several streets that rely on wells for potable water supply.

A large portion of the Birch Cove Lakes watershed is undeveloped and so no groundwater wells have been drilled in these areas. Most of this undeveloped area is situated on granite bedrock. Residential and commercial development is mainly located on the metamorphosed sedimentary rocks of the Goldenville Formation and numerous wells have been drilled in the past decades to obtain potable water.

A search of the Nova Scotia Department of Natural Resources (NSDNR) Groundwater Map Viewer (NSDNR 2012) was conducted to determine well construction information for wells within the Birch Cove Lakes watershed or slightly beyond the watershed boundary. The NSDNR contains geo-referenced well information based on the Nova Scotia Environment (NSE) 2011 Well Driller's Database for wells constructed between 1940 and 2011 (NSE 2011).

There are at least 125 drilled wells in the Goldenville Formation quartzite bedrock and at least 76 wells in the granite within the Birch Cove Lakes watershed or slightly beyond the watershed boundary (Figure 5). According to the Groundwater Map Viewer there are no wells constructed within the Halifax Formation bedrock within the Birch Cove Lakes watershed (NSDNR 2011). In order to provide a general description of well characteristics in the Halifax Formation, the search radius was extended to include wells from the community of Fairview, which is approximately 3 km southeast of the Bayers Lake Business Park.

Wells completed in Goldenville Formation quartzite range in depth from 6.4 m to 152.3 m, with a mean depth of 61.0 m. Well yields range from 0.9 L/min to 1326 L/min, with a mean yield of 43 L/min and a geometric mean yield of 16 L/min. The statistical term "geometric mean" is used as a more accurate representation of typical values when the reported values differ by several orders of magnitude, as is the case with well yields. Well casing lengths range from

3.0 m to 18.3 m, with a mean casing length of 7.4 m. Overburden thickness (the thickness of surficial deposits on top of the bedrock) ranges from nil to 13.1 m, with a mean thickness of 3.5 m.

Well construction information for wells in the granite bedrock consists of 76 wells located in the Kingswood Subdivision along Lakeshore Drive and Long Lake Drive. The total well depths for granite wells are comparable to well depths in the Goldenville quartzite, ranging from 25 m to 137 m, with a mean depth of 63.1 m. Well yields are lower in the granite, ranging from 0.1 L/min to 363 L/min, with a mean yield of 26 L/min and a geometric mean of 13 L/min. Casing lengths range from 6.1 m to 23.1 m, with a mean casing length of 7.4 m. Overburden thickness or depth to bedrock ranges from nil to 19.5 m, with a mean thickness of 3.4 m.

Based on well construction information from 16 wells in the Halifax Formation slate near Fairview, well depths are slightly shallower than wells completed in the neighbouring granite and Goldenville formations and range from 14 m to 103.5 m with a mean depth of 46 m. Well yields are comparable to those in the granite aquifer, ranging from 0.9 L/min and 68 L/min, with mean yield of 20 L/min. There is greater overburden cover overlying the slate bedrock, with overburden thicknesses ranging from 0.6 m to 14 m, with a mean thickness of 5 m.

Reported well yields in well drillers' logs do not necessarily represent the short term or long term safe yield of the well, and by extension, the groundwater quantity characteristics of the host aquifer. Well pumping and recovery tests are generally the most reliable methods for determining hydraulic constants of materials surrounding a well (Singer and Cheng 2002). A total of 22 pumping tests are reported for wells drilled within the Birch Cove Lakes watershed or in the immediate vicinity of the watershed. Pumping test details and interpreted aquifer properties will be summarized in the final report.

In general, the metamorphic sedimentary rocks of the Meguma Group including the Halifax and Goldenville formations have a greater water-bearing potential than the intrusive South Mountain Batholith granite. Sedimentary and metamorphosed sedimentary rocks typically have greater water bearing potential because primary porosity (water held in the voids between grains) and secondary porosity (water held in secondary fractures, joints, bedding planes and faults) contribute to groundwater flow, whereas flow in granite bedrock aquifers is dependent exclusively on secondary porosity. Water availability in granite bedrock depends on whether water-bearing fractures are intersected by the well.

Groundwater Recharge

Groundwater recharge is the process by which surface water within a watershed 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. Although groundwater recharge will occur everywhere within a watershed, from a practical point of view, only thick, higher permeability soils can transmit enough recharge to support a groundwater resource.

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 HRM, who depend on its reliability and high quality.

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.

Deep groundwater recharge is restricted by the low permeability of the bedrock. Thick sequences of glacial materials that can host extensive and productive aquifers are generally not present in the Birch Cove Lakes watershed. Given that these thick deposits often contribute infiltration to deeper bedrock aquifers, it is expected that the percentage of groundwater recharge reaching deep geological units is very low.

In general, glacial tills are considered aquitards, which inhibit significant infiltration to deeper soil or rock aquifers below the till cover. As aquitards, most of soils developed on glacial tills within the Birch Cove Lakes watershed show infiltration rates of 150 mm/yr or less, with the main component of groundwater movement occurring as shallow lateral flow toward streams and lakes. In areas with very thin overburden, recharge is controlled by the underlying very low permeability bedrock geology. The main function of the surficial till units will be to hold precipitation near surface long enough to prevent rapid runoff.

Areas with soil cover consisting of alluvial, lacustrine and/or drumlin deposits, cover an estimated 7% of the watershed, and have the highest potential groundwater recharge, exceeding 150 mm/year. Recharge through till deposits consisting of till blanket or veneer, representing 6% of the coverage in the watershed, have the next highest potential groundwater recharge rates, ranging from 50 to 150 mm/year. Areas where bedrock is exposed or covered by thin soils, which represent 75% of the coverage in the watershed, have potential groundwater recharge rates in the order of 25 to 50 mm/year. Heavily urbanized areas exhibit the lowest potential recharge rates, typically less than 25 mm/yr, due to the impermeable surfaces resulting from pavement and buildings.

A water budget model was developed for the Birch Cove Lakes watershed to determine the relative proportion of water that infiltrates as recharge to groundwater aquifers compared to the remaining water available for surface runoff to streams, lakes and wetlands. Based on the water budget modeling which will be detailed in the final report, groundwater recharge represents a relatively small proportion of the total water budget for the watershed. Approximately 1,900,000 m^3/yr (6% of total precipitation) will infiltrate the ground as recharge and the remaining 31,000,000 m^3/yr (94%) will become surface runoff. This is largely due to the extensive outcrops of low-permeability exposed bedrock and bedrock covered in thin soils within the watershed. When rainfall or snow melt encounters the bedrock, most of the precipitation will run off via overland flow into the surface watercourses, rather than infiltrate into the ground.

Groundwater Quality

There is limited available information regarding groundwater quality within the Birch Cove Lakes watershed. As noted above, no groundwater wells are drilled in the granite, which underlies approximately 50% of watershed. The discussion below relies on wells drilled in granite outside of the watershed boundary. Groundwater quality in the Goldenville Formation is better known but no recent systematic studies have been conducted. Groundwater quality with the Halifax Formation is slightly better known due to the studies conducted on the acid-generating properties of these rocks.

In a 1976 study of 106 wells installed in the Goldenville formation mostly between the Bedford Highway and Highway 102, 31% of the wells exceeded the recommended limit for iron and over half (54%) for manganese. Recommended chloride limits were exceeded in 14% of the Birch Cove wells. Poor water quality was observed in both drilled and dug wells (Cross and Woodlock 1976). At that time, five drilled wells and six dug wells surrounding Kearney Lake were sampled as part of the study. Chloride values were not elevated compared to more developed areas and iron was generally below 0.30 mg/L, the Canadian Drinking Water Standard at the time. In contrast, manganese around Kearney Lake was elevated (generally greater than 0.05 mg/L) and was comparable to wells further east. Most of the wells in the Kearney Lake area were described by residents as having “hard” water and “iron” was reported as a typical water quality problem.

A total of 11 groundwater samples taken from wells installed in the Goldenville Formation quartzite, either within the Birch Cove Lakes watershed or slightly beyond the watershed limits are reported in NSDNR (2012). Results are compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ), Health Canada (2010) and the median of select inorganic chemical parameters as reported in Kennedy et al. (2008) for the plutonic and metamorphic groundwater regions of Nova Scotia. Based on these 11 groundwater samples, the water in the Goldenville Formation quartzite is described as hard (mean alkalinity, 63.7 mg/L, mean hardness, 252 mg/L), neutral (pH 7.4), moderate total dissolved solids (TDS geometric mean, 223.3 mg/L, mean 557.3 mg/L), calcium-bicarbonate groundwater type. Exceedances to the GCDWQ are observed for sodium (1 in 11 samples), chloride (2 in 11 samples), TDS (1 in 11 samples), iron (1 in 11 samples) and manganese (3 in 11 samples). According to Jacques Whitford (2009), naturally-occurring water quality issues in Goldenville Formation bedrock include elevated iron, manganese, arsenic and hardness.

As a part of the environmental assessment for the proposed Highway 113 project, groundwater quality was assessed in 18 wells within the Birch Cove Lakes watershed. Exceedances to the GCDWQ at that time included sodium (1 well), cadmium (1 well), chloride, TDS and uranium (4 wells), pH below 6.5 (8 wells), colour (3 wells), turbidity (11 wells), arsenic (5 wells), iron (8 wells) and manganese (13 wells) Dillon (2009).

According to Jacques Whitford (2009), naturally occurring water quality issues with wells completed in granite aquifers include elevated arsenic, uranium, fluoride, iron and manganese. The contact zones between granite intrusive and the host Meguma group bedrock can locally exhibit highly mineralized groundwater chemistry, with elevated concentrations of iron, manganese and other metals. Naturally occurring groundwater quality issues in the Halifax Formation aquifers include elevated iron, manganese and hardness (Jacques Whitford 2009).

2.3 Ecological Resources

2.3.1 Resource Description

Ecological Land Classification

The Birch Cove Lakes watershed is located within two distinct ecoregions (NSDNR 2002). The Eastern Region (Eastern Interior District) encompasses Charlies, Washmill, Kearney, and Paper Mill Lakes subwatersheds, extending east to the Bedford Basin, north to Sandy Lake, and south to Susies Lake. The Western Region extends west of Kearney and Susies Lakes and includes a number of subwatersheds within the Birch Cove Lakes watershed. The Western Region includes the watersheds of McQuade, Hobsons, Ash, Fox, Quarrie, Horseshoe, Three Finger, Crane, Flat, Cranberry and Susies Lakes.

The Eastern ecoregion contains a variety of landforms including rolling till plains, drumlin fields, exposed bedrock and wetlands. This ecoregion is removed from the immediate influence of the Atlantic Ocean climate regime and typically exhibits warmer summers and cooler winters than coastal areas. The forests of this ecoregion are predominantly coniferous with red and black spruce occupying much of the area, interspersed with scattered stands of hemlock and white pine. Tolerant hardwood stands, dominated by yellow birch and sugar maple, are found on drumlins and upper slopes and crests of steeper hills. The coarse textured soils developed on the granite bedrock are subject to drought in the summer and the vegetation is vulnerable to fire caused by lightning. Large areas of mature forest in this ecoregion have been destroyed by hurricanes (NSDNR 2003).

The Western ecoregion is extensive, spanning Yarmouth to Windsor, including Halifax peninsula but excluding the Annapolis Valley and the coastal regions along the Bay of Fundy. The climate of the ecoregion results in mild winters and warm summers. Forest stands typically consist of red spruce, hemlock and white pine, and occur on sandy and generally shallow soils. Significant portions of this ecoregion are occupied by bogs dominated by stunted black spruce. Natural disturbances to the forest cover through fire and blowdown from tropical storms and hurricanes are common within this ecoregion (NSDNR 2003). The thin soils underlain by slow weathering bedrock in both ecoregions are sensitive to acidification from the deposition of sulphur compounds originating from industrialized areas of the continent (Wolniewicz 2010).

Fisheries and Aquatic Habitat

There are limited data on the quality and quantity of fish and fish habitat within the Birch Cove Lakes watershed as it appears that no dedicated study of this subject has been conducted.

Fish habitat in many watercourses is reported as “fair”, reflecting underlying low nutrient granite bedrock (Dillon Consulting 2009). The lakes and streams within the watershed are typically acidic, have deeply coloured water indicative of dissolved organic matter, and support only a limited population of freshwater fish (EDM 2006). Low populations of brook trout are present in most streams with suitable habitat, although spawning habitat is reported as limited (Dillon Consulting 2009).

Of the waterbodies within the Birch Cove Lakes watershed, only Kearney Lake has been surveyed for fish species and habitat by the Nova Scotia Department of Natural Resources (NSDNR) or the Nova Scotia Department of Fisheries and Aquaculture (NSDFA). Species recorded in Kearney Lake include white sucker, brook trout, brown bullhead, and minnow (golden shiner) (Porter Dillon 1996).

Other fish species observed during previous studies in the area include minnows (stickleback, chub), perch, smelt, 9-spine stickleback, white sucker, and killifish (Dillon Consulting 2009, Porter Dillon 1996). Anadromous smelt were historically known for the Paper Mill Lake Run (Dillon Consulting 2009); however, the dam at the mouth of Paper Mill Lake may prevent upstream movement of smelt (Fielding 2011).

There are no rare aquatic species listed in the federal Species at Risk Act (SARA) or the Nova Scotia Endangered Species Act (NSEA) known to occur in the watershed. The American eel, a species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is reported to be present is expected in most permanent watercourses within the watershed (Dillon Consulting 2009).

Provincially listed priority species of conservation concern within the watershed include brook trout and gaspereau (Dillon Consulting 2009) both of which are listed as sensitive (yellow) (NSDNR 2009). Brook trout are expected to occur in most permanent coldwater watercourses and were observed in a tributary to Paper Mill Lake and in Ragged Lake located within two kilometers of the southern boundary of the watershed.

Anadromous fish which live in the sea and spawn in rivers (such as Atlantic salmon, gaspereau and smelt) are unlikely to occur in the Birch Cove lakes due to the poor upstream fish access (Dillon Consulting 2009). Although visual surveys of a number of lakes and tributaries in the watershed have indicated that salmonid habitat is present (Porter Dillon 1996), access to the interior lakes of watershed is obstructed by dams at the outlets of Paper Mill Lake, Kearney Lake and Quarrie Lake, none of which are equipped with fish passage or fish ladders (Fielding 2011).

The watershed primarily supports recreational fishing and has done so since at least the 1930s (HNWTA 2012). Brook trout and smallmouth bass are the dominant sport fish species caught in the area. Of the waterbodies within the Birch Cove Lakes watershed, only Kearney Lake is known to have been stocked with fish (Porter Dillon 1996).

The downstream marine environment in Bedford Basin also supports recreational fishing, although limited commercial lobster fishing has also occurred. Bedford Basin is currently closed to shellfish harvest (Dillon Consulting 2009).

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

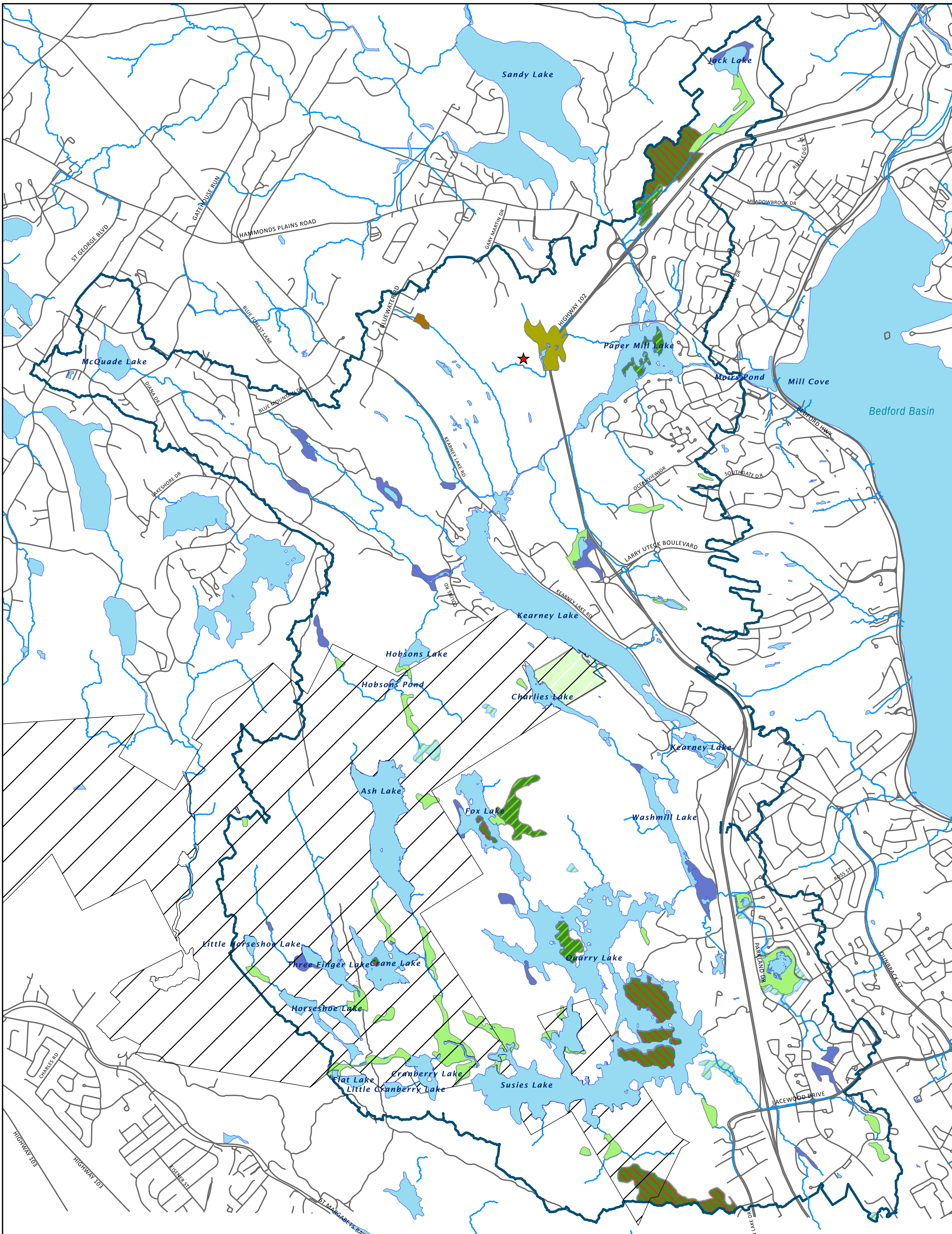
> "an area commonly referred to as marsh, swamp, fen or bog that either periodically or permanently has a water table at, near or above the land's surface or that is saturated with water. Such an area sustains aquatic processes as indicated by the presence of poorly drained soils, hydrophytic vegetation 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 throughout the watershed, but do not constitute a large proportion of the total area. Wetlands occupy just less than 1 km^2 of the watershed, or 93 ha - approximately the same surface area occupied by exposed bedrock (Figure 6). The highest density of wetland habitat is found in the southern portion of the watershed, south of Ash, Fox, and Washmill Lakes.

Wetlands of the Birch Cove Lakes watershed generally consist of marsh and swamp-type habitats. Most are small, occupying less than a hectare although several are in the 5-10 hectare range. Marshes account for approximately 62% of the total wetland habitat in the watershed, while swamps account for approximately 28% of the wetlands. The occasional fen and/or bog is observed in the northern portion of the watershed near Paper Mill Lake, representing 9% and 1% of the watershed's total wetland area, respectively (NSDNR 2004a).

The most common wetlands reported in the Birch Cove Lakes watershed are (a) low shrub dominated swamps that fringe shallow open water wetlands and are also present along the banks of streams, (b) coniferous treed swamps in poorly drained basins, and (c) coniferous treed bogs found in poorly drained basins or along the edges of ponds. Typical flora found in swamp habitats include sweet gale, leatherleaf, winterberry, speckled alder, black spruce, balsam fir and red maple. Marsh/open water habitats are dominated by cow lily, burreed, bladderwort, and bulrush (Jacques Whitford 2004).

Aquatic habitats occur within and adjacent to the watercourses and lakes in the watershed. The aquatic plant community is not very diverse, consisting of patches of bulrush, lilies, burreed and pondweed in sheltered cove areas (Dillon Consulting 2009).



- ★ Listera Australis
- Watercourse
- Roads
- Lakes
- Birch Cove Lakes Watershed
- Crown Land
- Forest - Old Growth
- Forest Significant Wildlife Habitat
- Wetland
- Wilderness Area

Wetland Classification

- Bog or Fen
- Fen
- Marsh
- Swamp
- Water

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Wetlands and Significant Vegetation

May 2012	1:30,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 001	

AECOM

Figure 6

0 495 990 1,980
Meters

Vegetation

Terrestrial uplands within the Birch Cove Lakes watershed are largely occupied by stands of softwood and mixed-wood forest, although hardwood forest, disturbed areas, and extensive barrens (exposed rock) habitat are also found throughout the area (Figure 6). The forest classification for the area is the Halifax Red Spruce-Hemlock-Pine Zone, which is underlain by granite bedrock (Loucks 1968). In previous studies, softwood stands along Fraser Lake have been noted as potential old growth habitat, while provincial mapping identifies an area of less than 0.2 km^2 between Fox and Washmill Lakes as being old growth habitat.

Softwood forests are present in patches throughout the watershed but are concentrated south of Susies Lake (EDM 2006), and are typically found in areas with impeded drainage (Jacques Whitford 2004). Softwood forest habitats are dominated by red and black spruce and balsam fir, with minor amounts of red maple. 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, particularly in the Black Duck Brook area (Dillon Consulting 2009).

Mixed woods occur in patches throughout the watershed, typically in areas where soil cover is more extensive than where hardwood stands are found (EDM 2006). Mixed woods in the watershed generally include red and black spruce, red maple, red oak and balsam fir. Shrub species such as false mountain holly, lambkill and lowbush blueberry are also often present, and wild sarsaparilla and ferns are prevalent throughout (Dillon Consulting 2009). These habitats are found mainly to the northwest of Kearney Lake on either side of the Kearney Lake Road (Jacques Whitford 2004).

Hardwood-dominated forests occur north of Quarrie and east of Kearney Lakes, where thicker soil has developed. Most of this area is windswept and exposed (EDM 2006). 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 (Dillon Consulting 2009). 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).

Extensive granite barrens habitat is present throughout the watershed. Where granite bedrock is close to the surface, soils are thin to non-existent and vegetation is dominated by dense low shrub species. This habitat type is mainly found in the area between Washmill and Charlies Lakes.

Habitat varies along the shorelines of Susies and Quarrie Lakes depending on soil development. Typical shoreline species include shrubs (steeplebush, leatherleaf, sheep laurel, blueberry), herbs of open areas (asters, goldenrods) and grasses (tickle-grass, deergrass) (Dillon Consulting 2009).

Disturbed habitats occur in various locations within the watershed and include residential and commercial development located primarily along roads at the south, east and north extremities of the watershed. Remnant forest fire burns and storm blowdown also occur throughout the watershed. Stands of red oak, red maple, white birch, white pine and black spruce occur in previously burned areas, along with typical barrens species (Dillon Consulting 2009).

Rare Flora

The environmental assessment (EA) report prepared by Dillon Consulting (2009) for the proposed Highway 113 project reported the potential presence of two rare plant species listed by NSDNR within the Birch Cove Lakes watershed: the southern twayblade and the mountain sandwort.

The southern twayblade is listed as red (at risk) by NSDNR and is also listed nationally as S1 (extremely rare) by the Atlantic Canada Conservation Data Centre (ACCDC). The southern twayblade is a small orchid and is considered part of the coastal plain flora of Nova Scotia. The characteristic habitat of the southern twayblade is wetland dominated by black spruce, balsam fir, false holly and cinnamon fern. It thrives in damp sphagnum moss patches lacking competition from other plant species. This species was observed during vascular plant surveys undertaken in support of the EA in 2008-2009 in a number of wetlands at the eastern end of the highway alignment near Paper Mill Lake (Figure 6). The EA noted that the location of these orchids typically varies from year to year, based on seasonal conditions and microclimates.

The EA also noted that mountain sandwort, listed as yellow (sensitive) by NSDNR, is reported to inhabit Blue Mountain Hill between Ragged and Ash Lakes; however, no colonies of mountain sandwort were identified within the proposed alignment during the botanical surveys (Dillon Consulting 2009). The characteristic habitat of the mountain sandwort is granitic ledges and gravel, on coasts at higher elevations.

No other federal or provincially listed plant species were identified. Also, no invasive species were identified although the encroachment of urban habitats often results in the introduction of non-native species (Dillon Consulting 2009).

Wildlife and Habitat Management

Until recent changes to NSDNR habitat maps, there were a number of NSDNR designated Significant Habitat Areas within and adjacent to the Birch Cove Lakes watershed. These Habitat Areas included an area designated for mainland moose (a provincially endangered species), an area designated for brook trout (a species/habitat of concern) and a designated ecological site, the Hemlock Ravine Park (outside of the watershed east of Highway 102) (Dillon Consulting 2009). In contrast, the most recent NSDNR mapping accessed in April 2012 no longer includes fisheries or restricted and limited land use data sets and no Significant Habitats Areas are identified within the watershed. An area south of Paper Mill Lake is designated as ‘Other Habitat’ due to the presence of an inactive eagle nest, although this area is not located within the Birch Cove Lakes watershed (NSDNR 2004b).

The Birch Cove Lakes watershed represents a wilderness corridor connecting approximately 220 km2 of undeveloped land on the Chebucto Peninsula with the province’s greater mainland (EDM 2006). The watershed has a low diversity of small mammals and a high concentration of white-tail deer (Washburn and Gillis 2000). Other than deer, which will avoid barren and wetland habitats, species typical of the forest and lakeshore habitats within the watershed 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).

Mainland moose are listed as endangered according to the Nova Scotia Endangered Species Act. There are approximately 1,000 mainland moose remaining in the province. The Chebucto moose group, which occupies areas within HRM, consists of an exceptionally small group of approximately 30 animals. NSDNR has noted that there are still mainland moose in the general area of the watershed; however, none has been reported north of Highway 103 for the last number of years. NSDNR suggests that they are unlikely to be present within the watershed boundaries (Snaith 2001; Tony Nette – 2009 NSDNR pers. comm. in Dillon Consulting 2009).

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 in the watershed (Porter Dillon 1996). More recently, Dillon Consulting (2009) reported that 62 species of birds were identified during the environmental assessment for proposed Highway 113 project. Of these 62 species, six Priority/At Risk Species were identified:

1. Canada warbler (NSDNR yellow/sensitive; COSEWIC/NSESA threatened) – typically nesting in mature to mid-aged mixed forest habitat;
2. common nighthawk (NSDNR yellow/sensitive, COSEWIC/NSESA threatened) – typically nesting on open ground, cutovers, or buildings;
3. olive-sided flycatcher (NSDNR yellow/sensitive, COSEWIC/NSESA threatened) – typically nesting in forest edge habitat;
4. gray jay (NSDNR yellow/sensitive) – typically nesting in mature conifer habitat;
5. boreal chickadee (NSDNR yellow/sensitive) – typically nesting in nest cavities in rotting tree stumps; and
6. common loon (NSDNR yellow/sensitive) – typically nesting on islands or similar protected.

The forested areas and wetland areas within the watershed serve as nesting habitat for passerines. One of the bird surveys conducted for the proposed Highway 113 project identified a single owl (great horned owl, NSDNR listed stable population) as breeding in the general area. No raptor nests have been identified within the watershed although a red-tailed hawk and osprey have been observed foraging in the area (Dillon Consulting 2009). Both of these species and bald eagles have been observed more recently (B. MacDonald, pers. comm. 2012).

Evidence of aquatic mammals such as beaver and muskrat has been reported along the stream mouths and wetlands of Susies and Quarrie Lakes, and mink and weasel (and possibly otter) are also expected to be present. Herpetiles observed or expected based on habitat in the area include a variety of common species of frogs, salamanders, peepers and snakes (Porter Dillon 1996).

2.4 Surface Water Resources

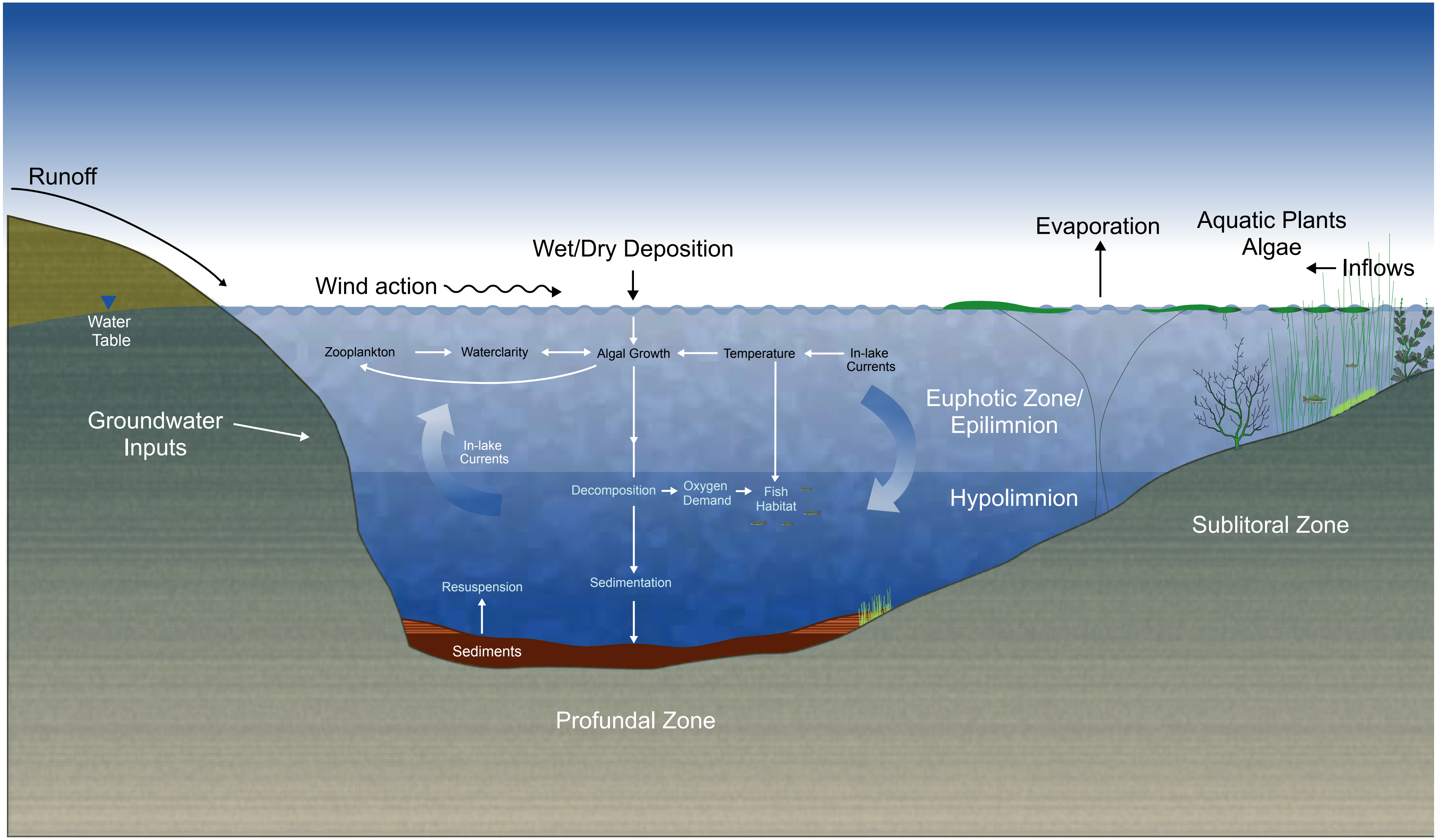
2.4.1 Lake Chemistry

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 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 key to understanding lake chemistry are illustrated in Figure 7.

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 within and 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 (water column) 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 Birch Cove Lakes watershed, ice cover on lakes is typically of short duration and so winter oxygen depletion is less common than in more continental climates.



LEGEND

Designed By:	DLS	Drawn By:	SBB
Checked By:	DLS	Approved By:	DLS
Date Issued:	May 2012	Project No.:	?????

Schematic Diagram of Lake Processes that Influence Water Quality

Schematic Cross-Section

AECOM

FIGURE 7

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

2.4.2 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 Birch Cove Lakes watershed lakes. The higher levels of alkalinity “buffer” or protect a water body against changes in pH from the addition of acidic or basic substances such as sulphate from acid rain or alkaline minerals in glacial deposits. 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****:*
   Metals including lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), and zinc (Zn) reflect the natural geology of a watershed but, at high concentrations 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 levels.

3. ***Nutrients****:*
   Total phosphorus (TP), total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate (NO_3), and dissolved organic carbon (DOC) describe the nutrient characteristics of a lake. Nutrients (phosphorus and nitrogen

forms) are critical water quality indicators, given the significance 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 of importance to urban lakes include 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. Although chlorophyll, the photosynthetic pigment in algae, is not, strictly speaking, a nutrient it is used as an indicator of algal response to lake nutrients.

4. ***Bacteria**:*
   Water borne diseases have re-emerged into the public consciousness after consumption of *E. Coli* contaminated well water killed and sickened the residents of Walkerton, Ontario. Although the lakes in the Birch Cove Lakes watershed are not a source of public potable water (they may be used for private supplies), many are used for recreational activities such as swimming, canoeing and other water sports. Bacteria are also 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.

2.4.3 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 nuisance 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 *α* 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.

One way to measure water clarity is using a Secchi disc. The disc is lowered into the lake until the observer loses sight of it. The depth of the water where the disk vanishes and reappears is the Secchi depth. Shallower Secchi depths indicate water that has lower clarity (is more turbid) and high Secchi depths indicate clearer water. This method is used primarily for its simplicity and low cost. When used to compare between similar lakes or to assess changes over time, is a good index of lake productivity.

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. Additionally, many lakes in Nova Scotia are "dystrophic". These brownish or yellowish colored lakes are commonly characterized by a lack of nutrients, a low pH (acidic) and high humus content. Plant and animal life are typically sparse, and the water has a high oxygen demand. Algal abundance in dystrophic lakes is limited by light penetration rather than phosphorus concentrations which can confound the trophic state classification.

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 and assigning lakes to a category based on the values measured. Environment Canada (CCME 2004) provided the following classification (Table 4) of trophic status for lakes and rivers, as taken from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

Table 4. Trophic Status Based Trigger Ranges for Canadian Waters (CCME, 2004)

	Trigger Ranges for Total Phosphorus (μg/L)	
Trophic Status	**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	-

2.4.4 Urbanizing Lakes

Halifax is a unique metropolitan centre by virtue of the large number of lakes within its urban boundaries. The location of the lakes makes them particularly valuable assets to the urban population. This section of the report discusses the characteristics, features and values of urban lakes, what they are, and how they differ from other lakes.

Some of the characteristics that define urban lakes include (Schueler and Simpson 2001):

1. They have a watershed to drainage area ratio of at least 10:1, meaning that their watersheds exert a strong influence on water quality within the lake;
2. Their watersheds contain at least 5% impervious cover as an index of urban development. This promotes stormwater runoff and increases the likelihood of contaminant introduction to the lakes; and
3. They are generally managed for recreation, flood control, water supply or some other direct human use.

Urban lakes face different problems than those in rural areas. Residential and commercial development with its increasing areas of concrete, asphalt and buildings leaves more of the urban environment impermeable to rainwater and snowmelt. Urbanization also alters the state of natural vegetation, destroying or thinning existing vegetation or changing vegetation types.

Urbanization 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 pollutants to the lake.

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. These 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 fish kills. Additionally, the increase in impervious surfaces and heat retention of these surfaces can result in the increased speed and volume of runoff in urban areas and during the summer may increases water temperature, which can also adversely affect the lake’s aquatic health.

“Point source” pollutant inputs to lakes, normally considered to be outfalls from waste water treatment plants, may also degrade the quality of lake waters depending on the extent of wastewater treatment prior to discharge. Sewage treatment facility overflows and bypasses during storms or malfunction can also occur. High nutrient loads, especially phosphorus from wastewater treatment facilities, can significantly add to the natural and non-point loading of phosphorus to lakes resulting in their rapid eutrophication.

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 of urban lakes to the public. 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 retrofit the watershed after the lake has degraded to an unacceptable condition.

2.4.5 Lake Description

Morphometry and Characteristics of the Lakes

The irregular landscape and drainage patterns of the Birch Cove Lakes watershed create many lakes that add much to the scenic and recreational value of the watershed. Wet areas mapping produced by NSDNR (2007) shows how these water bodies and wetlands are connected via subsurface flows and unmapped stream / drainage channels. The largest deep water body is Kearney Lake which is connected hydraulically to Washmill Lake, Quarrie Lake and Susies Lake to the south and Paper Mill Lake to the north. This system of lakes and streams flows to the north discharging into the Bedford Basin and form a natural corridor through the watershed.

The lakes and ponds in the watershed are shallow with the largest by surface area, Susies Lake and Quarrie Lake, being no more than 10 metres deep. Elsewhere, the granite bedrock outcrops are narrow and formed into ridges, producing deeper lakes such as Kearney Lake, which has a maximum depth of 28 metres (NSDTPW and NSDNR, 2006).

The lakes in the Birch Cove Lakes watershed range in size from approximately 1 ha (Little Horseshoe) to 82 ha (Susies Lake). The smaller lakes (<5 ha) tend to be located in the headwaters (e.g. Little Horseshoe, Little Cranberry, Flat Lake, Hobsons Lake, Jack Lake and Cranberry Lake), whereas the larger lakes are located in the lower portion of the drainage basin (e.g. Kearney, Susies, and Quarrie Lakes).

The detailed bathymetry is available for only a few lakes (Table 5). These include Kearney Lake, Paper Mill Lake, Susies Lake, Quarrie Lake and Washmill Lake. Paper Mill, Susies and Quarrie Lakes are shallow lakes with relatively large surface areas and mean depths of less than 5 m. Washmill and Kearney Lakes are narrow lakes with mean depth of 2.5 and 11 m respectively. Kearney Lake is the deepest lake with a maximum depth of 27 m. Due to its large surface area and depth, Kearney Lake has the greatest volume, followed by Susies and Quarrie Lakes.

Table 5 Morphometry of Lakes in Birch Cove

Lake	Surface Area (ha)	Maximum[1] Depth (m)	Average[1] Depth (m)	Volume[1] (m^3)
Little Horseshoe Lake	1.1			
Little Cranberry Lake	1.6			
Flat Lake	1.9			
Hobsons Lake	3.3			
Jack Lake	3.9			
Kearney Lake (upper)	4.0			
Cranberry Lake	4.5			
Charlies Lake	5.7			
McQuade Lake	6.5			
Three Finger Lake	6.6			
Horseshoe Lake	7.7			
Washmill Lake	7.8	8[a]	2.5[a]	19.3×10^6
Crane Lake	11.1			
Fox Lake	14.1			
Paper Mill Lake	25.1	6[b]	2.2[b]	55.3×10^6
Ash Lake	29.8			
Quarrie Lake	48.1	8[a]	3.5[a]	168.4×10^6
Kearney Lake (Main)	64.2	27[b]	11.3[b]	739.4×10^6
Susies Lake	82.7	11[a]	3.7[a]	264.7×10^6

Notes: [a] from Porter Dillon 1996, [b] from Scott and Hart 2004. [1] Based on surface area and mean depth.

<u>Data Sources</u>

One of the key objectives of the Birch Cove Lakes watershed study is to establish water quality objectives to prevent any further deterioration in water quality. Water quality data collected in the past six years was used to assess current conditions, prior to any further development in the watershed. Historical data (collected prior to 2006) was used for comparison purposes, when appropriate. The year 2006 was selected as starting year since this is the first year of the on-going, more comprehensive data set collected by or on behalf of HRM. Jacques Whitford (2004) reported data collected by AMEC in 2003; however, the report raised questions regarding the validity of the results. All previous data were collected prior to 2000 and were considered to be too old to establish current conditions for the purposes of this study.

Water quality data for the Birch Cove Lakes were obtained primarily from the various programs of Halifax Regional Municipality (HRM). Data were provided for the lakes and tributaries of Washmill, Kearney and Paper Mill Lakes and the sample locations are presented in Figure 8.

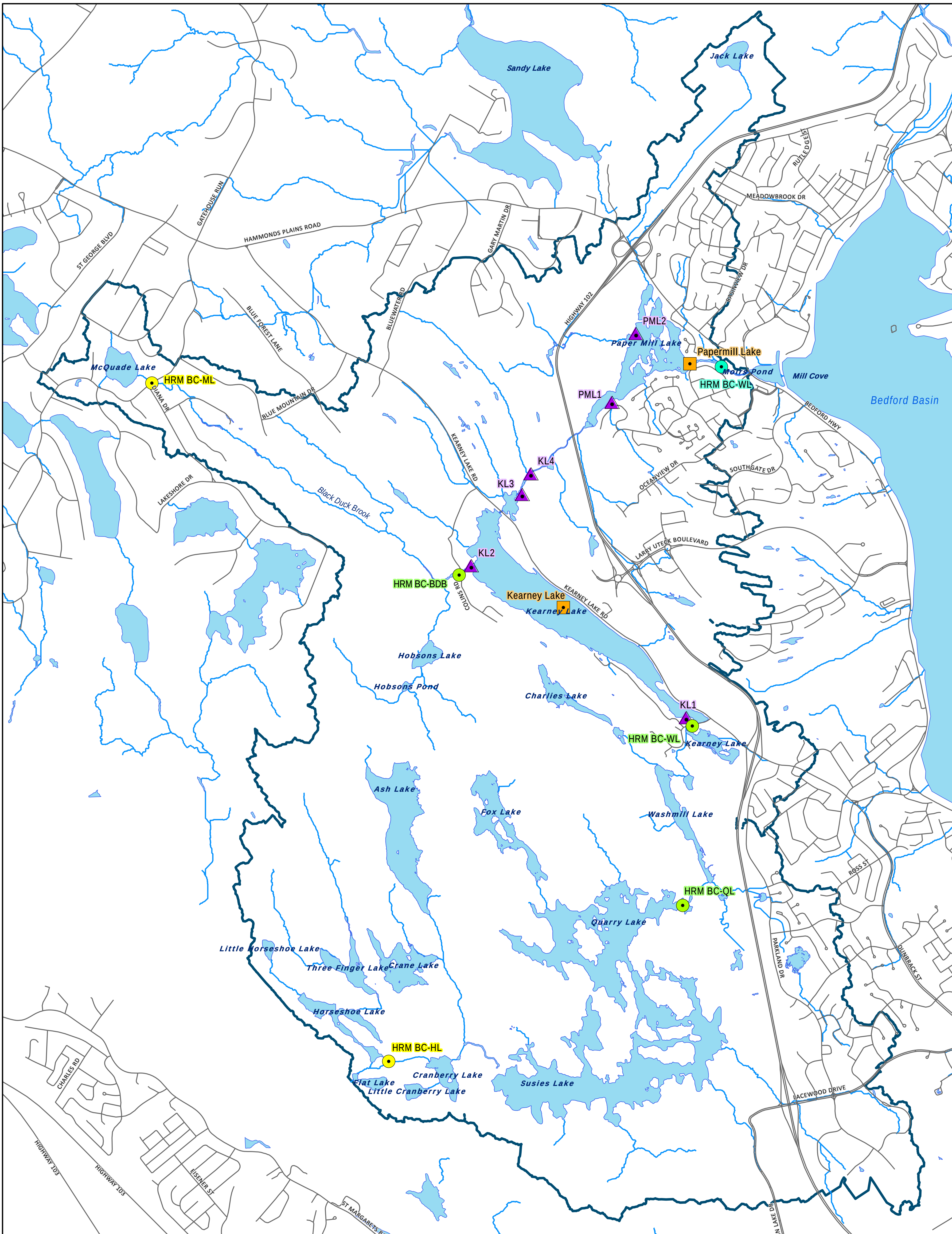
AECOM Supplementary Water Quality Data

AECOM undertook a review of the existing water quality data and identified areas in the Birch Cove Lakes watershed that lacked recent or any water quality data. To help address these gaps, AECOM is undertaking additional limited water quality sampling on a quarterly basis over the course of this project. These new sampling sites include the outflows of Washmill Lake, McQuade Lake, Big Horseshoe Lake, Quarrie Lake, and Black Duck Brook just upstream of Kearney Lake (Figure 8).

AECOM assembled a database in Excel spreadsheet form to compile all laboratory and field analyses for water quality samples collected within the Birch Cove Lakes watershed. The data sources consisted of:

1. Data collected by HRM (May 2006 to October 2008) as part of the HRM Lakes Water Quality Sampling Program;
2. Data collected by SNC Lavalin on behalf of HRM (June 2009 to October 2011) as a part of the Water Quality Monitoring for Bedford West Sub Areas 3 & 4;
3. Data collected by Nova Scotia Environment (NSE) and Nova Scotia Department of Fisheries and Aquaculture (NSDFA) as a part of the Nova Scotia Lakes Inventory Program (1940 to Present); and
4. Data collected by AECOM (August 2011 to April 2012[1]) as a part of the scope of work for the subject watershed study.

[1] *Two additional sampling events (May and August, 2012) will be reported in the Final Report.*



- AECOM Quality (since August 2011) / Quantity (since November 2011) Sampling
- AECOM Quality Sampling (since August 2011)
- AECOM Quantity Sampling (since November 2011)
- HRM Sampling (since May 2006)
- Bedford West Sampling (since June 2009)
- Roads
- Watercourse
- Lakes
- Birch Cove Lakes Watershed

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Current Surface Water Quality Monitoring Stations

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	

AECOM

Figure 8

0 500 1,000 2,000
Meters

The HRM lakes water quality data were provided to AECOM by HRM in Excel spreadsheets. AECOM also downloaded files from the HRM website at http://www.halifax.ca/environment/lakesandrivers.html. Nova Scotia Lakes Inventory Program data were obtained electronically from http://www.gov.ns.ca/nse/surface.water/lakesurveyprogram.asp. Data for water quality samples collected within the Birch Cove Lakes watershed were extracted from the data provided from the website. This included data from the years 1983 and 1984. It should be noted that the Nova Scotia Lakes Inventory data did not include a reference map so confirmation of the latitude and longitude coordinates was not possible.

SNC Lavalin Bedford West sampling data were provided to AECOM electronically as spreadsheets by HRM. Data from sampling from AECOM for 2011 and 2012 were entered into the database as data became available from the laboratory.

Easting and Northing coordinates were provided for most sampling locations for HRM based on sample co-ordinates included with the HRM 2006 sampling results. Where coordinates were not provided for the HRM lake station and Bedford West datasets , HRM provided coordinates electronically by email or manually marked maps showing the locations which were then mapped for the database. Latitude and Longitude coordinates were provided with the Nova Scotia Lakes Inventory Data. These data were converted to Easting and Northing coordinates using GIS.

Original reports were reviewed for the reported laboratory detection limits (when available) and data points that were below these detection limits were indicated by the "<" sign and the detection limit. For detection limits that were not provided, AECOM contacted HRM for clarification. For parameters further used in AECOM's calculations, an additional column was inserted into the database with the detection limit without the "<" sign so that the value could be used in subsequent reporting.

Table 6 presents the water quality data sources used for this report.

Table 6. Data Sources Used to Establish Current Water Quality in Birch Cove

Sampled by	Sampling Program	Sampling Period	Sampling Locations
Halifax Regional Municipality	HRM Lakes Water Quality Sampling Program	2006 to 2008; three times per year, spring summer and fall	Locations on Kearney Lake and Paper Mill Lake
SNC Lavalin	HRM Water Quality Monitoring for Bedford West Sub Areas 3 & 4	2009 to 2011; three times per year, spring summer and fall	Locations on Kearney Lake, Paper Mill Lake and Black Duck Brook
AECOM		2011 to 2012 – 2 events to date, 4 events in total	Washmill Lake, McQuade Lake, Big Horseshoe Lake, Quarrie Lake, and Black Duck Brook

Water Quality Data Analysis and Synthesis

In Kearney and Paper Mill Lakes, where there were a sufficient number of data points, the minimum, maximum, 25th percentile, 75th percentile, median, average, and standard deviation were calculated for the key water quality parameters. These parameters included: total phosphorus (TP), total kjeldahl nitrogen (TKN), and chlorophyll α, as indicators of nutrient enrichment and trophic status; TSS and Secchi Depth as indicators of water clarity; and nitrate, ammonia, *E. coli*, and dissolved chloride as indicators of anthropogenic influences. The results are summarized in Table 7.

For data analysis (e.g. calculating averages) data points that were reported as less than the detection limit were taken at the detection limit concentration. For example, for TSS with a detection limit of 1 mg/L; reported values of <1 mg/L were processed as 1 mg/L.

Total phosphorus has different detection limits depending on the technique used to analyse the samples. For example, a metal scan that included TP has a detection limit of 2 μg/L (0.002 mg/L) while the colourimetric TP technique has a detection limit ranging from 2 to 5 μg/L (0.002 to 0.005 mg/L). The threshold for moving from the mesotrophic to eutrophic trophic status is 20 μg/L (0.020 mg/L) the same as the high detection limit from the metals scan. Consequently, any data point equal to or less than the detection limit of 20 μg/L (0.02 mg/L) was removed from analysis, as the actual phosphorus concentration could be an order of magnitude less than the detection limit. If a data point was above the detection limit of 20 μg/L (0.02 mg/L) the value was retained for analysis as it represented an actual phosphorus concentration. Data points with values less than the lower detection limits were considered equal to the detection limit (i.e., a sample result reported as <2 μg/L (<0.002 mg/L) was analyzed as if the result were 2 μg/L (0.002 mg/L) as this was considered conservative measure which would not bias the interpretation of the lake trophic status.

All replicate samples were used in the analysis as a second value for the same sampling date.

General Water Quality

The following section discusses the recent water quality of selected lakes in the Birch Cove Lakes watershed for specific water quality variables. Historical water quality is included for comparison purposes where appropriate.

Kearney Lake

Historically water samples have been collected from the centre of Kearney Lake and from two locations along the watercourse to Paper Mill Lake (KL3 and KL4; Table 7 and Figure 8). Stations KL3 and KL4 are located upstream and downstream of the dam, respectively. Samples have been collected since 2006, two to three times per year.

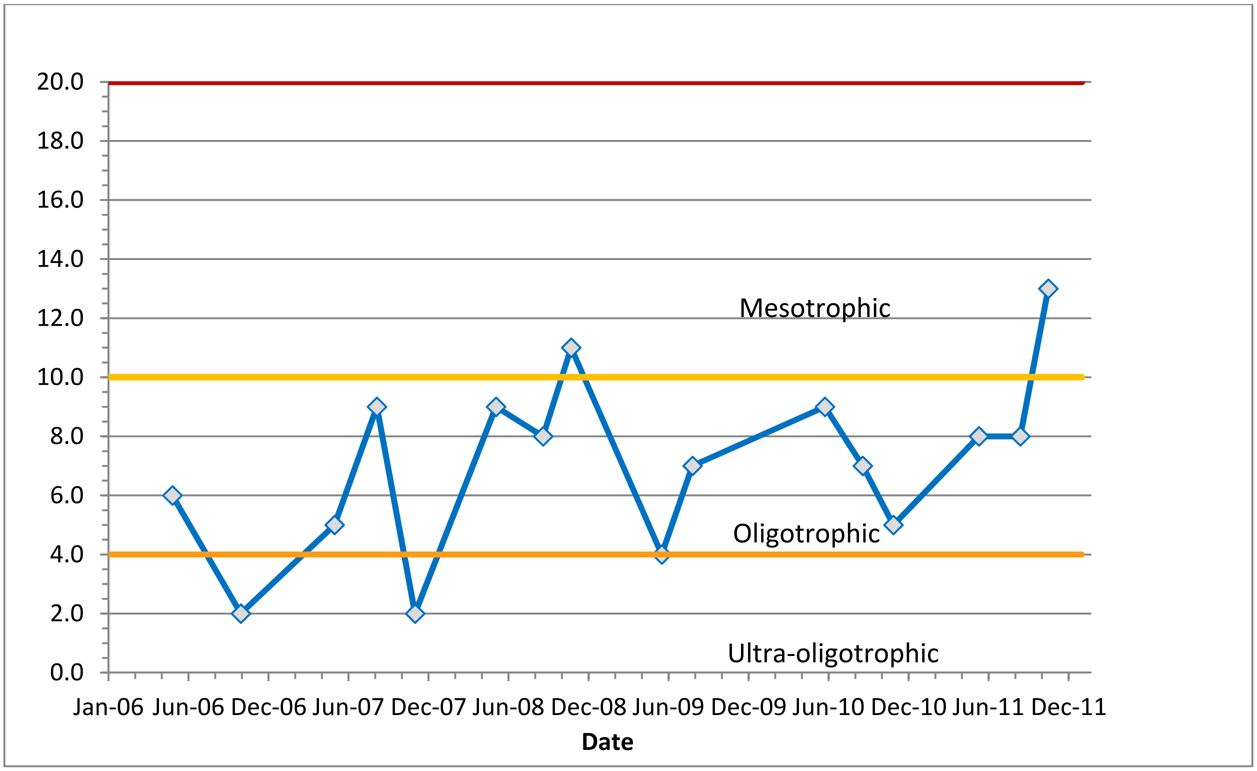
In samples collected from the centre of Kearney Lake, epilimnetic (surface) phosphorus concentrations ranged from <2 μg/L to 13 μg/L (<0.002 to 0.013 mg/L) (Figure 9) with a median concentration of 8 μg/L (0.008 mg/L). Concentrations are generally in the mesotrophic range, with some samples in the oligotrophic range and one sample in the eutrophic range, as noted by the median concentration of 8 μg/L (0.008 mg/L). Chlorophyll α concentrations were low and ranged from 0.35 to 2.60 μg/L. The high TP concentration measured on October 16, 2011, followed a 21.6 mm rain event on October 14, 2011 and wet weather the first two weeks in October. Differences in spring, summer and fall epilimnetic phosphorus concentrations were negligible (as noted in Table 8), indicating that the phosphorus concentrations have been relatively consistent between seasons. Samples collected 1 m below the thermocline for phosphorus were relatively low and comparable to epilimnion phosphorus concentrations.

Table 7. Summary of Selected Surface Water Quality Parameters in the Birch Cove Lakes watershed (2006-2011

		TP Surface*	TP Deep*	TKN	Nitrate	Ammonia	Chlorophyll α	TSS	Secchi Depth	E.coli [a]	Dissolved Chloride	N:P Ratio
		µg/L	**µg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**mg/L**	**m**	**/100mL**	**mg/L**	
Paper Mill Lake	**No of Samples**	16	n/a	11	8	14	17	17	11	6	15	
	min	<2		<0.1 [b]	0.07	<0.05	0.07	<1	2.2	2	24	
	max	18		0.4	0.49	<0.05	4.75	8	3.5	250	77	
	median	7		0.2	0.17	<0.05	1.17	2	2.8		58	
	average	7		0.2	0.22	<0.06	1.39	3.2	2.1	67	52	35
	standard deviation	4		0.1	0.16		1.04	2	0.4		17	
Kearney Lake	**No of Samples**	16	4	11	8	14	17	17	14	7	16	
	min	2	3	0 [b]	0.1	<0.05	0.35	<1 [b]	2.4	1	10	
	max	13	10	0.80	0.21	<0.05	2.60	17	5	250	80	
	median	8	8	0.30	0.17	<0.05	0.97	2	3.8		62	
	average	7	6	0.32	0.16	<0.05	1.12	3.29	4.15	15	58	46
	standard deviation	3	3	0.22	0.04		0.58	3.9	0.9		21	
Washmill Lake (KL1 and AECOM)	**No of Samples**	9	n/a	2	6	9	11	13	8	8	11	
	min	<2		0.1	0.10	<0.05	0.53	<1	2.35	8	27	
	max	12		0.3	0.21	<0.05	1.73	17	5.00	>250	81	
	median	8			0.17	<0.05	0.99	2	4.17		60	
	average	8		0.2	0.17	<0.05	1.06	3	3.89	31	56	26
	standard deviation	3			0.04	0.00	0.39	4	1.11		18	
Black Duck Brock (KL2 and AECOM)	**No of Samples**	9	n/a	1	5	9	10	12	n/a	7	10	
	min	8		0.20	0.06	0.05	0.21	<1		2	9	
	max	40			0.12	0.06	6.05	7		1500	25	
	median	9			0.07	0.05	0.78	2			17	
	average	15			0.08	0.05	1.29	3		49	17	
	standard deviation	12			0.03	0.00	1.75	2			5	

Table 7. Summary of Selected Surface Water Quality Parameters in the Birch Cove Lakes watershed (2006-2011

Quarrie Lake	**No of Samples**	2	n/a	2	2	n/a	2	4	n/a	n/a	2	
	min	3		0.3	<0.05		0.94	<1			25	
	max	14		0.4	0.1		1.03	2			40	
	average	9		0.35				1.3				41
	standard deviation							0.5				
Big Horseshoe Lake	**No of Samples**	2	n/a	2	2	n/a	2	4 [b]	n/a	n/a	2	
	min	9		0.6	<0.05		1.68	<1			3	
	max	20		0.7	<0.05		1.97	2.2			4	
	average	15		0.65				2.6				45
	standard deviation							1.7				
McQuade Lake	**No of Samples**	2	n/a	2	2	n/a	2	4	n/a	n/a	2	
	min	2		0.4	0.13		4.24	<1			26	
	max	20		0.4	0.19		7.44	2			32	
	average	11		0.40				1.8				37
	standard deviation							0.5				



Notes: ultra-oligotrophic: TP ≤4 µg/L, oligotrophic: TP>4 µg/L and ≤10 µg/L, mesotrophic: TP >10 µg/Land ≤ 20 µg/L, meso-eutrophic: TP >20 µg/L and ≤ 35µg/L

Figure 9. Epilimnetic Phosphorus Concentration (µg/L) in Kearney Lake (2006-2011)

From the central Kearney Lake station, nitrogen compounds were also low; TKN ranged from non-detectable to 0.8 mg/L, with a median concentration of 0.30 mg/L and ammonia was below detection limit during each sampling event. *E. coli* concentrations were also low and ranged from below the detection limit (1 CFU/100 mL) to 37 CFU/100 mL[2].

Metal concentrations were low, mostly below analytical detection limits. Only aluminum, copper, iron and zinc exceeded their CWQG for protection of aquatic life on only selected occasions.

The water quality at the outflow stations KL3 and KL4 were similar, and of good quality. At KL3, the upstream station, total phosphorus concentrations range from <2 to 12 µg/L (<0.002 mg/L to 0.012 mg/L) with a median concentration of 5 µg/L (0.005 mg/L). At KL4, concentrations ranged from <2 µg/L to 26 µg/L (<0.002 to 0.0026 mg/L) with a median concentration of 3 µg/L (0.003 mg/L). Again, the maximum values were measured on October 16, 2011, following rain. At both stations nitrogen compounds, TSS, chlorophyll a, *E. coli* were low (frequently below the detection limit), and water quality was similar to that measured in Kearney Lake.

[2] Two common measurements of bacteria in aquatic environments are most probable number (MPN) and colony-forming unit (CFU), both which are typically reported in a volume of 100 mL E. coli concentrations reported in both units were deemed essentially equivalent and combined for the purpose of data analysis.

Paper Mill Lake

Water samples have been collected from three locations in Paper Mill Lake: the inflow (PML1), the western basin of the lake (PML2) and the outlet (Paper Mill Lake; Figure 8). In addition there are two stations located along a drainage discharge from Highway 102.

At all sampling locations in Paper Mill Lake, median TSS, nitrate, nitrite, ammonia, and orthophosphate concentrations were low. The inflow from Kearney Lake (PML1) is of high quality. The pH and conductivity are similar to that measured in Kearney Lake. Sodium and chloride concentrations are relatively low (26.8 and 44 mg/L, respectively). Total phosphorus concentrations in the inflow range from <2 to 30 µg/L (<0.002 to 0.03 mg/L) (Figure 10) with a median concentration of 11 µg/L (0.011 mg/L) orthophosphate concentrations were below detection (10 µg/L or 0.01 mg/L). The concentrations of nitrogen compounds were low. *E. coli* concentrations were also low (geometric mean of 34 CFU/100ml).

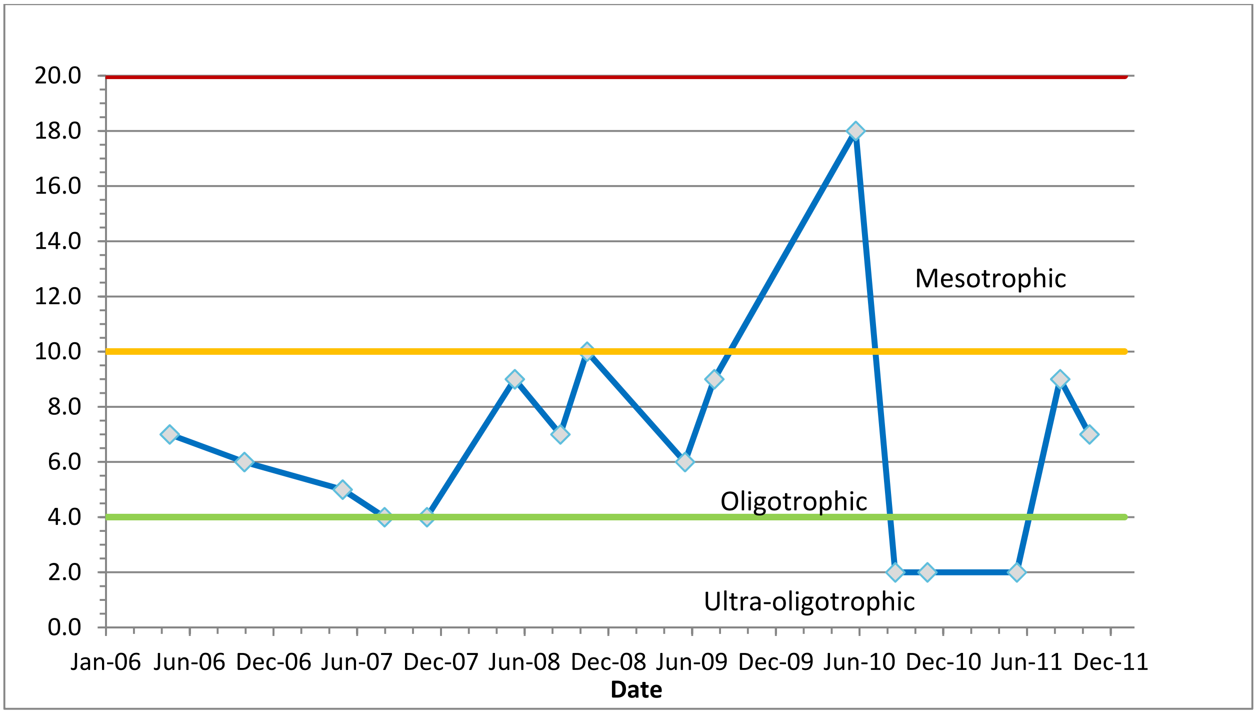
In the north western part of the lake (PML2), the pH and the conductivity are similar to values measured at the lake inflow (6.67 and 234 µS/cm, respectively). Dissolved chloride and sodium are greater than those measured at the Kearney Lake inflow, indicating a possible input from the nearby inflow from Highway 102. Total median phosphorus is low at 7 µg/L (0.007 mg/L) and orthophosphate concentrations were below detection (10 µg/L or 0.01 mg/L). The concentrations of nitrogen compounds were low, with nitrite and ammonia below detection. *E. coli* concentrations were also low (geometric mean of 34 CFU/100ml).

The drainage discharge inflow from Highway 102 has high concentrations of phosphorus with a median total phosphorus concentration of 20 µg/L (0.02 mg/L).

At the outflow representing the whole lake concentrations, the total phosphorus concentrations ranged from <2 to 18 µg/L (<0.002 to 0.018 mg/L) with no seasonal variations in concentrations (Table 8). Concentrations fluctuate in the mesotrophic range, with selected values in the oligotrophic range. The TP concentration at the outflow has been relatively stable. The median total phosphorus concentration is 7 µg/L (0.007 mg/L) which is in the mesotrophic range. However, some samples are in the oligotrophic to eutrophic levels. Chlorophyll α concentrations were low and ranged from 0.07 to 4.75 µg/L, with a median concentration of 1.17 µg/L.

Table 8. Seasonal Total Phosphorus Concentrations in Kearney and Paper Mill Lakes (µg/L)

		Spring	Summer	Fall and Winter	Annual Mean
		April, May, June	**July, Aug, Sept**	**Oct & Nov**	
Kearney Lake (surface)	**Number of Samples**	6	5	5	16
	Min	4	7	<2	<2
	Max	9	9	13	13
	Median	7	8	5	7.5
	standard deviation	2	1	5	3
Paper Mill Lake	**Number of Samples**	6	5	5	16
	Min	<2	2	<2	<2
	Max	18	9	10	18
	Median	7	7	6	7
	standard deviation	5	3	3	4



Notes: ultra-oligotrophic: TP ≤4 μg/L, oligotrophic: TP>4 μg/L and ≤ 10 μg/L; mesotrophic: TP >10 μg/L and ≤ 20 μg/L; meso-eutrophic: TP >20 μg/L and ≤35 μg/L

Figure 10. Total Phosphorus Concentrations (μg/L) Measured at the Outflow of Paper Mill Lake (2006-2011)

Metal concentrations were low, with most below method detection limits. Only aluminum, iron and zinc exceeded their CWQG for protection of aquatic life on only selected occasions.

Washmill Lake

The water quality of Washmill Lake was measured in the interconnecting channel leading to Kearney Lake by HRM and AECOM. The pH is within the normal range for lakes, and the conductivity (median 248 μS/cm), was slightly higher than other lakes, which is also reflected in higher concentrations of dissolved chloride and sodium, possibly indicative of runoff contaminated with road salt. Total phosphorus ranged from <2 μg/L to 12 μg/L (<0.002 mg/L to 0.012 mg/L) with a median concentration of 8 μg/L (0.008 mg/L). Concentrations are generally in the mesotrophic range. Orthophosphate concentrations were below the detection limit (10 μg/L or 0.01 mg/L). The concentrations of nitrogen compounds were low. Total suspended solids were elevated on one occasion (17 mg/L – August 2010), but were otherwise low (<4 mg/L).

Black Duck Brook

The water quality of Black Duck Brook was measured by HRM and AECOM upstream of Lake Kearney. Water quality measured here is indicative of water quality leaving McQuade Lake plus any additions as it flows through the development around McQuade Lake, and minus losses through settling. The total phosphorus concentrations ranged from 8 to 40 μg/L (0.008 to 0.040 mg/L) with a median concentration of 8 μg/L (0.008 mg/L). Again, concentrations are generally in the mesotrophic range, bordering on oligotrophic. Nitrate and nitrite, and ammonia concentrations were low. Chlorophyll α concentrations were low, and ranged from 0.20 to 6.05 μg/L, with a median concentration of 0.73 μg/L. The high concentration of 6.05 μg/L was measured in August 13 2009; the same sampling event in which the highest total phosphorus concentration of 0.040 mg/L was measured.

Quarrie Lake, Big Horseshoe Lake and McQuade Lake

Quarrie, Big Horseshoe, and McQuade Lake have been sampled by AECOM on two occasions and two more sampling events are scheduled. Preliminary data analysis indicates that Big Horsehoe Lake has higher total phosphorus and total kjeldahl nitrogen than the other lakes. Dissolved chloride is low in the lakes, indicating their relatively undeveloped watersheds. Big Horseshoe Lake had the lowest dissolved chloride concentration with only 3 and 4 mg/L. In McQuade Lake, which is surrounded by development, total phosphorus concentrations were in the mesotrophic range with a much higher chlorophyll α concentration than the other two lakes. The total phosphorus concentrations in Quarrie and Big Horseshoe Lakes were in the oligotrophic range, and had low chlorophyll α values.

Headwater Lakes

Many of the sub-watersheds of the headwaters lakes have remained largely undeveloped. These include Hobsons, Charlies, Ash, Fox, Crane, Three Finger, Flat, and Cranberry Lakes. Total phosphorus was measured in these lakes in 1994 (Porter Dillon 1996). Although dated, these data provide an indication of water quality in the absence of more recent data. Table 9 summarizes the total phosphorus data collected in 1994 for these watersheds. At the time of sample collection, the trophic status of Ash, Charlies, Crane, and Fox was ultra-oligotrophic, and Charlies, Big Cranberry, Hobsons, Flat, and Three Finger were oligotrophic. All lakes had low phosphorus concentrations.

Table 9 Historical Concentrations of Total Phosphorus (µg/L) in Select Headwater Lakes

Lake	Range (n=2)	Average
Ash	18-25	2
Charlies	2.1-4.9	4
Big Cranberry	9-8.3	9
Crane	2.5-4.2	3
Fox	1.7-3	2
Hobsons	6.8-7.8	7
Flat	9.7-4.4	7
Three Finger	4.6-3.7	4

Source: Porter Dillon 1996

Nitrogen to Phosphorus Ratios

In order to manage lake eutrophication, the accepted approach is to control the nutrient that is feeding the algae in a lake. There are three primary nutrients required for plant growth – phosphorus, nitrogen and carbon – and for most water bodies, phosphorus is the limiting nutrient. That is, phosphorus becomes depleted and stops plant or algal growth before either nitrogen or carbon. Phosphorus is most commonly derived from anthropogenic activities in the watershed and thus phosphorus inputs can be controlled through reduction of non-point sources (agriculture, land uses, septic systems) or point sources such as sewage treatment plants.

One method of determining if phosphorus is the limiting nutrient in lakes is to calculate the total nitrogen (TN) to total phosphorus (TP) ratio in the pelagic (deeper) zone of lakes. Ratios of TN:TP ≤14 are limited in nitrogen, while lakes with ratios of TN:TP >15 are limited in phosphorus and the TN:TP ratio generally decreases with increased TP (Downing and McCauley, 1992).

To determine if phosphorus is the limiting nutrient with respect to plant and algal growth in the Birch Cove Lakes watershed the TN:TP ratio was calculated for each lake (Table 10). For Quarrie, Horseshoe, and McQuade Lake, where only two data points have been collected, the average of the two values was used for this calculation. The TN:TP ratio for all lakes in Birch Cove was >15, indicating that they are phosphorus limited. Horseshoe Lake had the highest ratio (45), and Washmill Lake had the lowest ratio (24).

Table 10. Nitrogen to Phosphorus Ratio for Lakes in Birch Cove

Lake	TN:TP
Horseshoe Lake	45
Quarrie Lake	41
Kearney Lake	40
McQuade Lake	37
Paper Mill Lake	31
Washmill Lake	24

Relationships between Trophic Status Indicators

Although there are a variety of phosphorus inputs to urban lakes, sources are generally associated with suspended solids (particulate matter from soil particles and urban runoff) or with dissolved organic carbon from organic matter in wetlands and vegetation in the watershed. Analysis of the relationships among these trophic status indicators can help to assess the various sources (i.e. suspended solids or DOC) of phosphorus among lakes. Dissolved Organic Carbon (DOC) has not been historically sampled in the Birch Cove Lakes watershed, however TSS and colour are sampled routinely.

Figure 11 shows that there was no relationship between TSS and phosphorus in the Kearney and Paper Mill Lakes. High TSS concentrations were not associated with enriched phosphorus concentrations, as would be expected if it was contributing to the phosphorus concentrations in the lakes. On the other hand, TSS concentrations measured here show a relatively small range and additional sampling with a focus on high flows may demonstrate a TP/TSS relationship.

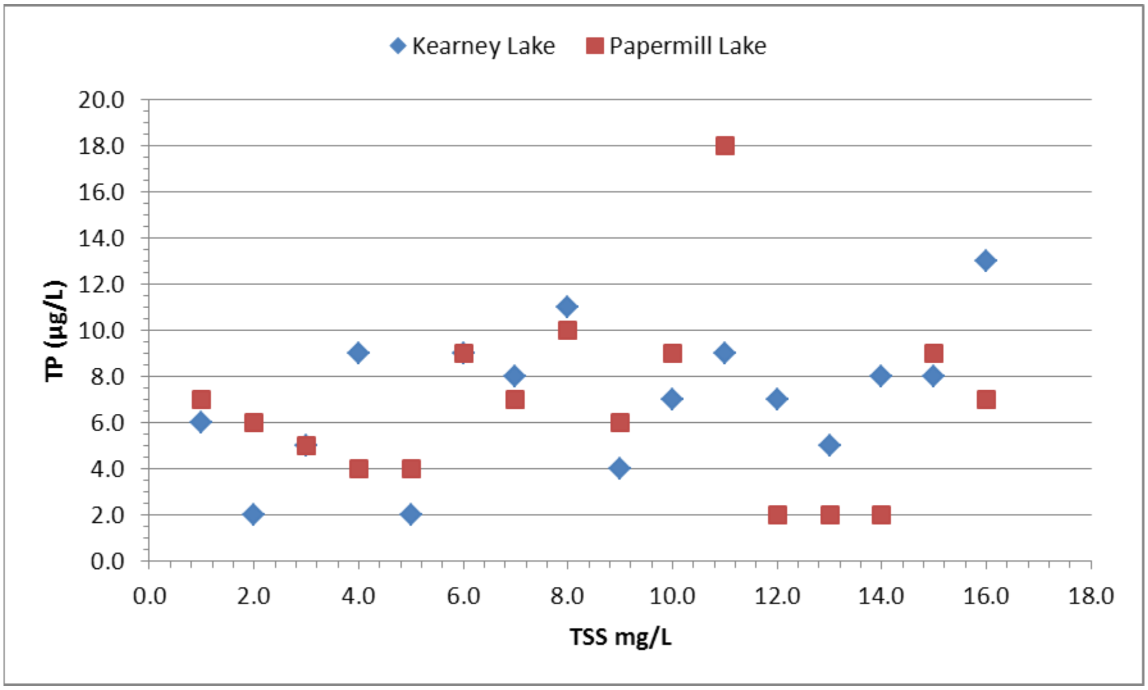


Figure 11. Relationship between TSS (mg/L) and Total Phosphorus (µg/L) in Birch Cove Lakes

Because additional phosphorus loads can result in increased plant and algal growth, study of the relationships between total phosphorus and chlorophyll α and Secchi Depth may provide some insight into how these lakes might "look" with increased phosphorus concentrations. For example, how much phosphorus will result in increased algal growth and reduction in water clarity? In addition, a strong relationship between these parameters can be used as an inexpensive monitoring tool of lake trophic state. Figure 12 shows the relationship for TP and chlorophyll α and Figure 13 shows the relationship for TP and Secchi Depth. The role of phosphorus as a limiting algal nutrient is shown by a positive relationship (a linear trend) between chlorophyll α and phosphorus concentrations. The relationships in Figure 12 are weak (i.e. trend lines are not statistically significant) but stronger relationships may develop as more data are collected. Other factors besides phosphorus may be influencing algal growth, such as grazing by zooplankton and light penetration.

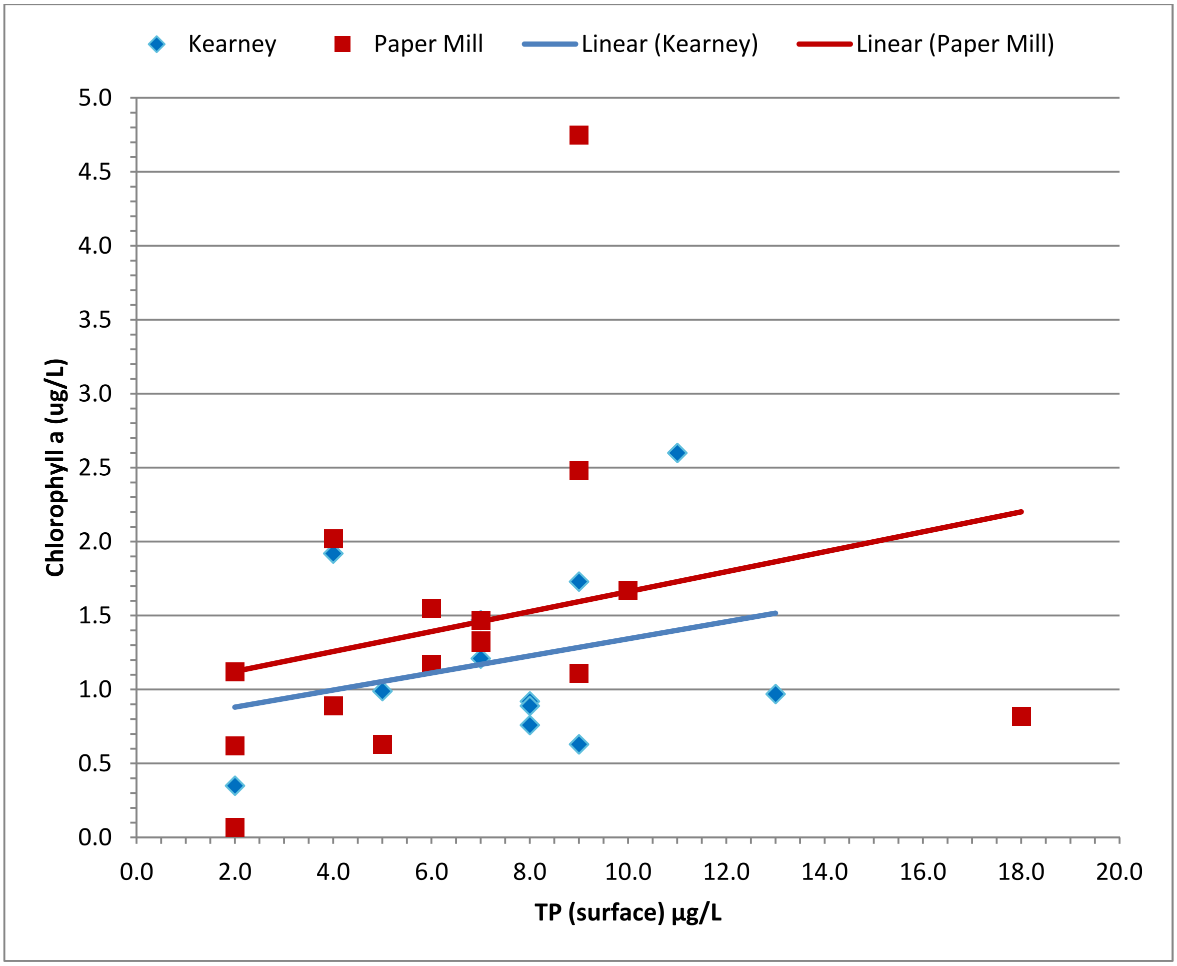


Figure 12. Relationship between Total Phosphorus (µg/L) and Chlorophyll α (µg/L)

Recreational lake users most often perceive water quality as a function of water clarity. Clear waters are considered clean. Figure 13 relates water clarity (Secchi depth) to total phosphorus. No clear relationship has developed. Again this may become clearer as more data are collected, or, as noted above, this relationship will be influenced by the dystrophic nature of the lakes.

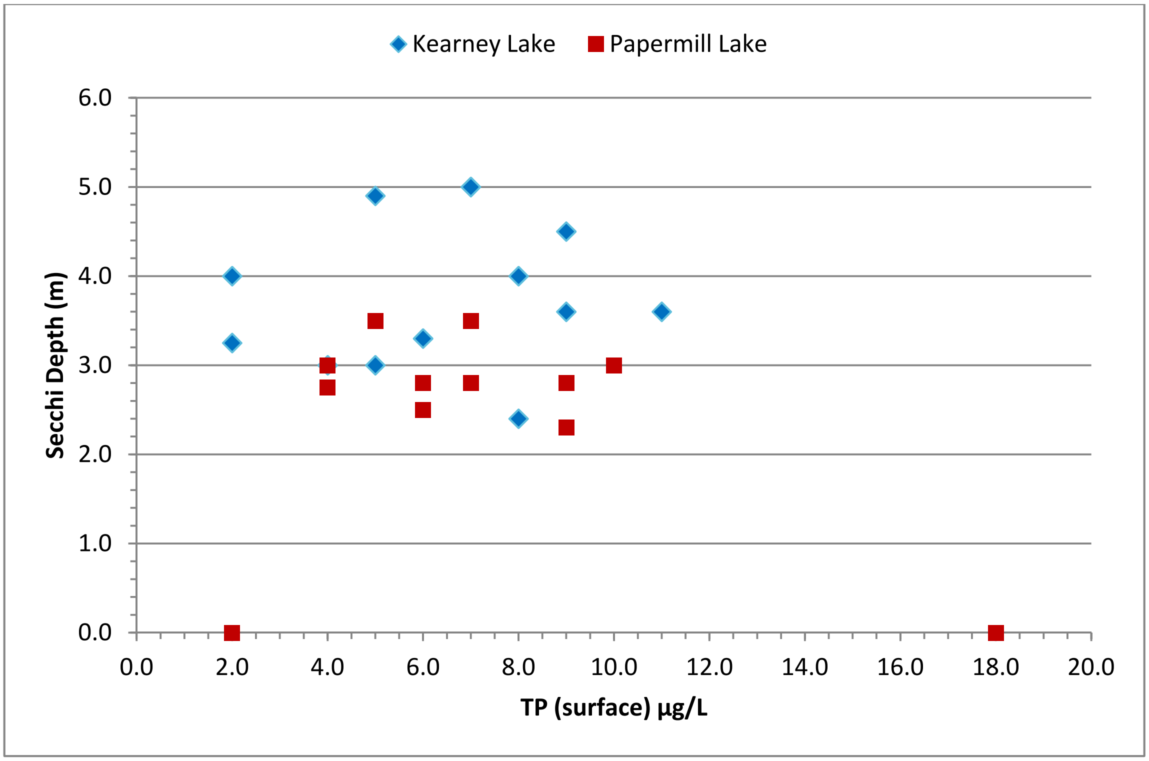


Figure 13. Relationship between Total Phosphorus (µg/L) and Secchi Depth (m)

Water Quantity

Water quantity within a watershed is a function of the watershed hydrology and hydraulics. Hydrology is defined as the movement of water while hydraulics refers to the properties that aid or impede water movement. A number of factors affect the hydrology of a watershed such as the land use, local topography, soil types, groundwater inputs or baseflow and precipitation received in the watershed. Once the water has made its way to the nearby streams or lakes, the various hydraulic processes carry the water though the system. Factors that impact watershed hydraulics include: channel roughness, channel geometry, storage areas such as lakes and wetlands, channel slope and structures that limit channel flow (such as dams or road crossings).

Urbanization in a watershed has a significant impact on both the watershed hydrology and hydraulics. Urbanization typically increases the impervious surface areas within the watershed. This results in stormwater that would have infiltrated into the soil discharging directly into the lakes and streams. This creates a greater peak or maximum flow in the watershed after a rainfall event as opposed to the more gradual, lower peak flow of a natural watershed. These higher peak flows can lead to increased flooding and erosion within the watershed. The lakes within the watershed are able to provide significant amounts of storage to buffer the effects of these flow increases, however constrictions in the rivers (such as road crossing or other structures) may cause flood impacts in the areas downstream of the development if the increased flows that result from development are not controlled. High flows resulting from urbanization also typically produce greater loadings of suspended solids and nutrients to the water courses. The addition of nutrients can result in decreased water quality and increased trophic state, which is usually inconsistent with the public desire to maintain high water quality for aesthetic value and recreational activities.

To better understand the implications of land use in the Birch Cove Lakes watershed, hydrologic/hydraulic models were created to assess the effects of land uses changes over time in the watershed. Details of these models will be presented in the final report.

Previous hydraulic and hydrologic work completed in the watershed was done by SGE Acres Ltd. (2003) who looked at the safety of the existing dams and assessed how the structures could be modified for stormwater management purposes. None of the three dams in the watershed are currently used in an active sense to management stormwater quality or quantity. Active use of these dams to manage water quality will be addressed in the Final Report.

<u>AECOM Supplementary Water Quantity Data</u>

Due to the absence of concurrent flow measurements within the Birch Cove watershed, AECOM recommended and received approval to undertake flow measurements. To assess the existing hydrology and hydraulics in the watershed, four locations were selected to monitor the quantity of water (or flow) in the system. Flow is estimated using a depth or level logger installed within the stream. As depth is only one component of the equation, a rating curve is developed to correlate flow to changes in water depth. To do so, a number of velocity measurements are collected using a current velocity meter across the stream channel to measure actual flow within the water course. Specific measurements of flow are correlated to the logger depth at the point in time when the flow measurements were taken. Flow was monitored at four locations (also illustrated on Figure 8):

- Black Duck brook upstream of Kearney Lake;
- Quarrie Lake outlet;
- Kearney Lake inflow; and
- Paper Mill Lake outlet.

Black Duck Brook drains McQuade Lake and Hobsons Lake. This area is not hydraulically controlled by structures such as dams. The land use in these areas is predominately forest and low density residential.

Quarrie Lake outlet is controlled by a dam structure, originally constructed in 1927 and since rebuilt in 2005. Quarrie Lake receives flow from Ash Lake, Crane Lake, Three Finger Lake, Little Horseshoe Lake, Big Horseshoe Lake, Little Cranberry Lake, Flat Lake, Big Cranberry Lake, Susies Lake and Fox Lake. For this site, flow measurements were collected; however, a stage discharge curve for the dam structure was used to calculate flow at this point. The landuse contributing flow to these areas is predominately undeveloped forest; however there is some development in the headwaters of Susies Lake sub-watershed. Development in these areas includes high density residential and commercial (Bayers Lake shopping area).

Quarrie Lake and Charlies Lake flow into Washmill Lake and outlet to Kearney Lake. While much of the land use in the Quarrie Lake sub-watershed is forested, the tributaries that flow into Washmill Lake also include high and medium density residential developments, an active quarry, and wetlands.

Kearney Lake is the deepest and largest of the lakes in the watershed. The main body of the lake flows under Kearney Lake Road and through the Kearney Lake Dam, originally constructed in 1928. The water then flows northeast to Paper Mill Lake. Some smaller tributaries also contribute flow upstream of Paper Mill Lake. Jack Lake and a number of smaller tributaries also flow into Paper Mill Lake. Much of the land in the surrounding area is urbanized as medium and high density residential development. The outflow of Paper Mill Lake is also controlled by a dam structure, originally rebuilt in 1930 and scheduled to undergo rehabilitation in 2012. Stream flow is monitored downstream of the outlet of Paper Mill Lake dam and upstream of the influence of Moirs Pond and the Bedford Basin.

Flow measurements were collected on a monthly basis from November 2011 to May 2012 for a total of 7 flow measurements. This time period provides a diverse range of flows, from high flows observed in the fall and winter months to low flows recorded during the spring (as conditions were unusually dry during the spring 2012). The range of flows and the time period over which they were collected will provide a reliable rating curve that can be applied to estimate continuous flow using the depth loggers.

This hydrometric data was applied to the subwatershed study for two applications:

- Estimating the amount of baseflow that can be expected in the watershed for an average year; and
- Validating the model to ensure it is not under or over estimating the flows in the watershed.

Details of the model will be presented in the final report including the results of the hydrometric monitoring program, the rating curves developed for each site and the hydrographs for the monitoring period.

3 Data Processing (GIS) for Landuse and Watershed Mapping

3.1 Application of GIS for Data Processing

A Geographical Information Systems (GIS) is a system of computer hardware and software used for managing and manipulating spatial geographic data. GIS was a key tool in the preparation and manipulation of data for this project. A discussion of the details regarding the GIS data will be provided in the final report. The GIS-based work for this project included:

1. Data input from maps, aerial photos, satellites, surveys, and other sources
2. Data storage, retrieval, and query
3. Data transformation, analysis, and modeling, including spatial statistics
4. Data reporting, such as maps, reports, and plans

Spatial features are stored in a coordinate system (latitude/longitude, state plane, UTM, etc.) which references a particular place on the earth. Descriptive attribute information, in tabular form, is associated with a point, line or polygon feature. Spatial data and associated attributes in the same coordinate system can then be layered together, as shown in Figure 14, for mapping and analysis.

A detailed background review of the GIS files available at the Halifax Regional Municipality (HRM), of GIS information used in previous reports, and sources freely available on the Internet, was conducted. Table 11 identifies all those files that were received directly from HRM or downloaded from the Internet. Details on additional sources of GIS information will be provided in the final report. Files were acquired, organised and saved in a GIS file geo-database for multiple uses within the project.

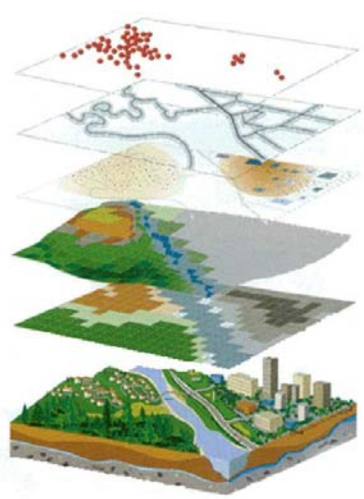


Figure 14. Illustration of Spatial Data Layering in GIS

Table 11. GIS Files Received & Downloaded

Data Name	Source	Status	Notes	Project Use
Base Data	HRM	Received from HRM		
Parcels	HRM	Received from HRM		Land use classifications
Zoning	HRM	Received from HRM		Land use classifications
Building Polygons	HRM	Received from HRM	Detailed account of Building footprints	Land use classifications
Contours 1m	HRM	Received from HRM	In the form of DEM/DSM	Land use classifications
Watersheds	HRM	AECOM to Create	In the form of DEM/DSM (Derived by AECOM)	Hydraulic modeling
Lakes	HRM	Received from HRM		Land use classifications
Streams	HRM	Received from HRM		Watershed Delineation / Constraint Mapping
DEM_2m	HRM	Received from HRM	Derived from LiDAR by Monette and Hopkinson of AGRG	Watershed Delineation / Constraint Mapping
Slope Grid	HRM	Received from HRM	In the form of DEM/DSM (Derived by AECOM)	Hydraulic modeling / Constraint Mapping
BANC Development	HRM	Received from HRM		Land use classifications
BMBCL Conceptual Park Boundary	HRM	Received from HRM		Land use classifications
BMBCL Urban Settlement	HRM	Received from HRM		Land use classifications
BMBCL URD USD	HRM	Received from HRM	Urban Reserve / Urban Settlement Designations	Land use classifications
Coxs Lake Park Reserve	HRM	Received from HRM		Land use classifications
Resource Natural Corridor Lands	HRM	Received from HRM		Land use classifications
First Nations Reserves	HRM	Received from HRM	Indian and Northern Affairs Canada	Land use classifications
Sewage Treatment Plants	HRM	Received from HRM		
Soils	HRM	Received from HRM		Water Budget Analysis
GLFUM Reg Plan	HRM	Received from HRM	General Land use planning description	Land use classifications
Proposed HWY 113 Alignment	NSTPW	Received from HRM		Land use classifications
Forest Inventory	NSDNR			Land use classifications
IRM Data	NSDNR			
Flow Accumulation	NSDNR	Downloaded from Website	Used to compare to LiDAR GIS results	Watershed Delineation
Wetlands	NSDNR	Downloaded from Website / Received from HRM		Land use classifications / Constraint Mapping
Significant Habitat	NSDNR	Downloaded from Website / Received from HRM		Land use classifications / Constraint Mapping
Old unique forests	NSDEL (Dept. of Envt & Labour)	Received from HRM		Land use classifications / Constraint Mapping
Ecosites	NSDEL (Dept. of Envt & Labour)			
Highly scientific natural areas	NSDEL (Dept. of Envt & Labour)			
Lakes & costal	NSDEL (Dept. of Envt & Labour)			

Table 11. GIS Files Received & Downloaded

Data Name	Source	Status	Notes	Project Use
Sites of Ecological Significance	NSDEL (Dept. of Envt & Labour)			
Ortho	NSDNR	Not Used		
Ortho	BING Imagery	Used via Arc GIS		
Crown Land	NSDNR	Received from HRM		To create Land use classifications
Trails	HRM			
Rare flora	Atlantic Canada Conservation Data Centre			
Special Areas	Atlantic Canada Conservation Data Centre			
ELC (Eco Districts - high level)	Mineral Resource Branch	Downloaded from Website		
Surficial Geology		Downloaded from Website		
Deer Wintering Areas	NSDNR			
Wet Areas	NSDNR	Downloaded from Website		
Restricted & Limited Use	NSDNR	Downloaded from Website	all files	
Transportation & Utility Features	NSDNR	Downloaded from Website		
Mineral Resource Land-Use		Downloaded from Website		

3.2 LiDAR

Light Detection And Ranging, or LiDAR, is a system for measuring ground surface elevation from an airplane. LiDAR combines global positioning satellite (GPS), precision aircraft guidance, laser range finding, and high speed computer processing to collect ground elevation data. Mounted on an aircraft, a high-accuracy scanner sweeps the laser pulses across the flight path and collects information by bouncing laser beams off the ground and measuring its return time to the aircraft. Depending on the laser pulses time of return, the resulting information will capture the ground or bedrock (referred to as a digital elevation model, or DEM) or the tops of trees / houses (referred to as a digital surface mode, or DSM) (Figure 15).

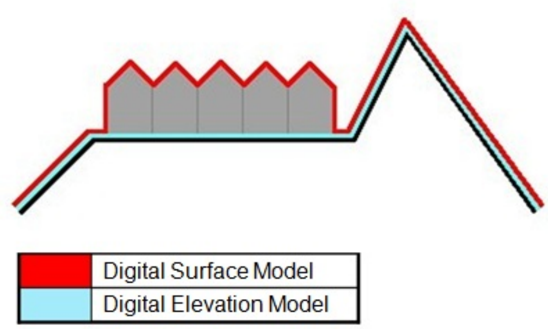


Figure 15. Illustration of Digital Surface Model (DSM) and Digital Elevation Model (DEM)

A DEM and DSM are numerical representations of terrain elevation. They store terrain data in a grid format of co-ordinates and corresponding elevation values. The grid size is a compromise between the required accuracy, available information and computation time. The smaller the grid size, the more accurate the results from the DEM/DSM will be.

HRM contracted Monette and Hopkinson of Applied Geomatics Research Group (AGRG), supervised by Dr. Tim Webster, to convert LiDAR points flown in 2007, to gridded surface (Webster, 2010). The purpose was to create a DEM from the LiDAR ground points for most of the HRM. Detailed documentation on this process will be provided in the final report. The resulting DEM grid has 2m grid resolution which is highly accurate and useful for the mapping undertaken in this study.

3.3 Watershed Delineation

A key use of a DEM is the ease with which it can extract topographic information of hydraulic interest. Techniques are available for extracting slope properties, catchments areas, drainage divides, and channel networks. These techniques are faster and provide more precise and reproducible measurements than traditional manual techniques applied to topographic maps (Trible 1991). As such, they have the potential to greatly assist in the parameterization of hydraulic surface runoff models, especially for large watersheds (i.e. >10km^2) where manual determination of drainage networks and subwatershed properties are tedious, time consuming, error-prone, and often highly subjective processes. The automatic techniques also have the advantage of generating digital data that can be readily imported and analysed through GIS.

Using the LiDARderived 2m DEM, the Birch Cove Lakes watershed was developed. A brief description and function of the steps required to create a watershed boundary in GIS can be seen in Table 12. A more in-depth and detailed account of the watershed model will be presented in the final report.

Table 12. Overview of Watershed Modeling

Options	Functions
Hydrological modeling	Creates watersheds and calculates their attributes
Flow direction	Computes the direction of flow for each cell in a DEM
Identify Sinks	Creates a grid showing the location of sinks or areas of internal drainage in a DEM
Fill Sinks	Fills in the sinks in a DEM, creating a new DEM
Flow Accumulation	Calculates the accumulated flow or number of up-slope cells, based on a flow direction grid
Stream Networks	Isolating out areas of concentrated flow
Stream Order	Method of classifying streams based upon their number of tributaries
Pour Point placement	Everything upstream of a pour point will define a single watershed
Watershed	Creates a watershed based upon a user-specified flow accumulation threshold

The subwatershed model uses the DEM to identify low points in the surface and assumes they are flow paths or watercourses. In order to ensure the flow of water in the model represented actual watershed flow conditions, a quality assurance / quality control (QA/QC) step was undertaken. This step involved verification of the watercourses used in the model through a detailed analysis of air photos and local knowledge of the landscape. During this process, those watercourses that did not meet the QA/QC review were deleted from the model or identified as intermittent or ephemeral watercourses.

3.4 Existing Development

An integral part of the hydraulic modeling was the development of a detailed land use layer. HRM does not keep a detailed account of its land use classifications in their GIS repertoire, thus a combination of aerial photo interpretation; HRM bylaw zoning regulations and parcel fabric were combined to create a comprehensive existing land use layer (Figure 16).

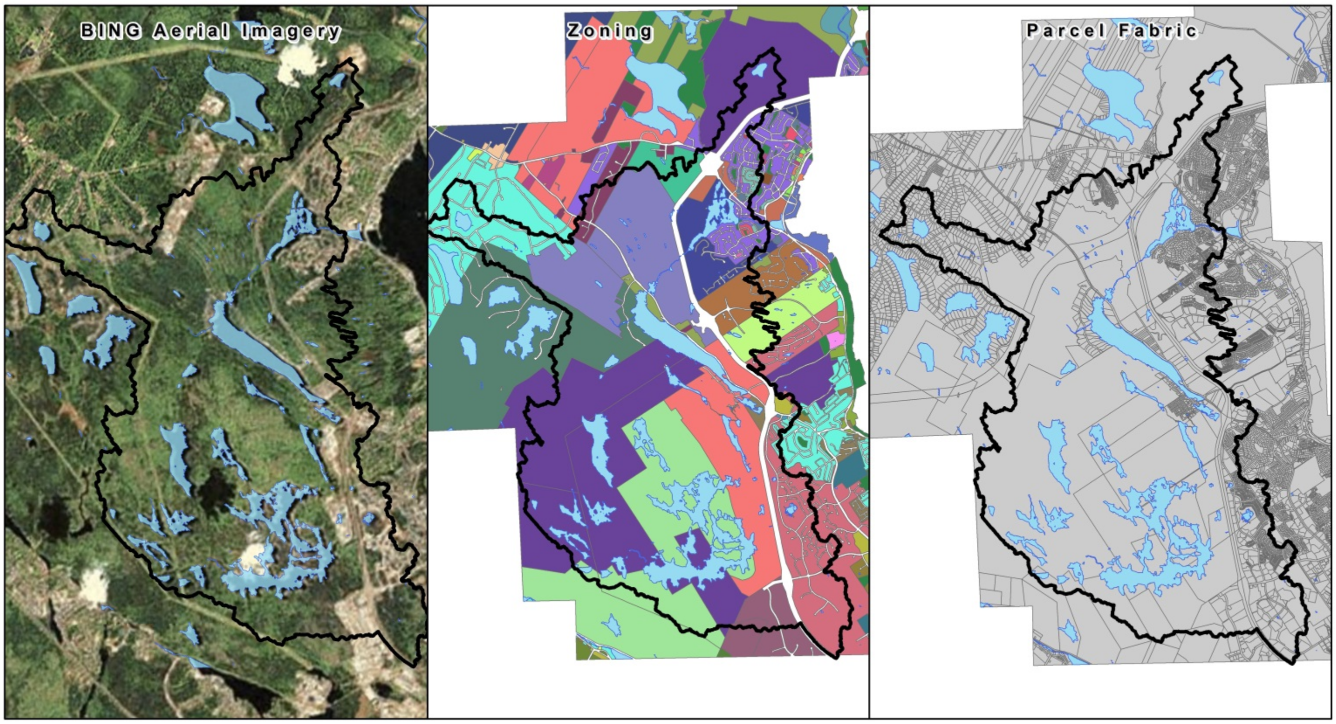


Figure 16. Illustration of Data Layers Use to Develop Land Use in Birch Cove Lakes watershed

Since the Birch Cove Lakes watershed is predominantly undeveloped, the existing land use file was merged with environmental GIS data such as wetlands, significant wildlife habitat and old growth forest. For a more in-depth analysis of the ground cover, forest classification was broken down further by percent tree cover. Those tree stands averaging less than 60% tree cover were classified as Forest – Meadow while all others remained Forest. Using air photo interpretation, exposed bedrock was manually added into the land use layer. These environmental classifications are an important part of the land use model because the different land uses, whether natural or man-made, imply different surface water runoff rates based mainly on the extent of evaluation of impervious areas. Table 13 details the existing land use classifications.

Table 13. Existing Land Use Classifications

Land Use	Description	General Classification
Bedrock	Rock visible from air photo	Bedrock
Commercial	Shops / malls / box stores	Commercial
Crown Land	Provincial land	Forest
Forest	Significant tree cover	Forest
Forest - Meadow	Open grass lands / minimal tree cover	Forest - Meadow
Forest - Old Growth	Designated old growth by NSDNR	Forest
Forest - Sensitive Habitat	Designated sensitive by NSDNR	Forest
High Density Residential	Parcel < .5ha	Residential
Medium Density Residential	Parcel > 0.5 ha <1.5 ha	Residential
Low Density Residential	Parcel >1.5 ha	Residential
Industrial	Industrial	Industrial
Institutional	Schools / library	Institutional
Open Space	Park or inner city open area	Forest - Meadow
Path	Concrete path too small for car	Roadway
Power Lines	Designated by Zoning	Forest - Meadow
Quarry	Open Pit	Quarry
Roadway	All major / minor road	Roadway
Water	Lakes / Rivers	Water
Wetland	designated wetland by NSDNR	Wetland

3.5 Development in the Birch Cove Lakes Watershed

The objective of the modeling work undertaken in this study is to understand how development will affect the water quality within the lakes and rivers of the Birch Cove Lakes watershed. The general factors that have been incorporated into the modeling as mitigation measures for development in the watershed are considered below. The models are designed to provide an evaluation of the benefits of further mitigation measures on managing the water quality within the watershed. Thus, starting from existing conditions, the models will consider three development scenarios, namely "approved developments" for areas where development agreements have been approved or are in the process of being approved; "planned development" where Secondary Planning Strategies have been adopted by HRM but development agreements have yet to be approved; and "Proposed Development" encompassing the Highway 102 West Corridor Lands which are designated by the Regional Plan for potential future development.

3.5.1 Approved Development Agreements

In order to understand potential changes to water quality from development within the watershed, three development scenarios were modeled. In the first case, the current state of development or "existing conditions" was modeled. Based on information provided by HRM, existing land use conditions are shown on Figure 17. In the second case, the study added all approved developments within the watershed (Figure 18). Finally, the additional impacts of both the planned and the proposed development commitments (Figure 19) will be assessed.

Development Patterns

Short term development will occur in the lower reaches of the watershed, and is concentrated in three areas: between Kearney Lake and Highway 102, east of Highway 102, and northwest of Paper Mill Lake, both east and west of Highway 102. A development agreement for a commercial extension to the Bayers Lake Business Park has recently been proposed by Banc Developments at the southern tip of the watershed (Figure 18).

Nearest to Kearney Lake (Bedford West Sub-Areas 5 and 9), high and medium density residential development is proposed, with a narrow strip of commercial properties fronting Kearney Lake Road. A larger commercial and commercial-residential zone is proposed along Highway 102, while open space is designated around the Kearney Lake outlet and downstream along Kearney Lake Run.

On the eastern side of Highway 102, mixed use, residential and institutional development is planned in the vicinity of Starboard Drive. Along the portion of Larry Uteck Boulevard within the watershed, high and medium density residential and mixed use land uses are proposed, while commercial development is proposed for the intersection of Larry Uteck and Starboard Drive.

Further north, within the Bedford West Sub-Areas 3 and 4 located west of Highway 102, development will consist of a mixed use business campus around and including the RIM complex, high density residential units and limited institutional use. Residential land use is proposed along the northwestern shore of Paper Mill Lake extending to Highway 102, while a commercial district is proposed for the intersection of Highway 102 and Hammonds Plains Road.

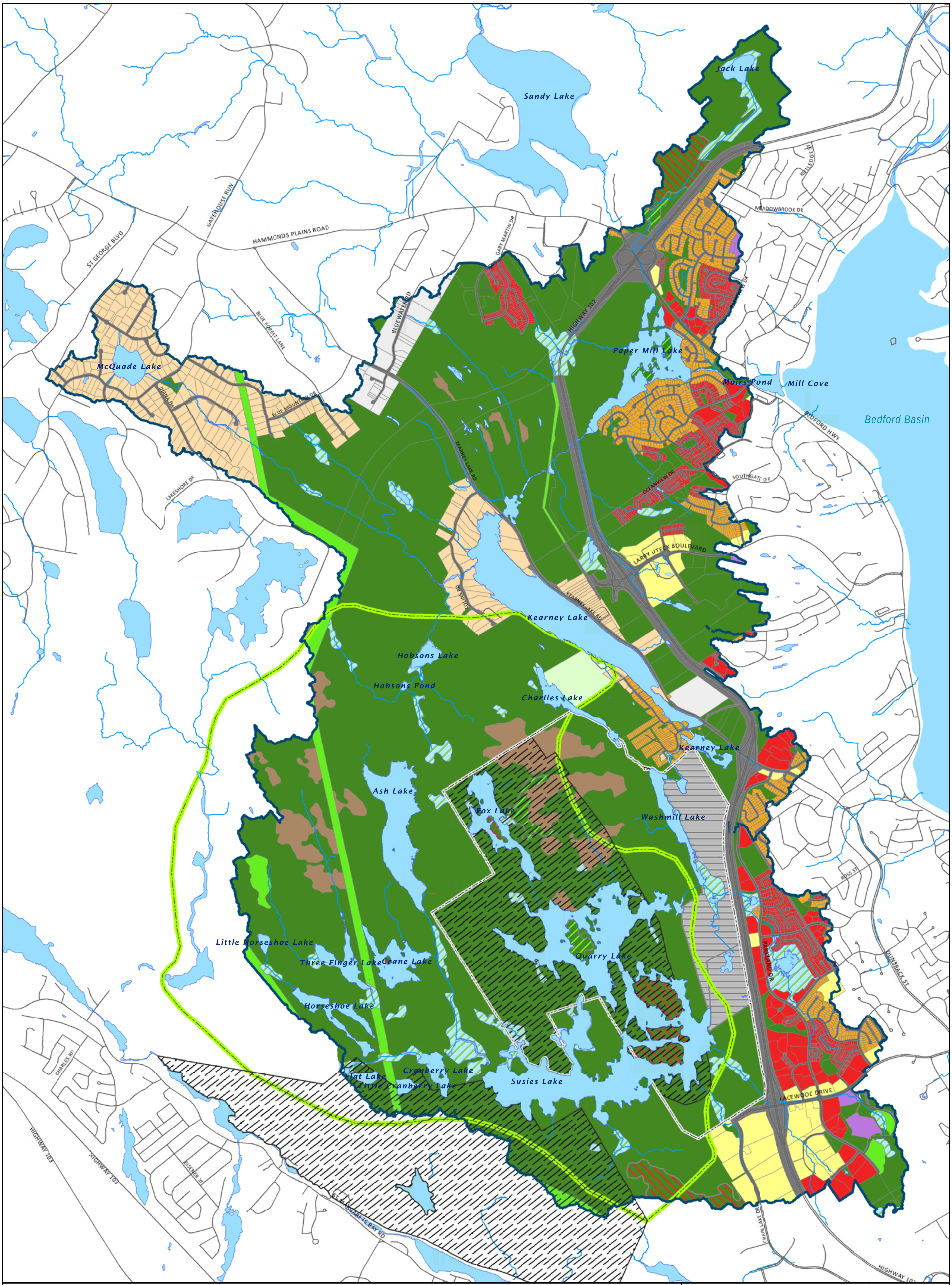
All these developments will be provided with municipal water and wastewater services.

3.5.2 Planned Development

HRM is committed to supporting additional land development within the Birch Cove Lakes watershed over the longer term. Although no development agreements are currently in place, development is expected in Bedford West Sub-Areas 6, 7 8, 10 and 11 which straddle the proposed Highway 113 corridor to the north and northwest of Kearney Lake (Figure 19). This development is largely residential in nature, although commercial developments are expected to border Kearney Lake Road

Additional mixed used and residential development is expected east of Highway 102. This development will be located between the residential and commercial properties along Starboard Drive and Larry Uteck Boulevard described above.

All development commitments will be provided with municipal water and wastewater services.



Existing Land Use

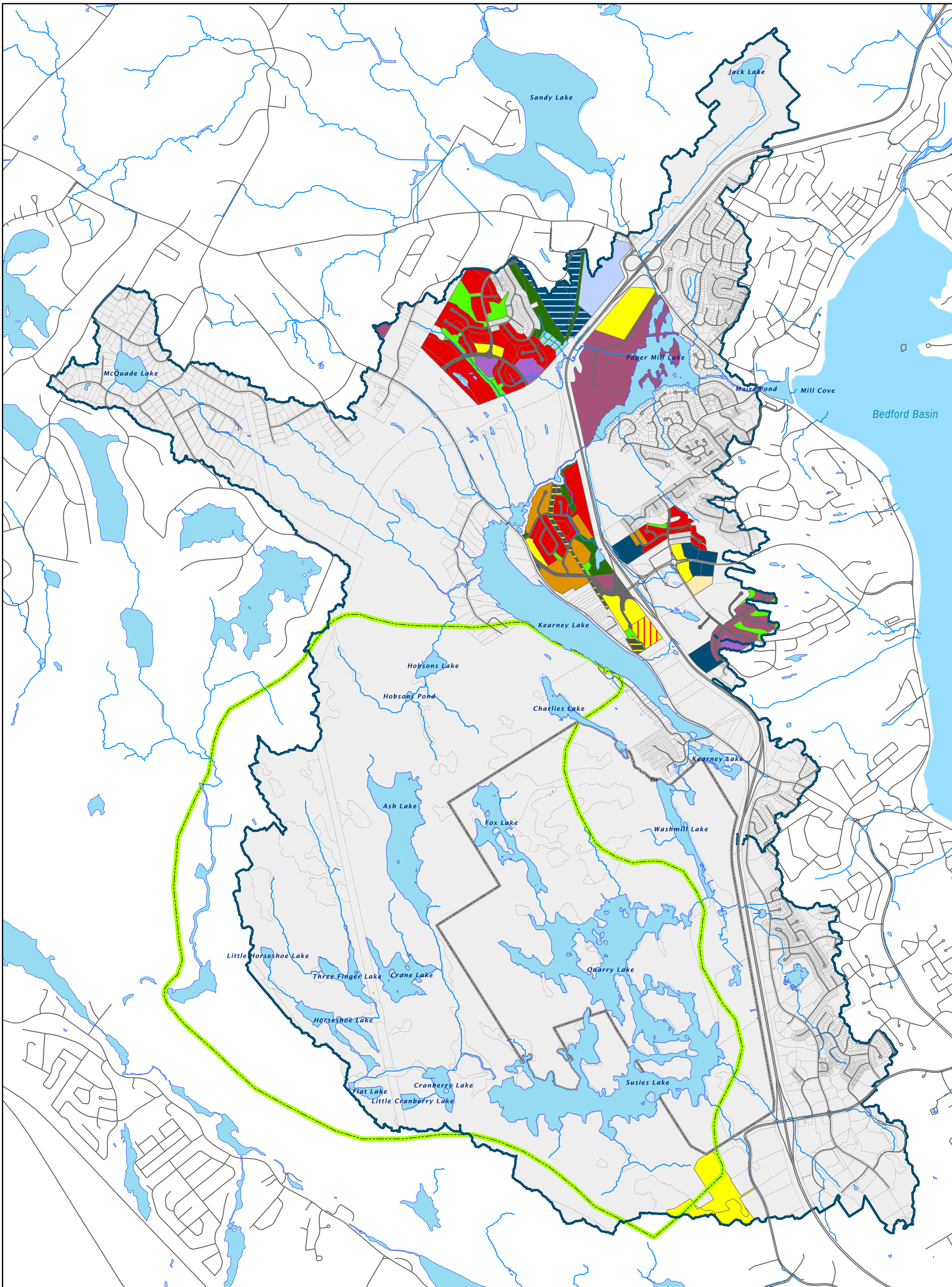
Watercourses	Bedrock	Commercial
Roads	Crown Land	Industrial
Privately Owned Land	Forest	Institutional
Urban Reserve	Forest - Meadow	Quary
Birch Cove Lakes Watershed	Forest - Old Growth	Roadway
Conceptual Park Boundary	Forest - Sensitive Habitat	High Density Residential
	Lakes	Medium Density Residential
	Wetland	Low Density Residential

Halifax Regional Municipality
Shubenacadie Lakes Watershed Study

Existing Land Use

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 17

AECOM



Watercourses
Roads
Privately Owned Land
Birch Cove Lakes Watershed
Conceptual Park Boundary

Approved Development Land Use Changes

Forest
Park
Water
Wetland
No Change (Existing Land Use)
Business Campus
Commercial District
Commercial and Residential
High Density Residential
Medium Density Residential
Institutional
Lifestyle Community
Mixed Use
Mixed Use Business Campus
Open Space
Residential
Roadway
Utility

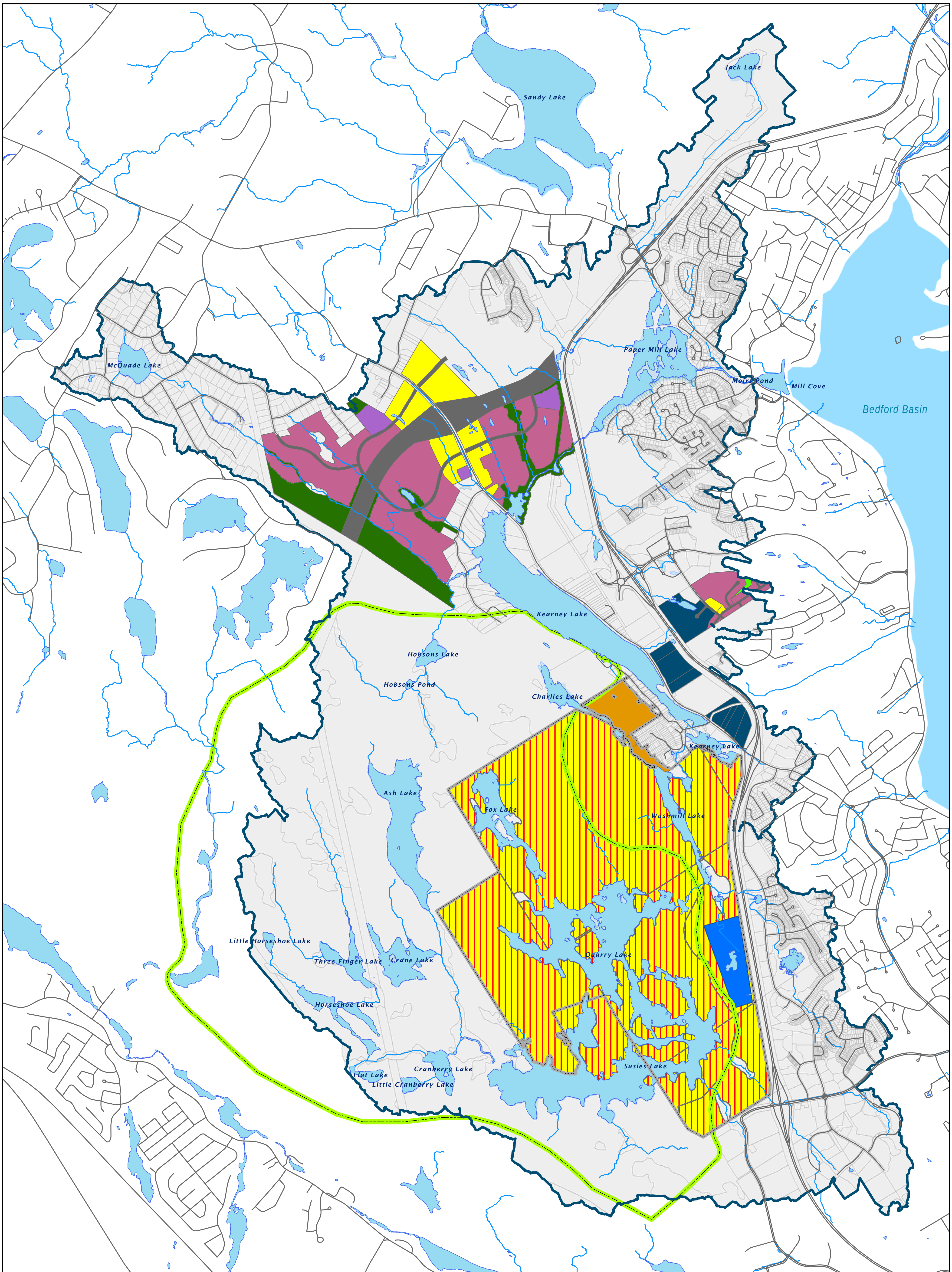
0 0.3 0.6 1.2
Kilometers

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Approved Land Use Plans

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 18

AECOM



- Watercourses
- Roads
- Privately Owned Land
- Birch Cove Lakes Watershed
- Conceptual Park Boundary

Ultimate Build Out Land Use Changes

- Forest
- Park
- Lake
- No Change (Existing Land Use)
- Commercial District
- Proposed Development
- Institutional
- Mixed Use
- Medium Density Residential
- Residential
- Roadway

0 0.3 0.6 1.2
Kilometers

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Land Use Commitments

June 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	**Figure 19**

AECOM

3.5.3 Sanitary Sewer Servicing Options

The extent of current sanitary sewer coverage is illustrated in Figure 20. One of the most significant impacts on lake water quality is the proximity of septic systems. This is especially a concern in areas where the land is only slightly above the surface water level and the septic systems may not function very well due to high water tables. Further, maintenance of septic systems is often minimal until a serious problem occurs. As a result, many older septic systems are virtually non-functioning. We expect this to be the case in many of the long-established properties adjacent to the lakes of Birch Cove Lakes watershed. Consequently in lake modeling for TP, the ability of a septic system to keep phosphorus from reaching a water body (i.e. the retention) may range from 100% for a new system with a large buffer between the system and the shoreline to virtually 0% for an old, poorly maintained system close to the shore and with a high water table.

The modeling has assumed that all new developments within the watershed will be required to have sanitary sewer connections to all new medium and high density residential developments and commercial and commercial/residential developments. In some cases, where the sanitary sewer coverage is convenient to new residential development and where the lakes could be particularly sensitive, in particular for the new developments proposed around Paper Mill Lake, we have assumed that these areas will be fully serviced. We have also assumed that new low density residential on the east side of Kearney Lake will be fully serviced. We have also assumed that future, low density residential developments, such as on the northwest side of Kearney Lake, where there is currently no servicing, will not use septic systems and will either be fully serviced or will take advantage of community owned package treatment plants located away from the lake and not impacting the lake.

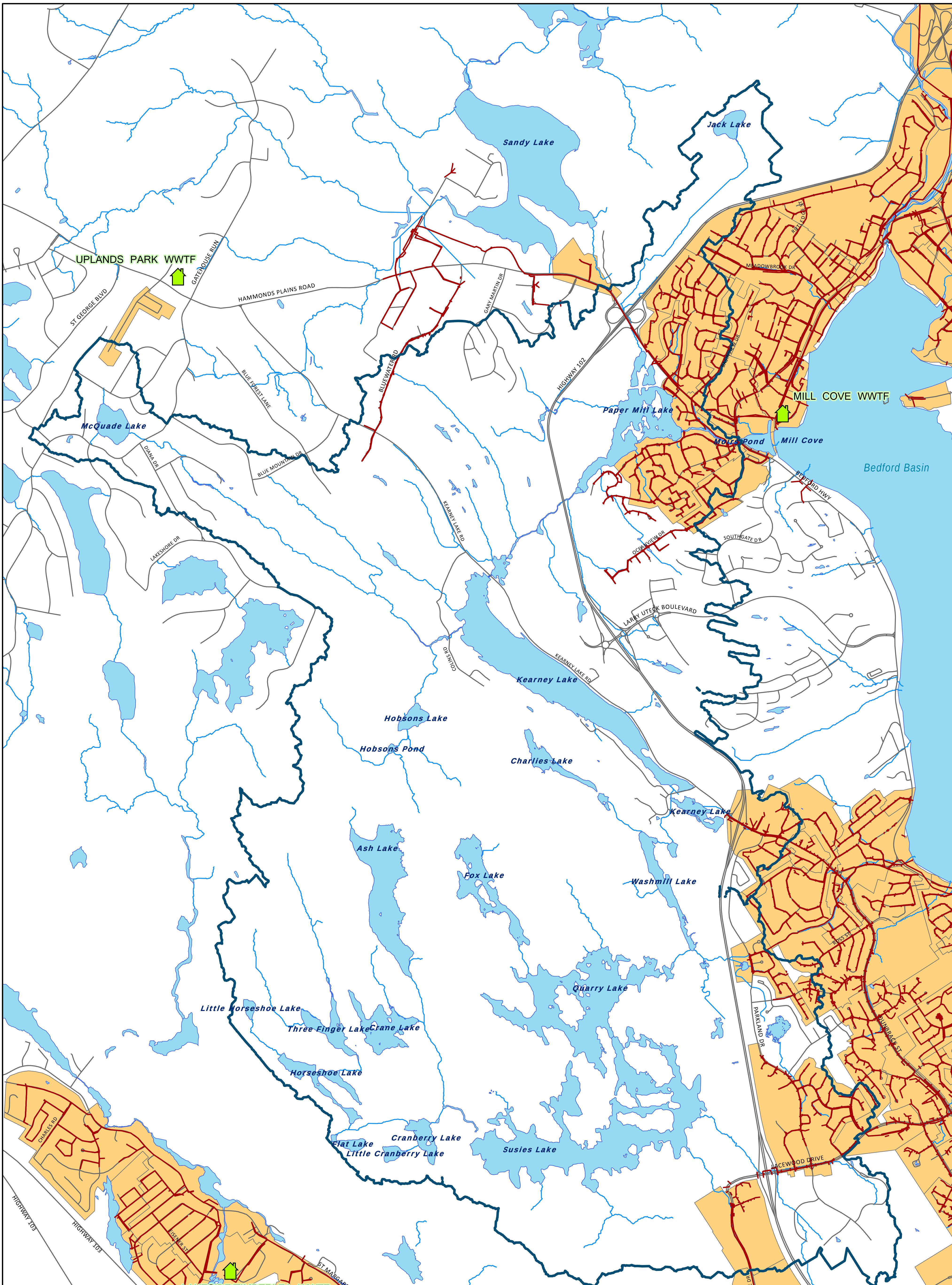
<u>Development Constraints</u>

Critical to the modeling is the concept of development constraints that preclude development in sensitive areas or areas that may result in disproportionately high impacts on the lake water quality. Consequently, we have developed a constraints map (Figure 21) that has been built into the land use assumptions used in the water quality/quantity models. The elements of the constraints map include proximity to watercourses, protection of wetlands, slope, significant woodlots, protected habitat or locations of rare and endangered species and the presence of acid generating rock close to the surface.

As illustrated in Figure 21 we have assumed that there will be an automatic 20 m setback for all development along watercourses, contiguous wetlands and lakes. This buffer should ideally be retained in a natural vegetation state to eliminate 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. Wetlands provide important aquatic habitat and potentially retain nutrients and other pollutants rather than allowing them to reach water courses. We have assumed that this buffer will also protect wetlands that are connected with watercourses. Further, we have applied the 20 m buffer to significant wildlife habitat areas and old growth forests as mapped by NSDNR.

The Halifax Mainland Land Use By-Law regarding the “slope constraint to development” {14QA(1)} states that:

> “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.”



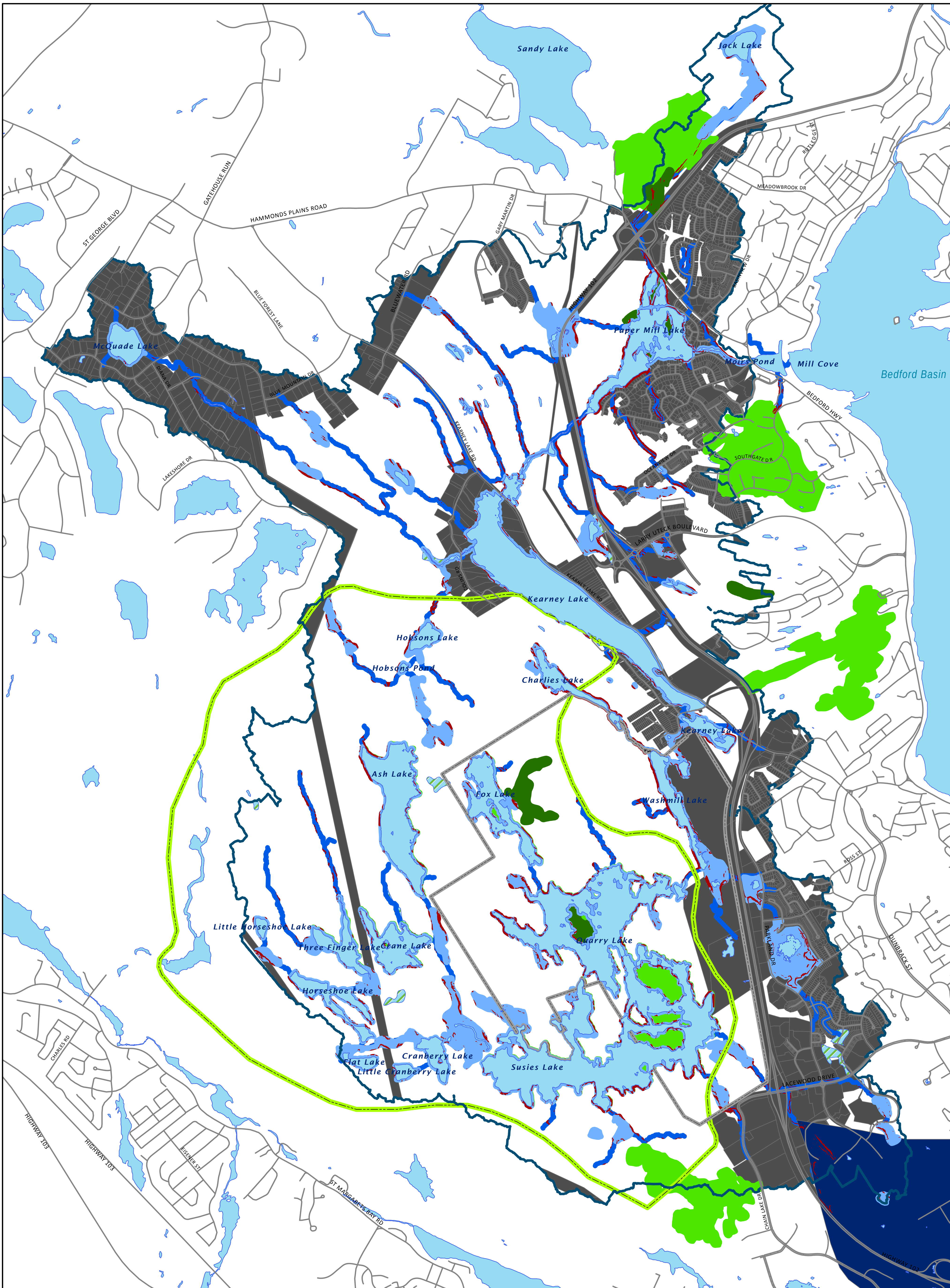
Wastewater Treatment Facility	Birch Cove Lakes Watershed
Watercourse	Water
Roads	
Sewer Pipes	
Sewershed	

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Sewer Coverage

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 20

AECOM



- Watercourses
- Roads
- Water
- Isolated Wetlands
- Birch Cove Lakes Watershed
- Conceptual Park Boundary
- Privately Owned Land

Constraints

- Water & Contiguous Wetland Buffer 20m
- Acid Generating Slate (Halifax Formation)
- Significant Wildlife Habitat Buffer 20m
- Old Growth Forests Buffer 20m
- Riparian Buffer 20m
- Slope Greater than 20%
- Existing Development

0 0.2 0.4 0.8
Kilometers

Halifax Regional Municipality
Birch Cove Lakes Watershed Study

Constraints

May 2012	1:30,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 001	Figure 21

AECOM

The draft River Lakes Environmental Protection Policy offers what we believe is a more rigorous and more readily enforceable constraint to development on land with a slope >20%. Specifically it states that there will be a "Prohibition of the removal of vegetation on all areas with slopes of 20% or more …" Evidently this is intended to apply to all areas; however, for the modeling it has been assumed that this constraint only applies within the 20 m buffer along water courses, lakes and wetlands and thus it applies regardless of slope.

Many water bodies in the HRM area are sensitive to acidification. The slates of the Halifax Formation are especially prone to producing acid drainage when exposed to the air. These slates occur in the extreme southeast part of the Birch cove Lakes watershed. We note that there are existing restrictions on development on these slates and consequently have considered them as a development constraint for our purposes.

4 Receiving Water Quality Objectives

4.1 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 Birch Cove Lakes watershed and widely accepted standards of water quality. These objectives will protect and maintain the high quality of the water within the watershed in light of the HRM development plans. 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 Birch Cove Lakes watershed.

4.2 Water Quality Indicators

Suburban development within the Birch Cove Lakes watershed will require removal and transformation of forested and natural areas for residential and commercial communities. 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 (Table 14). Other parameters such as metals, oil and grease, chlorophyll *α*, and nitrogen, may also increase due to development in the watershed, however watershed management /and implementation of mitigation measures to reduce development impacts will also limit the changes to all of these parameters.

Table 14. 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
NO3	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 (Holland et al., 2010)).
E. coli	Increase due to septic systems, WWTP bypass overflows, and stormwater runoff	An indicator of fecal contamination in recreational water

4.3 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. As such, when developing water quality objectives for Birch Cove, 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 15 summarizes the CWQG, USEPA, and Vermont water quality guidelines and standards for the key indicator parameters identified for the Birch Cove Lakes watershed.

Table 15. 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_3	13 mg NO_3/L	n/a	5.0 mg/L as NO_3-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
E. coli	2000 *E. coli*/L[1] (geometric mean of 5 samples)	126 *E. coli*/100mL (geometric mean of 5 samples)	Water Class dependent

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.

4.4 Recommended Water Quality Objectives for Birch Cove Lakes Watershed

Recommended water quality objectives for the Birch Cove Lakes watershed have been derived for the indicator parameters most sensitive to changes in land use within the watershed. The objectives and early warning alert values for these indicators can be used in association with the monitoring data to indicate a reduction in water quality in the lakes and prompt management action or mitigation. Early warning alert values are provided with the objectives on the basis that it is desirable to have an alert that an objective is being approached. This permits a response and implementation time for mitigation. Objectives and alerts should not be based on single points as there is considerable natural variability in the watershed. In light of this natural variation, a water quality evaluation methodology is proposed.

Existing water quality in the Birch Cove Lakes watershed is high, and concentrations of the indicator parameters are presently below CWQG (Table 15). **Because the CWQGs are set to protect the most sensitive species, and because water quality in the Birch Cove lakes is currently better than these objectives, we recommend that the CWQGs for nitrate, un-ionized ammonia, total suspended solids, and chloride be adopted for the Birch Cove Lakes 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[3]. We suggest this value is appropriate for the *E. coli* parameter. These values are illustrated in Table 16.

[3] *Note these are the same measurements but expressed for a different volume (mL versus L) and consequently the number of allowable counts changes*

Table 16. Recommended Water Quality Objectives for Birch Cove Lakes Watershed Excluding TP

Parameter	Derivation of Objective	Birch Cove Watershed Water Quality Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
NO_3 – Nitrate	CCME	13 mg NO_3/L	≤10 mg/L	75^{th} percentile of 3 year historical data
Un-ionized Ammonia	CCME	0.019 mg/L	≤0.014 mg/L	75^{th} percentile of 3 year historical data
Total Suspended Solids (TSS)	CCME	Short term: 25 mg/L increase Long term: 5 mg/L increase	Lake dependent	75^{th} 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^{th} percentile of 3 year historical data
E. coli	Nova Scotia and Health Canada	200 *E. coli*/100mL (geometric mean of 5 samples)	200 *E. coli*/100mL	Geometric mean of 5 samples

4.5 A 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:

a) It is non-toxic and is a required and limiting nutrient in fresh water, such that small increases stimulate aquatic productivity;
b) The natural or baseline water quality and trophic status for lakes varies extensively across Canada;
c) 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;
d) 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;
e) 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
f) 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 17) and reflect, in part, the differences in natural water quality across Canada.

Table 17. 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)	

4.5.1 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 4) as adapted from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

4.6 Development of Total Phosphorus Water Quality Objectives for Birch Cove

For the Birch Cove lakes we recommend building on this classification with each water body categorized into one trophic status based on existing conditions either measured or predicted based on model results. **As a result, the management objective would be to meet or maintain the trophic status of a water body so the water quality objective for TP becomes the upper limit of the TP range indicated in Table 19 for each trophic state**. If a monitoring program showed that the trophic status of the water body was changing to the next higher trophic state (i.e. the water quality objective was being exceeded) then management action would be warranted to protect the lake and in this case the water quality objective 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 of our lakes and waterways to the extent possible."

In Section 2.4, the water quality data from the Birch Cove Lakes watershed was reviewed. For the most part, the trophic status of the lakes is oligotrophic to mesotrophic; characterized by low concentrations of nutrients and chlorophyll *α*. To give more power to the summary statistics, statistical analysis was used to determine if total phosphorus results from different sampling stations in and around Kearney and Paper Mill Lakes could be grouped together and summarized. The analyses found that total phosphorus average values were not significantly different between sampling stations on Kearney Lake or Paper Mill Lake and so the data have been pooled (Table 18; detailed analysis to be provided in the Final Report). Data collected by SNC Lavalin and AECOM data were already grouped, as these water quality stations were co-located.

Table 18. Pooled Total Phosphorus (µg/L) Data for Kearney, Paper Mill, and Washmill Lakes and Black Duck Brook (2006 to 2012).

	Kearney Lake	Paper Mill Lake	Washmill Lake	Black Duck Brook
Number of Samples	37	30	9	9
Min	<2	<2	<2	8
Max	26	30	12	40
Median	7	7	8	9
Mean	7	8	8	15
Standard Deviation	5	6	3	12

Pooled mean concentrations indicate that Kearney, Paper Mill and Washmill Lakes are in the upper limits of the oligotrophic trophic status. Black Duck Brook, which is reflective of water quality leaving the highly developed McQuade Lake subwatershed, indicates that McQuade Lake is mesotrophic. In Section 2.4, we found that the less developed lakes, such as Quarrie and Horseshoe Lakes had total phosphorus concentrations that ranged from ultra-oligotrophic (Quarrie Lake) to meso-eutrophic (Horseshoe Lake). Only two samples have been collected from each of those lakes as part of the recent AECOM sampling. One of these samples followed a rain event so characterization of the lakes requires confirmation.

Unfortunately, mitigation measures to reduce TP concentrations are seldom instantaneous or completely effective, so water quality objectives combined with early warning alerts are often used to evaluate lake quality rather than waiting for the specific TP 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 appropriate management tools for water bodies. There are a variety of ways to determine whether or not water quality objectives or early warning indicators are being met or exceeded. The selection of the best early warning system depends on a number of things including the size and hydraulic turnover rate of the lake, ongoing land use changes within the watershed, natural water quality variability, the extent of baseline data, the design of the monitoring program and the importance placed on the protection of the lake by regulators and residents. As can be seen from the water quality summary of the Birch Cove Lakes above, there is considerable variability in TP 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. The proposed approach for each lake is presented in Table 19.

Lake specific TP objectives and early warning alert values have been developed based on existing data if available or on modeling results from the modeling work described in Section 5 below. Table 19 provides a summary of the TP water quality objectives and early warning alert values and a method to evaluate whether or not the objective or alert value is being approached for each lake.

Table 19. Water Quality Objectives, Early Warning Alert Value and Proposed Evaluation Methodology for Alert Values for Total Phosphorus (µg/L) in Birch Cove Lakes Watershed

Parameter	Derivation of Objective	Birch Cove Objective or Lake Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
TP - Ash Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Charlies Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Cranberry Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Crane Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Flat Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Fox Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Hobsons Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP – Horseshoe Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - McQuade Lake	Mesotrophic	≤20	15	3 year running mean of Black Duck Brook measurements
TP - Susies Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Quarrie Lake[2]	Oligotrophic	≤10	8	3 year running mean at outfall
TP – Three Finger Lake	Oligotrophic	≤10	10	Based on modeling results[1]
TP - Washmill Lake	Oligotrophic	≤10	8	3 year running mean of data
TP - Kearney Lake	Oligotrophic	≤10	8	3 year running mean of data
TP - Paper Mill Lake	Oligotrophic	≤10	8	3 year running mean of data

[1]No recent water quality data to verify model predicted water quality results. Data should be collected to validate objective and proposed alert value. Until additional data are available, the evaluation is dependent upon modeling and the early warning alert value is based on the upper TP limit of the oligotrophic state due to uncertainty in the model.
[2]Only two samples to date, Objective needs to be validated with additional analytical data and proposed alert value confirmed.

The absence of actual recent measured water quality data for Ash, Charlies, Cranberry, Crane, Flat, Fox, Hobsons, Horseshoe, Susies and Three Finger Lakes makes the assessment of objectives and alert values entirely dependent upon the modeling results. Early water quality data from some of these lakes (Table 9) indicate that the TP concentrations for these lakes are in the oligotrophic range. These data, however, are limited to just two samples. Consequently, these water quality objectives and alert values need to be confirmed through monitoring before they can be refined. This is especially important for Charlies and Fox Lakes which may be affected by development within their watersheds in the future.

5 Next Steps

Additional work will be completed as part of this project to meet the remaining objectives of Policy E-17 for presentation in the Final Report. In particular, an extensive modeling effort will be undertaken to define existing water quality conditions and evaluate the impacts of current conditions on receiving water quality with respect to discharge and water quality. In particular, we will be assessing the effect of future land use changes on the trophic state and phosphorus concentrations in the primary lakes using a Lake Capacity Model (LCM) that has been employed previously in the Halifax region. The LCM model is a steady state empirically derived model that predicts the trophic state of a receiving water body. The trophic state indicates the response of the lake to phosphorus loadings.

However, urbanization usually results in extensive changes to the hydrology of a watershed and as noted elsewhere in this report, the peak flows tend to increase due to a faster and higher rate of runoff and reduced infiltration. The higher peak flow results in greater erosion. These changes result from the reduction of pervious surfaces due to the increase in roof area, parking lots, roads etc. and more direct delivery of pollutants including phosphorus to the watercourses. The management of stormwater in urban areas through the use of various techniques is critical to maintaining water quality in urbanizing watersheds. While the LCM deals with this in a steady state manner by accounting for changes in land use, it does not address the dynamic nature of pollutant delivery nor the benefits of stormwater management best practices in an adequate and time dependent manner. Consequently, we will also adapt a stormwater management model to predicting phosphorus loads within the Birch Cove Lakes watershed. The strength of this model is that it considers the hydrology of the watercourse and how this will be impacted by development and predicts not only changes in flow but also changes in sediment and phosphorus loading. The model adopted here is the U.S. Environmental Protection Agency's StormWater Management Model (SWMM).

These two models will be compared based on the fact that the LCM has historically been applied in the region (Scott and Hart 2004; Porter Dillon Limited 1996) and the fact that the SWMM model is more appropriate and accurate for managing urbanizing lakes with a strong influence from storm water. Both models will employ the three land use scenarios outlined above to generate loadings for the watershed and evaluating the predicted impacts of land use changes. They will also be used to evaluate the lake water quality objectives presented in this preliminary report and to assess the benefits that could be achieved from mitigation measures to reduce the impacts of development, reduce or maintain phosphorus loadings and maintain or improve lake trophic state. The mitigation measures that will be considered using one or both models may include alternatives to individual septic systems, stormwater quantity and quality management for new developments and for existing urbanized areas, alternative land use patterns (e.g. sensitive land areas protected from development through land exchanges or alternative development scenarios) and various size buffer strips.

Also as part of the final report AECOM will recommend a cost effective and environmentally sound water quality monitoring program for the watershed in the light of existing data and water bodies that need to be assessed as a result of planned development. Considerations will also have to be given to developing a water quantity monitoring program for the watershed to better calibrate the stormwater model and to confirm the predicted impacts of development on flow and pollutant loading and the benefits of the mitigation options.

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<u>Personal Communication</u>

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7 Glossary

Acidification – Raising the acidity (lowering the pH) of a water body by adding an acid.

Alluvial – Soil or earth material which has been deposited by running water, as in a riverbed, flood plain, or delta.

Anoxic – (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.

Anthropogenic – referring to changes or activities that are man-made, rather than those resulting from natural processes.

Aquifer – 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.

Aquitard – 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.

Baseflow – runoff that has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

Batholith – A mass of igneous rock that forms intrusively and can rise to the surface.

Bathymetry – (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.

Bedrock – Solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

Bog – A wet, overwhelmingly vegetative substratum which lacks drainage and where humic and other acids give rise to modifications of plant structure and function.

Catchment Area (syn. watershed or subwatershed) - All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.

Chloride – Negative chlorine ions, Cl-, 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.

Chlorophyll – (1) The green pigments of plants. There are seven known types of chlorophyll, *Chlorophyll a* and *Chlorophyll b* 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 an common indicator of water quality.

Dissolved Organic Carbon – 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.

Dissolved Oxygen – 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.

Drift – To be carried along by current of air or water. 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 *mycorrhizal* (fungi, heaths, orchids, and saprophytes), can tolerate bog conditions.

Drumlin – An elongated hill or ridge of glacial drift.

Dystrophic – Characterized by having brownish acidic waters, a high concentration of humic matter, and a small plant population.

Ecoregion – A recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterize that region.

Epilimnetic – Relation to an eplimnion. An eplimnion 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.

Eutrophication – 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.

Fen – 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.

Fluvial – Of or pertaining to rivers and streams; growing or living in streams ponds; produced the action of a river or stream.

Glaciation – Alteration of the earth's solid surface through erosion and deposition by glacier ice.

Hydraulics – (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.

Hydrology – 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.

Hypolimnion – 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.

Impervious Surface - 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.

Lacustrine – Pertaining to, produced by, or inhabiting a lake.

LiDAR - An acronym for Light Detection And Ranging. A system for measuring ground surface elevation from an airplane.

Marsh – 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.

Mesotrophic – 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.

Morphometry – The shape and structure of the lake basin

Non-Point Source of Pollution – 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.

Oligotrophic - 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.

Overburden – The earth, rock, and other materials that lie above a desired ore or mineral deposit.

Pelagic – Referring to the open sea or open part of a large lake at depth.

Phosphorus – An element that is essential to plant life but contributes to an increased trophic level (eutrophication) of water bodies.

Point Source Pollution – Pollutants discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.

Quartzites – A hard metamorphic rock made up of interlocking quartz grains that have been cemented by silica.

Sediment – Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion, and transported by water, wind, ice, and gravity.

Surficial Geology - the loose deposits of soil, sand, gravel and other material deposited on top of the bedrock

Recharge – introduction of surface or ground water to groundwater storage such as an aquifer.

Riparian – 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.

Run Off – (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.

Stormwater Runoff – The water and associated material draining into streams, lakes, or sewers as the result of a storm.

Swamp – 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.

Temperature – The degree of hotness or coldness. A measure of the average energy of the molecular motion in a body or substance at a certain point.

Till – 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 pathon 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.

Thermal Stratification – 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.

Thermocline – (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.

Total Kjeldahl Nitrogen – Total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.

Total Phosphorus – The sum of reactive, condensed and organic phosphorous.

Total Suspended Solids – 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.

Trophic State: A measurement of the biological productivity of a water feature.

Turbidity – 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.

Uplands – (1) The ground above a floodplain; that zone sufficiently above and/or away from transported waters as to be dependent upon local precipitation for its water supplies. (2) Land which is neither a wetland nor covered with water.

Vernal Pond – (1) Wetlands that occur in shallow basins that are generally underlain by an impervious subsoil layer (e.g., a clay pan or hard pan) or bedrock outcrop, which produces a seasonally perched water table. (2) A type of Wetland in which water is present for only part of the year, usually during the wet or rainy seasons (e.g., spring).

Water Budget – A method for measuring the amount of water entering, being stored and leaving a watershed.

Water Quality – A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Watershed – (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.

Wetland – 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.

8 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
DSM – Digital Surface Model
GCDWQ – Guidelines for Canadian Drinking Water Quality
GCM – Global Climate Model
GHG Greenhouse Gas
GIS -Geographical Information System
GPS – Global Positioning System
HNWTA – Halifax Northwest Trails Association
HRM – Halifax Regional Municipality
IPCC – Intergovernmental Panel on Climate Change
LCM – Lakeshore Capacity Model
LiDAR – Light Detection and Ranging
NH_3 – Ammonia
NO_3 – 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
SARA – Species at Risk Act
SWMM – Stormwater Management Model
TKN – Total Kjeldahl Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids
USEPA – United States Environmental Protection Agency
UTM – Universal Transverse Mercator
WWTP – Waste Water Treatment Plant