Lake Echo Watershed Servicing Study

Final Report

101015.00 ● Final Report ● November 20, 2012

ISO 9001
Registered Company

Prepared for:
Halifax Regional Municipality

Prepared by:
CBCL Limited
Consulting Engineers

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List of Acronyms

BOD_5	Biochemical Oxygen Demand - 5 day
C.BOD	Carbonaceous Biological Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
CDWQGs	Canadian Drinking Water Quality Guidelines
DAF	Dissolved Air Floatation
DOC	Dissolved Organic Carbon
FC	Fecal coliform
GIS	Geographical Information System
HAA	Haloacetic acid
HRM	Halifax Regional Municipality
MLD	Million liters per day
MPS	Municipal Planning Strategy
NOM	Non-organic Molecule
NSE	Nova Scotia Environment
NSTIR	Nova Scotia Transportation and Infrastructure Renewal
pH	Potency of Hydrogen Ion
RCAP	Rapid Chemical Analysis Program
TDS	Total Dissolved Solids
THM	Trihalomethane(s)
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
UV_{254}	Ultraviolet light – wavelength 254
WHPA	Well Head Protection Area

EXECUTIVE SUMMARY

Introduction

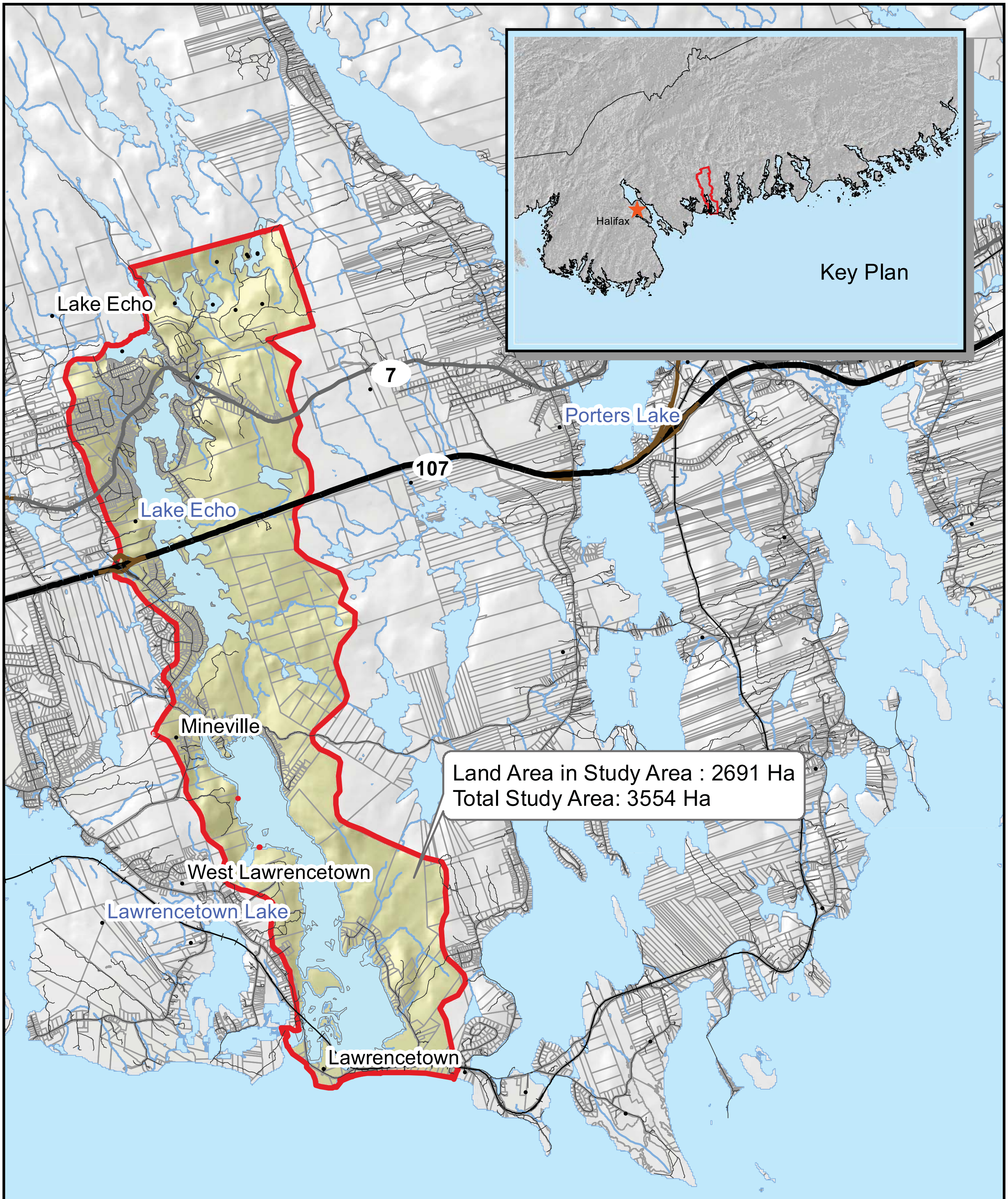
The community of Lake Echo is located in the Halifax Regional Municipality (HRM) east of Dartmouth, as shown in Figure ES1.1. There is considerable residential development occurring in the area as well as some commercial development. The existing community comprises approximately 1,000 residences distributed around the lake, along the main roads (Highway 7 and Mineville Rd) and in several subdivisions. Properties in these sub-divisions vary in size, depending on when they were constructed and the lot size requirements at the time. Original development was cottages in Lake Echo on small lots. The newest development has the largest lots. There is also commercial development and small businesses, as well as churches and schools.

Existing development is serviced by onsite wastewater treatment systems, wells for water supply and roadside ditches for stormwater drainage.

In the Halifax Regional Municipality's Regional Municipal Planning Strategy (HRM Regional MPS), Lake Echo is designated as a Rural Commuter Centre, which is defined as a low to medium density residential development with open space design subdivisions and a mix of convenience commercial, institutional and recreational uses. The MPS envisions the provision of express bus facilities connected to downtown Halifax and shared parking facilities for park and ride and commercial uses.

This study provides a means to evaluate opportunities for the provision of services required for planned development including wastewater treatment and dispersal, stormwater management and potable water while minimizing negative impacts on the natural environment. In order that HRM may promote and direct development that best suits requirements for developable land and minimizes negative impacts on the environment, the objectives of this study are to:

- Identify opportunities for development within the Study Area (identified in Figure ES1.1);
- Provide a range of servicing schemes for wastewater collection, treatment and dispersal (excluding central sanitary sewerage), stormwater management and water for those lands;
- Assess the "level of development" various schemes will support and the impacts on the surrounding environment of various servicing schemes; and
- Develop a site specific plan showing all land suitable for development complete with potential development densities and the services required to allow these densities to be realized.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study
Figure ES1.1 Study Area Location
May 2012

0 1,000 2,000 4,000 Meters

Study Area

CBCL Project # 101015
Data Sources: HRM, NSDNR
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

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Component Studies

Several component studies were undertaken to address the study objectives as established by policy E-17 the HRM Regional MPS. Some of these were used to establish existing conditions in the Study Area as well as to:

- Determine the factors restricting further development; and
- Identify opportunities for further development.

The results of these component studies are outlined below.

Wastewater Collection and Treatment

Existing wastewater collection and dispersal systems in the Study Area are predominantly onsite wastewater systems comprised of:

- A septic tank for solids removal; and
- An effluent dispersal system such as an area bed or contour system. Some original systems have failed and have been replaced with various alternatives including peat filters.

Figure ES 1.2.1, reproduced from the onsite study completed by Land Design Engineering in 2005[1], indicates that in general the soils in the Study Area are considered most suited for onsite systems. Discussions with local installers indicate that the failed systems have been in pockets of unsuitable soils and on lots that do not meet current Nova Scotia Environment standards for the design of onsite wastewater systems.

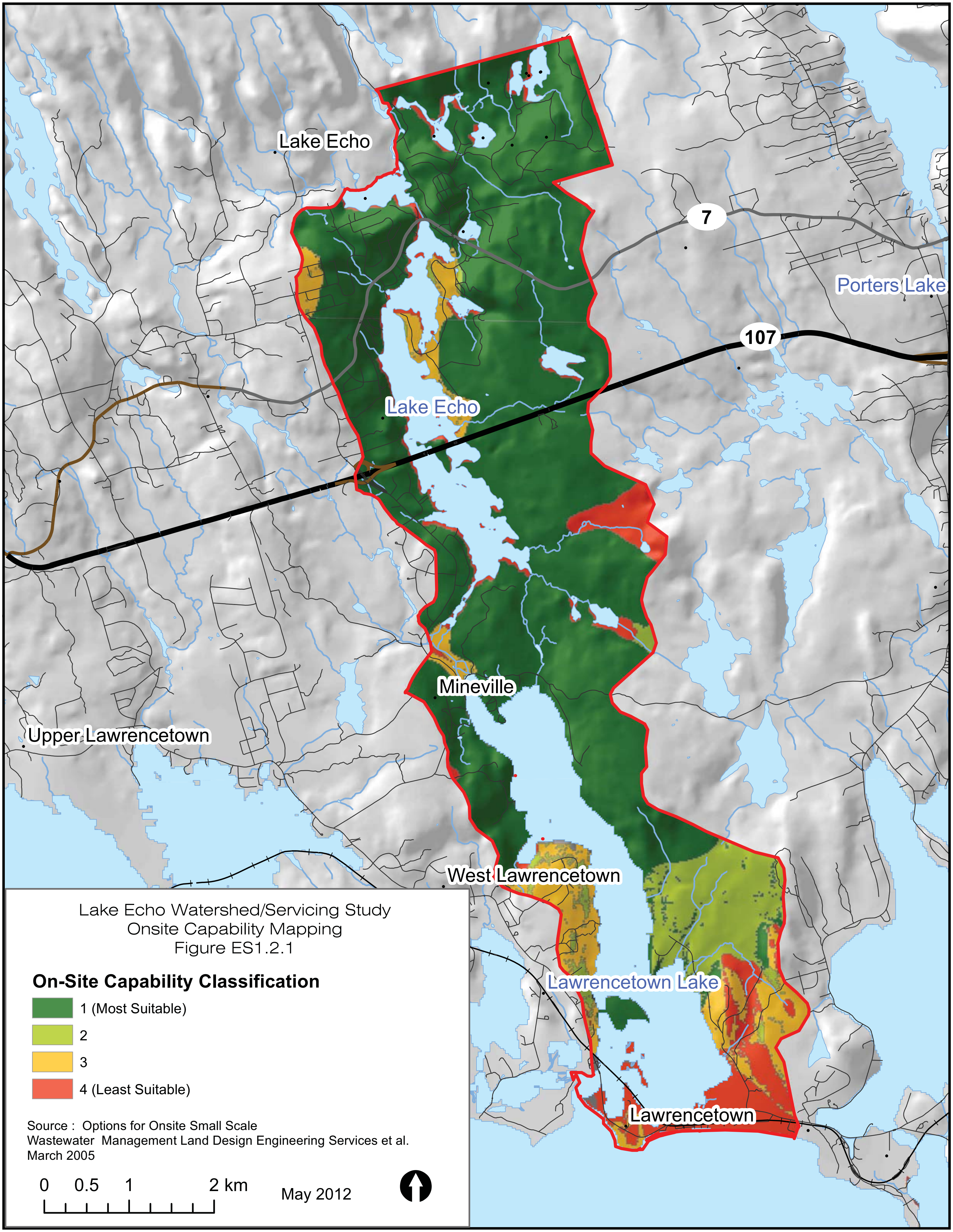
Water Supply, Treatment, and Distribution

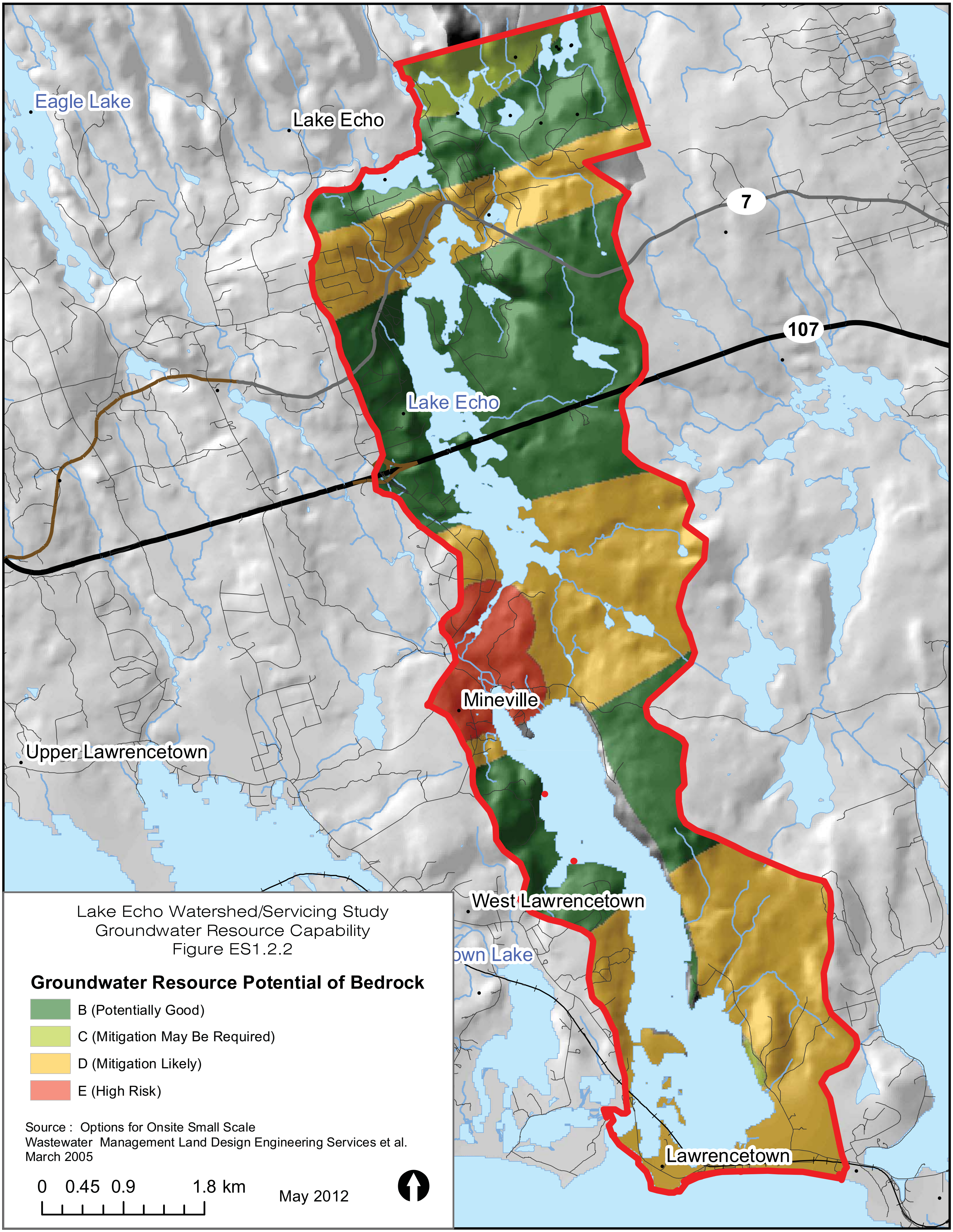
Figure ES 1.2.2, also reproduced from the onsite study completed by Land Design Engineering[2], indicates that in general wells installed in the bedrock in the Study Area can supply well water of suitable quality to supply households or groups of up to 10 households, but that treatment to remove contaminants including iron, manganese and in some areas arsenic is required or is likely required in most of the Study Area.

Water balance calculations were completed at a screening level for the Study Area to determine typical groundwater recharge rates in the community. Water demands for existing development were estimated based on typical average daily demands. These account for 4 percent of the overall recharge to local aquifers. It is estimated that the potential increase in demand generated by the high growth scenario in the community could account for up to 8 percent of the local area recharge which is not expected to stress these aquifers.

At the screening level, infiltration area required to supply groundwater to meet water demands for a single family is estimated to be 5,854 square metres, based on typical groundwater infiltration rates for the area and the assumptions that all permeable areas contribute equally to groundwater recharge throughout the Study Area.

[1] Land Design Engineering Services et al. March 2005. Options for Onsite & Small Scale Wastewater Management.
[2] Ibid.


Lake Echo
7
Porters Lake
107
Lake Echo
Mineville
Upper Lawrencetown
West Lawrencetown
Lawrencetown Lake
Lawrencetown
Lake Echo Watershed/Servicing Study
Onsite Capability Mapping
Figure ES1.2.1
On-Site Capability Classification
1 (Most Suitable)
2
3
4 (Least Suitable)
Source : Options for Onsite Small Scale
Wastewater Management Land Design Engineering Services et al.
March 2005
0 0.5 1 2 km
May 2012



Eagle Lake
Lake Echo
7
107
Lake Echo
Mineville
Upper Lawrencetown
West Lawrencetown
own Lake
Lawrencetown
Lake Echo Watershed/Servicing Study
Groundwater Resource Capability
Figure ES1.2.2
Groundwater Resource Potential of Bedrock
B (Potentially Good)
C (Mitigation May Be Required)
D (Mitigation Likely)
E (High Risk)
Source : Options for Onsite Small Scale
Wastewater Management Land Design Engineering Services et al.
March 2005
0 0.45 0.9 1.8 km
May 2012

The greatest risk to using groundwater from local surficial aquifers (in the soils above the bedrock) for potable water is the potential for groundwater contamination from local sources. The location of potential sources of contamination are investigated and documented in the main report and appendices.

Water Quality Objectives

An online survey of interested stakeholders was completed to assess the importance of water quality in local water bodies and to determine desired uses of them. A questionnaire was developed and made available online from July 18 to September 16, 2011. There were 111 responses to the survey. In response to the question, **"Are you concerned about the water quality of the water bodies?"** more than 90 percent of the respondents were concerned with the water quality in the lakes in the watershed.

When asked: **"At what level would you be satisfied with future water quality?"** more than 90 percent of those responding indicated that the lakes should at least be suitable as fish and wildlife habitat and of those 20 to 25 percent indicated that the waters should be of the highest possible quality.

To meet these water quality objectives for water bodies in the Study Area, water quality in the lakes should meet the CCME Guidelines for human consumption of fish.

Receiving Water Quality

A receiving water sampling program was completed for the study based on the following parameters:

- Water samples were collected in spring, summer and fall of 2010, during dry conditions as well as following rain events; and
- Samples were analysed for evidence of sewage (E coli, BOD5 and Total Suspended Solids) and typical indicators of eutrophication (nitrogen (in various forms), total phosphorous and Chlorophyll A).

Results of sampling and modelling indicate:

- On an **annual basis** the trophic status of the lakes in the study area is mesotrophic or better, meaning that there is generally plenty of oxygen and that biological oxygen demand is low. The exception is McCoy's Pond in which the trophic status was considered meso-eutrophic to hyper-eutrophic in all sample sets analysed. Water of poor quality is discharged from the pond to Lake Echo but does not account for water quality observed in the Lake on its own, other sources must be contributing;
- Lake Echo experiences **incidents** of high concentrations of nutrients (nitrogen and phosphorous) and chlorophyll A, indicating meso to hyper - eutrophic conditions during the summer and fall. It also experiences incidents of high E coli concentrations; and
- Low pH (the result of acid rain and runoff) also limits the suitability of Lake Echo as habitat for species at risk.

These conditions can change with changes in climate and land use in the tributary areas.

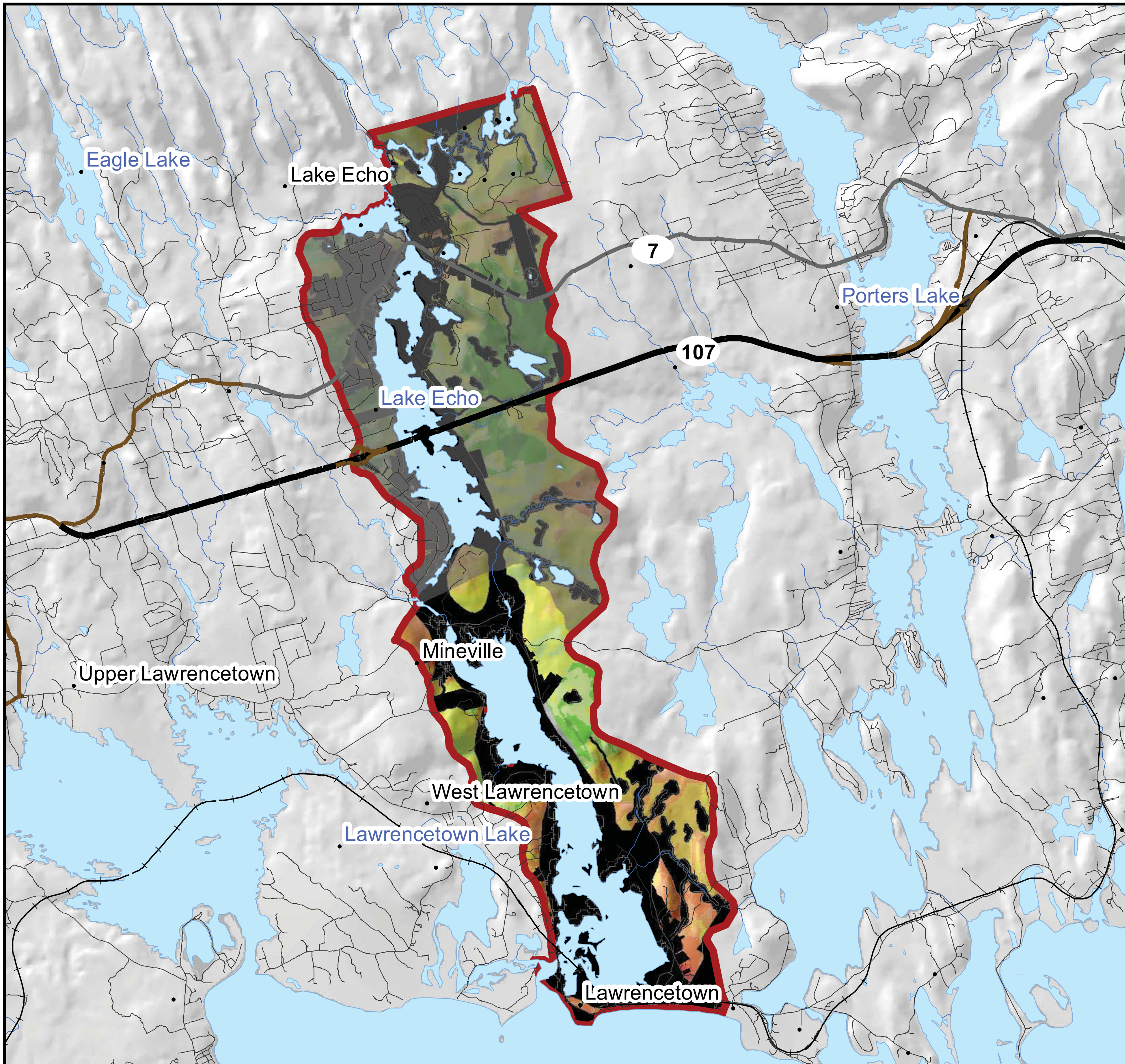
Meetings with Focus Group of Community Representatives
Several community and business leaders were contacted and asked to meet with the study team to discuss their vision for the community (see Figure ES.1.2.3). Population forecasts, existing water quality in receiving waters, water use objectives and associated water quality objectives from the survey were discussed as well as options for servicing future development in the community. The representatives listened to the presentations provided by the study team and were then asked to describe the type of development they expected to occur over the next 20 years in the community.

Figure ES1.2.3: Focus Group's Alternatives for a Community Centre

Participants indicated that most felt there was not really a centre of the community, although this was the original intent of the existing Community Center. Alternate sites for a new centre of development were requested, the group responded by identifying 2 locations, a proposed retirement village development to the northeast of Lake Echo (Lake Echo Case 01278) and a completely new centre adjacent Highway 107 on the east side of the lake. A significant portion of the new development was expected to be in existing, approved sub-divisions in the study area. It was agreed that the study team would complete assessments of the impacts of these development locations, a detailed description and assessment of Case 01278 was completed in Chapter 6.

Desirability for Residential Development
Figure ES1.2.4 shows the relative desirability of the land in the Study Area for residential development. Desirability does not imply that the land is technically feasible to develop. Factors such as slopes could make building difficult. Factors used to determine desirability are explained in the main report.

Certain areas within the Study Area are considered unsuitable for development on the basis of their capability, regulatory restrictions or their environmental sensitivity. These are considered "No Go" areas and should not be developed. All other areas are considered suitable for development with the exception of areas that drain to waterbodies with no assimilative capacity.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

CBCL LIMITED Consulting Engineers

Land Available for Development with Existing Assimilative Capacity

Drawn: YO	Date: March 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure ES1.2.4

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
Projection: Transverse_Mercator
False Easting: 500000.00000000
False Northing: 0.00000000
Central Meridian: -63.00000000
Scale Factor: 0.99960000
Latitude Of Origin: 0.00000000
Linear Unit: Meter

0 550 1,100 2,200 Meters

File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Lands Available for Development with Existing Assimilative Capacity 2.mxd Last Saved: 20/11/2012 2:47:18 PM

Demographics and Potential Development Densities

To determine a range of possible future development scenarios, growth projections related to the Transit Plan[3] were reviewed and alternate projections related to "straight-line" extrapolations from the Nova Scotia Community Counts web site[4] and Statistics Canada[5] were developed. Based on this range of possible growth scenarios, the projections from the Transit Plan are selected as the high growth scenario; calculations using data obtained from the Nova Scotia Community Counts website are used to create the low growth scenario. A medium growth scenario mid-way between the high and low growth scenarios is also provided. Potential changes in population and housing units are summarized in Table ES 1.2.7.

Table ES1.2.7: Population Projections for the Lake Echo Study Area

Year	Low (Community Counts)	High (Transit Plan)	Mid-Range (between NS Community Counts and Transit Plan)
2010 population	2,800	4,200	3500
2010 units	1,000	1,600	1300
2030 population	2,300	5,200	3,700
2030 Units	1,000	2,300	1,600
Population growth 2010-2030	-500	1,000	200
Unit growth 2010-2030	-100	700	300

Note: High and low scenarios selected on basis of population change

The medium growth scenario requires approximately 170 hectares (9.1% of the area within the Study Area that is not in "No Go" areas, and approximately 43 % of the area best suited for development) and the high growth scenario requires approximately 400 hectares (43% of the area within the Study Area that is not in "No Go" areas, and all of the area best suited for development). A portion of this planned development will be in existing sub-divisions, the remainder will be in new sub-divisions. Given that these new developments will be open space subdivisions serviced by clustered onsite wastewater systems and wells, they can be located anywhere within the Study Area but should be encouraged to develop in the areas coloured green in Figure 5.2.1.

Conclusions and Recommendations

Conclusions about the state of existing development and its impacts on the environment as well as recommendations to improve existing conditions and to reduce the risks of additional negative impacts on the environment from potential future development are summarized as follows:

[3] Entra Consultants. 2007. Halifax Regional Municipality Regional Transit Plan – Park and Ride Express and Rural Transportation Services.

[4] Nova Scotia Community Counts, http://www.gov.ns.ca/finance/communitycounts/, accessed on 8 September 2010.

[5] Statistics Canada. 2006 Census Tract and Dissemination Area Population Data.

Water Quality

- Lake water quality is a concern to the majority of respondents to a survey of water quality. Any additional development in the Study Area should address potential impacts on water quality in McCoy's Pond and Lake Echo in particular;
- Some participants in the Community Focus Group meetings indicated that they felt that failed onsite wastewater systems were the primary sources of the pollutants. Participation in the testing of sample onsite wastewater treatment systems was low. None of the tests completed provided direct evidence that failed on-site systems were the sources of pollutants. All wastewater treatment systems are potential point sources of nutrients, E coli and other pollutants. Each system in the study area should be reviewed to ensure that discharges from these systems can be assimilated in the receiving environments. Other potential sources **such as** stormwater **including** lawn care products, pet wastes etc. should be investigated;
- The minimum water use objectives for the water bodies in the Study Area should be that all lakes should be suitable as fish and wildlife habitat and should meet CEME Guidelines for human consumption of fish; and
- Based on comparisons of the water quality necessary to facilitate the desired uses to existing water quality McCoy's Pond is unsuitable for desired uses at most times and Lake Echo is unsuitable for desired uses at times in the summer and fall. On this basis, there is no assimilative capacity to receive any additional pollutant loads in McCoy's Pond or in Lake Echo.

For the water bodies in the Study Area to be used as per the preferences indicated in the water quality survey, measures must be taken to improve existing water quality. Future development in the Study Area should minimize the risk of generating additional sources of pollutants and improve existing water quality where feasible. To allow additional development in any of the areas tributary to the waterbodies with no assimilative capacity requires implementing measures to reduce current pollutant loads to these waterbodies in an amount at least equivalent to:

- The existing loads in excess of the amount required to meet water quality objectives set by current guidelines for the objective water uses established through the survey; plus
- Pollutant loads expected from additional development in the watersheds tributary to each waterbody.

Recommended measures to reduce pollutant loads from existing development and minimize potential loads from future development to improve existing water quality in the Study Area include:

- Implement public education programs relating property owners' actions to water quality to reduce pollutant loads from individual properties;
- Encourage and assist with the development of stewardship programs for the lakes in the community as well as the adjacent shoreline;
- Identify deficiencies with existing wastewater and stormwater systems and design and construct retrofits to these systems;
- Design, construct, operate and maintain wastewater collection and treatment systems as well as stormwater collection and treatment systems to minimize potential pollutant loads generated by these systems; and
- An on-going lake water quality monitoring program. Baseline conditions have been developed for the upper end of Lake Echo using information provided from HRM's 2006 to 2011 Monitoring Program. To ensure successful development, this program should be continued and expanded to

include watershed lakes that may also be impacted by proposed development (Martins Lake, McCoy's Pond, Lawerencetown Lake and possibly Jack Weeks Lake and Lewis Lake). Regulators and managers of future development should make allowances to conduct sampling on a quarterly basis to establish baseline conditions in the lakes most likely to be impacted by development in the Study Area and to follow development progress and its impacts. Assessment of the ongoing data should be used to verify that the plan is achieving the desired reduction in pollutant loads and to modify development plans in response to unpredicted impacts.

Servicing

Specific recommendations for changes to traditional servicing to reduce potential pollutant loads to the water bodies in the Study Area are provided in Chapter 4. Generalized recommended are listed below:

WASTEWATER COLLECTION, TREATMENT AND DISPERSAL

- Ensure routine maintenance and monitoring of onsite wastewater treatment systems. It is currently the responsibility of homeowners to maintain on-site systems. While NSE regulates the design and construction of all wastewater treatment systems in the province and certifies operators and routinely reviews the effluent quality of larger system, it has no program for routine maintenance and inspection for individual onsite systems. An alternative approach to ensure proper maintenance and monitoring of all onsite wastewater treatment s, is to form a wastewater management district. There are none currently in operation in the community. The District, if formed, should include all onsite wastewater treatment systems on individual properties in the watershed areas tributary to Lake Echo as a minimum. Typically in Nova Scotia the Municipality (HRM) takes the role of forming the district and managing its operation to ensure the systems are operating as required to maintain desired water quality in the lakes and to provide assimilative capacity for future development in the community; and
- Routine maintenance, monitoring and reporting on the operation of cluster wastewater treatment systems. This is already required under current provincial regulations.

STORMWATER COLLECTION, TREATMENT AND DISPERSAL

Objectives for Stormwater Management Plans to rectify existing water quality issues and limit the risks of creating new risks should include:

- Minimize changes in runoff at source, including each building;
- Maintain peak runoff flows at or below existing flows from all areas;
- Promote infiltration of the cleanest runoff (from rooftops, etc.) for groundwater recharge; and
- Provide treatment of all other runoff and infiltration facilities.

Low impact development should be considered for all new developments and modifications of existing development. In any servicing situation, to achieve stormwater water quality objectives, the following should be considered:

- Low impact site development, minimizing the affected footprint and providing measures to minimize the collection of stormwater. Where it is necessary to collect stormwater, decrease the efficiency of the collection systems, particularly on private properties;
- Decrease the efficiency of local collection systems using swales with flow limiting culverts between them to encourage detention and infiltration. Filling of ditches should not be allowed; and

- Treatment of remaining runoff in centralized wet ponds and constructed wetlands with built in retention capacity. Co-use of detention storage with other public use lands such as parkland or recreation fields will lower the overall costs of this requirement as the costs of land can be significant.

WATER

- Groundwater supplies to service individual properties as well as clusters systems to service up to ten (10) properties are feasible. A combination of wells in bedrock and surficial aquifers is recommended. Treatment of these supplies may be required for removal of naturally occurring arsenic, iron and/or manganese to levels that meet current CDWQGs. Testing of individual wells is required to determine treatment requirements; and
- Groundwater supplies for a central water service area for those areas with underlying pyritic slate bedrock near the existing community center as well as the Wonderland Mobile Home Park plus some of the proposed future development to the northeast may be achievable. However, given the uncertainties with locating individual wells and minimizing interference between them, alternate sources such as from Lake Echo were investigated and appear feasible as well.

GENERAL

- Monitoring of construction activities with particular attention paid to assuring that erosion prevention and sediment control plans are implemented and components are maintained during construction and properly retired at the end of construction activities; and
- Condominium associations are required for ongoing responsibility of clustered water and wastewater services where these are considered.

Future Development

AREAS SUITABLE FOR DEVELOPMENT

Generally development should avoid “No Go” areas including:

- Water bodies, watercourses and designated wetlands;
- Coastal buffers;
- Provincial parks, reserves, and provincial crown lands;
- Cemeteries;
- All lands below elevation 2.5 metres and less than 2 metres above all local lakes;
- Significant wildlife and endangered species habitat as per map 5 of the Regional Municipal Planning Strategy;
- Areas of elevated archaeological potential as per map 11 of the Regional Municipal Planning Strategy; and
- Lands of high cultural significance as per category 5 on map 10 in the Regional Municipal Planning Strategy.

Certain areas within the Study Area are considered unsuitable for development on the basis of the lack of assimilative capability in the receiving waters including all areas directly tributary to McCoys Pond and Lake Echo). All areas outside the “No Go” areas are considered available for development. Figure ES1.2.4 illustrates the relative desirability for residential development of areas within the Study Area outside of the “No Go” areas. The areas required under the low, medium and high growth scenarios using onsite cluster servicing systems may be readily accepted in areas considered well suited for development in the

Study Area (see Figure ES1.2.4). There is no need to develop areas considered less than most suitable for the planned development. The medium growth scenario requires approximately 200 hectares (28% of the most suitable area within the Study Area) and the high growth requires approximately 260 hectares (52% of the most suitable area within the Study Area).

LOCATION OF DEVELOPMENT

The assumption that growth in the area will be based on the use of cluster servicing systems creates a large degree of flexibility in the location of future development. Unlike central systems that require a certain level of density to be concentrated in one area to make the systems cost effective, cluster systems can be cost-effectively developed separately in a variety of areas allowing developments throughout the Study Area to come on-line as desired.

Formation of a Wastewater Management District is recommended to improve the effectiveness of onsite wastewater treatment systems by providing monitoring, reporting and potentially maintenance and replacement (when necessary) of existing onsite systems in the study area. Expansion of the Wastewater Management District is straight forward with the use of cluster systems. Each subdivision/condominium corporation will build and own the infrastructure and the Wastewater Management District will only need to add additional staff and their supporting equipment for overseeing and analysing additional information from the additional cluster systems. The owners of the additional clusters will compensate Wastewater Management District for these services as each new development comes on-line. No large investments in infrastructure or new plants will be required.

FORM OF DEVELOPMENT

Any additional development should ensure minimal degradation of stormwater or preferably improved stormwater quality in an effort to improve receiving water quality. Improving the design and construction as well as maintenance and monitoring of onsite wastewater and stormwater systems will produce improvements in water quality. Additional improvements may be made by improving the process of locating and laying out development and selecting appropriate types of development.

It is recommended that classic open space subdivision designs be used to keep a significant portion of the Study Area free of development. Based on the *Conservation Design (CSD) Workshop Discussion Paper* distributed at a session hosted by HRM on 5 November 2010, classic open space design allows an overall density of one lot per 0.4 hectares (one lot per acre) with the requirement that the landowner preserves culturally and environmentally significant lands by retaining at least 60% of the parcel as open space. Within an overall development parcel, development may occur in the areas outside the no go areas defined above.

Table ES1.4 Life Cycle Costs of Services in Lake Echo

Component		System Cost						Cost per Service
		Capital Cost (1)	Initial Cost (2)	Annual Operating and Maintenance Costs (3)	Replacement Costs (4)	Present Worth of 100 Year Life Cycle(5)	Number of Services	Present Worth of 100 Year Life Cycle(5)
On-site		$ 27,500	$ 27,500	$ 502	$ 32,250	$ 58,110	1	$ 58,110
	Wastewater (a)	$ 12,000	$ 12,000	$ 199	$ 17,550	$ 27,191	1	$ 27,191
	Stormwater (b)	$ 2,500	$ 2,500	$ 138	$ 2,500	$ 8,100	1	$ 8,100
	Water (c)	$ 13,000	$ 13,000	$ 165	$ 12,200	$ 22,819	1	$ 22,819
10 Unit Cluster		$ 563,237	$ 563,237	$ 20,947	$ 503,311	$ 1,322,828	10	$ 132,283
	Wastewater (a)	$ 315,057	$ 315,057	$ 16,127	$ 283,909	$ 858,655	10	$ 85,865
	Stormwater (b)	$ 25,000	$ 25,000	$ 1,375	$ 25,000	$ 81,004	10	$ 8,100
	Water (c)	$ 223,179	$ 223,179	$ 3,445	$ 194,402	$ 383,169	10	$ 38,317
Central Services Alternatives								
Community Septic Tank Systems		$ 65,494,246	$ 65,494,246	$ 149,993	$ 26,197,698	$ 91,190,121	989	$ 92,204
	Area 1 Martin Lake to Lake Echo	$ 13,220,622	$ 13,220,622	$ 81,428	$ 5,288,249	$ 19,876,516	297	$ 66,924
	Area 2 East Side of Lake Echo	$ 17,268,800	$ 17,268,800	$ 31,815	$ 6,907,520	$ 23,821,915	202	$ 117,930
	Area 3 Bell Park Area	$ 8,925,897	$ 8,925,897	$ 11,850	$ 3,570,359	$ 12,181,124	158	$ 77,096
	Area 4 Mineville Road	$ 10,214,168	$ 10,214,168	$ 15,900	$ 4,085,667	$ 14,006,413	212	$ 66,068
	Area 5 Dempster Crescent	$ 10,501,690	$ 10,501,690	$ 5,250	$ 4,200,676	$ 14,081,980	70	$ 201,171
	Area 6 Candy Mountain Road	$ 5,363,070	$ 5,363,070	$ 3,750	$ 2,145,228	$ 7,222,172	50	$ 144,443
Water Service Area		$ 27,253,459	$ 27,253,459	$ 235,184	$ 23,738,975	$ 36,246,004	956	$ 28,769
	Groundwater Supply and Treatment	$ 7,002,956	$ 7,002,956	$ 156,000	$ 4,201,774	$ 14,021,283	956	$ 7,591
	Reservoir	$ 3,791,416	$ 3,791,416	$ 22,000	$ 3,791,416	$ 4,101,485	956	$ 2,221
	Transmission Mains	$ 7,809,079	$ 7,809,079	$ 5,760	$ 7,809,079	$ 8,090,399	956	$ 8,463
	Water Distribution to Existing Development	$ 7,133,019	$ 7,133,019	$ 15,200	$ 6,419,717	$ 7,604,288	956	$ 7,954
	Existing Services	$ 1,516,988	$ 1,516,988	$ 36,224	$ 1,516,988	$ 2,428,549	566	$ 2,540

Notes

(1) Capital Costs are based on 2011 construction rates
(2) Assumes no higher level government funding
(3) Based on discussions with operators of existing similar sized systems in HRM
(4) Assumes contours are replaced with RTF systems after 25 years
(5) 100 year life cycle cost
Cost per service for central system components are based on full development, at design capacity
(a) Assumes on-site systems are C2 contour systems, community systems are recirculating filters
(b) Assumes rain gardens, one per unit
(c) Assumes wells are into bedrock and water treatment is at point of use for onsite, central treatment for Water Service Area

Within individual house lots, responsible site planning, design and construction should be encouraged to mitigate the creation of impermeable surfaces (such as paved driveways, rooftops) through a variety of approaches such as the provision of multiuse land areas for recharge. Lawn areas, for example, can be designed to act as surface runoff detention areas, as well as aesthetic and recreational areas. Driveways can be designed to be more permeable through the use of unit pavers or gravel, and roof drains can be designed to discharge into soft landscaped areas or "rain gardens". In other cases, it may be more desirable to have impermeable surfaces directing runoff to recharge areas depending on the situation. The point is that in each case the question of stormwater runoff and recharge needs to be addressed at the community level as well as on each property. Responsible design also incorporates the use of native landscape, topography and native vegetation into the site development. Rather than stripping a site bare and completely reforming the topography, buildings should be placed in the landscape and the areas disturbed for construction should be limited to the smallest reasonable footprint.

MINIMUM LOT SIZE

Based on the screening level assessment for water supply by wells, the minimum lot size for residential development should generally be based on a requirement for a minimum of 5,854 square metres of permeable surface for each 1 cubic metre per day of demand, which is approximately equivalent to the demand for one dwelling unit. This should be added to the area taken by all impermeable surfaces on the property and the total compared to the minimum lot size required for the onsite wastewater treatment and dispersal system. The larger size should be used to establish a minimum property size on a site by site basis.

This minimum area of 5,854 square metres of permeable surface plus impermeable surfaces is for areas with a soil depth exceeding 300 mm. In locations with soil depths of 150to 299 mm, the minimum lot size should be 6,800 square metres and in locations with soil depths less than 149mm, the minimum lot size should be 9,000 square metres to meet NSE technical guidelines for onsite sewage disposal systems[6]. In the water service area where wastewater services are provided by onsite systems, the minimum lot size will be determined by these onsite wastewater guidelines.

Costs of Services

Table ES1.4 provides a cost summary for provision of services in the Study Area, including the potential water service area. Without a significant increase in density, it is more expensive to provide central services than onsite services. An increase in residential development may be achieved by utilizing some form of central or cluster services. It is interesting to note that there is a cost premium for clustered services compared to the costs of onsite systems to service a single unit. Clustered systems may allow some increase in population density to be achieved while still addressing environmental concerns.

[6] Nova Scotia Environment, April 2009. *On-Site Sewage Disposal Systems Technical Guideline: Minimum Lot Size requirements For Development Utilizing On-Site Sewage Disposal Systems.* Table 2.4.

CHAPTER 1 INTRODUCTION

1.1 Background

1.1.1 Community of Lake Echo

The community of Lake Echo is located in the Halifax Regional Municipality (HRM) east of Dartmouth, as shown in Figure 1.1. There is considerable residential development occurring in the area as well as some commercial development. The existing community comprises approximately 1,000 residences distributed around the lakes, along the main roads (Highway 7 and Mineville Rd) and in several subdivisions. Properties in these sub-divisions vary in size, depending on when the lots were approved and the lot size requirements at the time. Original development was cottages in Lake Echo on small lots. The newest development has the largest lots; these are sized to meet current design guidelines for on-site wastewater systems.

Commercial development and small businesses, including:

- Restaurants and convenience stores, along Highway 7;
- The fire hall;
- Several churches;
- One elementary school (Bell Park Academic Centre); and
- One community centre (Lake Echo Community Centre).

Existing development is serviced by onsite wastewater treatment systems, wells for water supply and roadside ditches for stormwater drainage.

1.1.2 Context of the Study within the HRM Regional Plan

The Halifax Regional Municipality's Regional Municipal Planning Strategy (MPS) has been created to ensure that development within the Municipality proceeds in an effective and efficient manner. Watershed studies are part of comprehensive secondary planning processes and form the basis of community planning strategies. These studies are to "determine the carrying capacity of the watersheds to meet the water quality objectives"[7] and are required before any other secondary planning processes are advanced.

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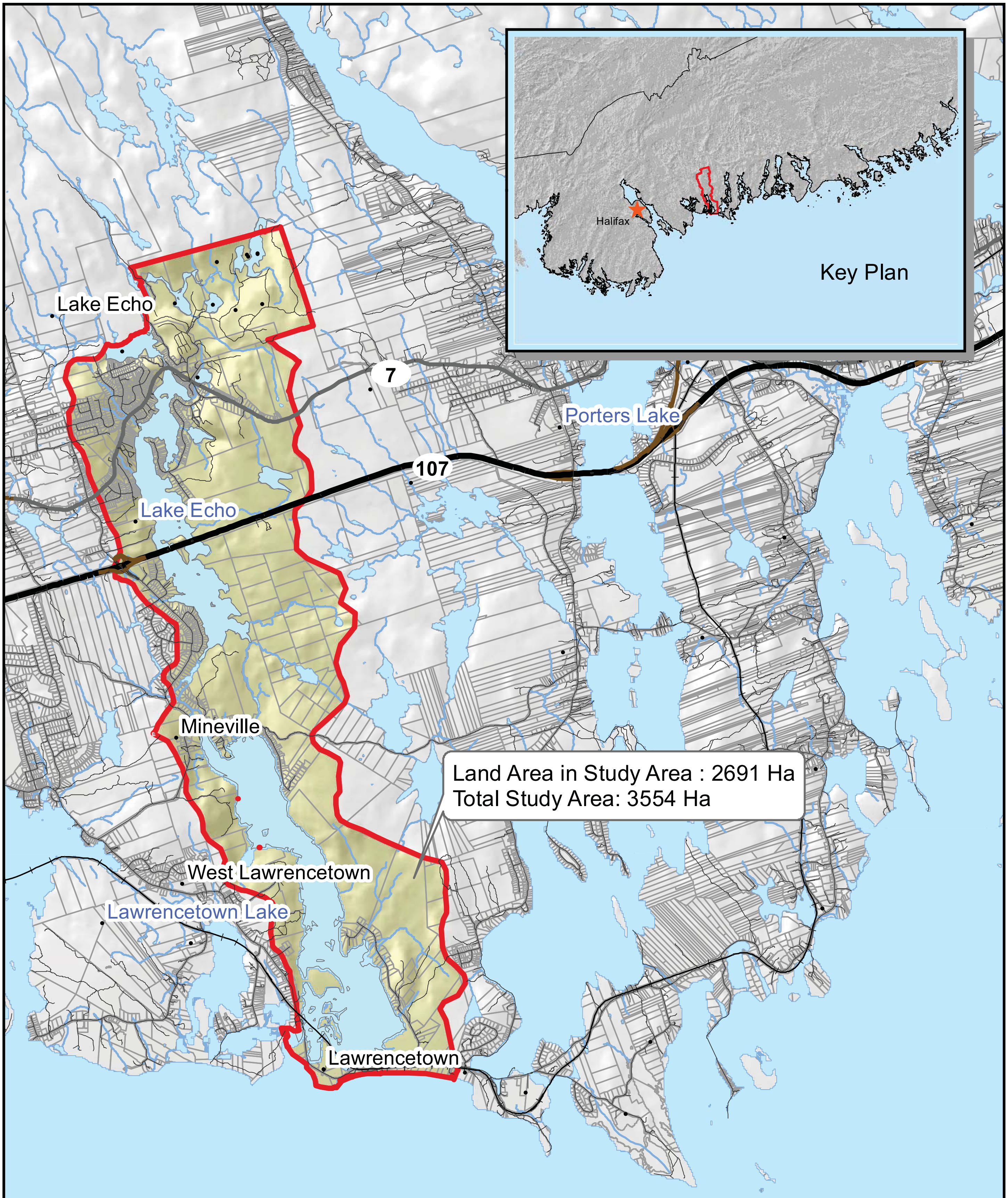
[7] Halifax Regional Municipality. (2006 with amendments to 8 May 2010). Regional Municipal Planning Strategy. p. 31 of digital copy.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study
Figure 1.1 Study Area Location
May 2012

0 1,000 2,000 4,000 Meters

Study Area

CBCL Project # 101015
Data Sources: HRM, NSDNR
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

CBCL LIMITED
Consulting Engineers

File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Study Area.mxd

Last Saved: 14/05/2012 10:33:23 AM

1.1.3 Watershed Studies

This watershed study will determine the carrying capacity of the lands and water systems in the watershed areas tributary to the Lake Echo Study Area with respect to suburban development (see Figure 1.1.3). Its objective is to assess how currently undeveloped land in this community can be developed without negatively impacting water quality objectives for the lakes and watercourses in the watershed areas. Carrying capacity is determined by two factors in this case:

- Ability of the environment to ameliorate the effects of land development; and
- The form that the land development takes.

The ability of the environment to ameliorate the effects of land development is influenced by two factors:

- The capacity of watercourses and lakes to accept pollutant loading without exceeding water quality objectives; and
- The location of development which influences the ability of the land to ameliorate pollutants before they reach the watercourses and lakes.

The form of development can influence the type and quantity of wastes that changes in land cover can produce. Careful consideration of the overall layout of development can preserve areas that:

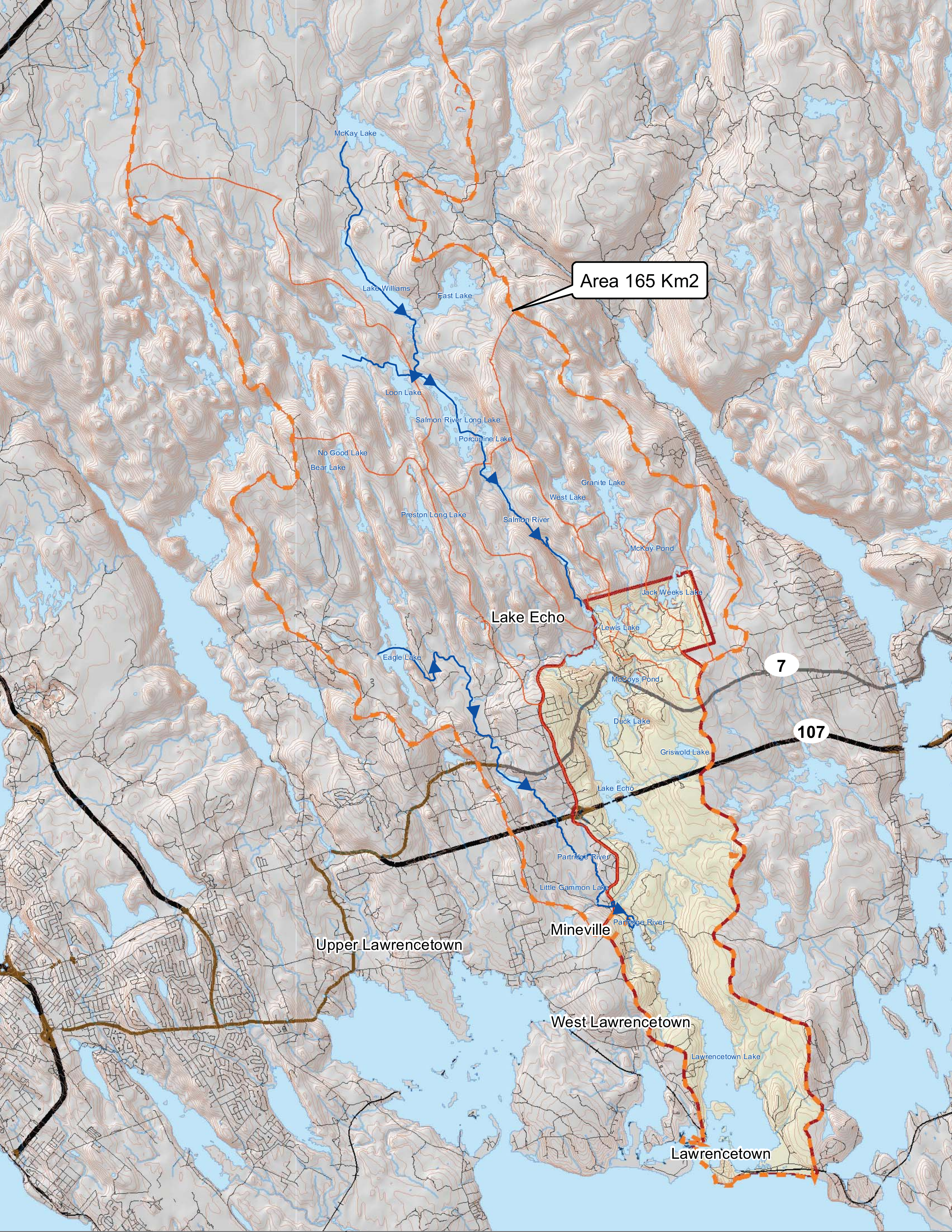
- Have the best ability to mitigate pollutants;
- Can absorb surface water to recharge groundwater and reduce runoff; and
- Preserve existing vegetation on sloped areas to reduce erosion.

Watershed plans should result in land development and provision of services for development with much less negative impact on the surrounding environment than current development approaches have generated. The overall process involves:

- Determining the existing condition of natural systems in the Study Area based on site specific scientific and engineering studies and analysis;
- Setting objectives for allowable impacts on these natural systems; and
- Defining appropriate development where locations, density and form of development are matched to the capability of the surroundings to accept the development.

However, the plan developed as part of this study affects development of only a part of the watershed; actions taken upstream in the watersheds that contribute flows through the community may impact the surface and ground water quality as it enters the Study Area. HRM is able to implement development policies that affect the area within its boundaries but does not have full control of water quality in the waters that enter or surround it. It must be realized in the planning process that these limitations exist and should be accounted for with appropriate contingency plans.

Terms of Reference for the study were received from HRM in January 2010, outlining a number of specific tasks to be completed as part of the overall evaluation of the development potential for this Study Area. The study was awarded to CBCL Limited in April 2010 and field work was completed from April until October 2010.



McKay Lake
Area 165 Km2
Lake Williams
East Lake
Loon Lake
Salmon River Long Lake
Porcupine Lake
No Good Lake
Bear Lake
Granite Lake
West Lake
Preston Long Lake
Salmon River
McKay Pond
Jack Weeks Lake
Lake Echo
Lewis Lake
Eagle Lake
7
McCoys Pond
Duck Lake
107
Griswold Lake
Lake Echo
Partridge River
Little Gammon Lake
Mineville
Partridge River
Upper Lawrencetown
West Lawrencetown
Lawrencetown Lake
Lawrencetown

1.2 Study Scope and Objectives

The general objectives of this study included:

- Identify opportunities for development within the Study Area defined around the existing community of Lake Echo; and
- Develop a site specific plan showing all land suitable for development complete with potential development densities and the services required to allow these densities to be realized.

In addition to these general objectives from the Request for Proposals for the study, a detailed assessment of the impacts of a particular sub-division plan was commissioned. The proposed sub-division is located at the northern end of Lake Echo, adjacent the existing Wonderland Mobile Home Park.

Specific objectives for this study as set out under Policy E-17 of the HRM Regional MPS and the Request for Proposals were:

- Assess quantity and quality of groundwater resources;
- Determine receiving water quality;
- Estimate the quantity and quality of surface water (freshwater and marine), including limiting the potential of eutrophication of potential receiving waters from stormwater and effluent from sewage treatment facilities;
- Identify strategies for minimizing the loss of existing watershed features and attributes;
- Compile an inventory of sources of contamination;
- Recommend strategies to specifically adapt HRM's Stormwater Guidelines to meet the water quantity and quality objectives for this watershed;
- Identify natural corridors and critical habitats for terrestrial and aquatic species and recommended measures to protect them;
- Identify appropriate riparian buffers based on watershed specific sites, issues and parameters; and
- Evaluate development potential in the Study Area based on these assessments.

In addition, the Terms of Reference for this study included a sanitary survey of the most densely developed areas within the existing community.

1.3 Organization of the Report

The report is organized as follows:

- Chapter 2 describes the methodology followed in the study as well as input received from HRM and the community;
- Chapter 3 provides a brief description, including relevant findings and recommendations, for the studies completed to address the specific objectives listed in Section 1.2 that required significant investigations;
- Chapter 4 considers alternatives for provision of services;
- In Chapter 5 the findings of the investigations and assessments are integrated and used to define preferred development in the study area; and
- Chapter 6 summarizes an assessment of impacts of proposed Lake Echo Development Case 01278.

CHAPTER 2 PROJECT METHODOLOGY

2.1 Methodology

Generally, the study methodology was as follows:

- Mapping and other relevant data were collected and assembled in a GIS map and database of the Study Area;
- Several sub-studies necessary to address each objective listed in Section 1.2 were completed. These studies were used to define:
  - A range in potential future development (the number of additional people and the number of additional buildings) expected in the Study Area;
  - Limitations and constraints on development within the Study Area;
  - Best methods for development with limited impacts on the surrounding environment;
- Study findings were compiled on the mapping and areas not suitable for future development ("No Go" areas) in the Study Area were identified;
- Various development density scenarios consistent with existing development were evaluated:
  - The location of a Community Centre was considered where some development will tend to be concentrated and desired densities were identified;
  - Reasonable development densities were considered for areas outside of the Community Centre, areas where the remaining expected development will occur;
- Facilities needed to provide sanitary, stormwater and water services consistent with current design guidelines for each service were identified; and
- The process, the findings and recommendations developed to address environmental issues resulting from existing development as well as to guide future development of the Study Area were assembled in this report.

Details of the more complex tasks completed for the study are described in a set of component study reports in the appendices; summaries of the work are presented in the next chapter.

2.2 Background Information Particular to Lake Echo

To develop a clear understanding of local conditions and to establish watershed specific targets for development, information from available sources was gathered and collated. Sources included:

- Provincial and Federal agencies;
- HRM GIS;

- Personal communication with the steering committee;
- A Focus Group of community representatives, formed as part of this study, met to discuss their vision of the Community and their thoughts on future development in the community;
- Previous reports completed for HRM:
  - HRM Options for Onsite & Small Scale Wastewater Management Study, Land Design, March 2005 – including copies of suitability mapping;
  - A report to Marine Drive, Valley and Canal Community Council, June 22 2011 on Case 01278: Application to Amend Planning Districts 8 and 9 MPS/LUB; and
- Lake Echo Watershed Study – Community Concerns, A Report prepared by Citizens for Responsible Development in Lake Echo, 4/19/2011.

Data gathered from these sources included:

- Federal and provincial regulations regarding discharges to surface waters, and water withdrawal as well as CCME water quality guidelines necessary to sustain various uses;
- Topographic mapping complete with delineated watershed boundaries;
- Watercourse and wetland locations and types;
- Soil types and the areal extents of each type;
- Native and non-native vegetation;
- Environmentally sensitive areas;
- Available information on levels of site contamination and any dangerous/hazardous materials;
- Existing servicing systems and utilities;
- Existing developed areas and general conditions;
- Property boundaries and ownership;
- Watershed boundaries on the larger scale from NSE Watershed Mapping for the Salmon River watershed;
- Assessment of areas most suitable (as well as those areas less suitable) for onsite wastewater services and groundwater potential of bedrock from the onsite study done for HRM in 2005 as well as knowledge of local conditions for onsite wastewater systems and wells based on previous investigations in the area; and
- Lake Echo water quality from HRMs 2006 – 2011 monitoring program (spring, summer and fall results for a range of parameters from 2007 to 2011) as well as pH data collected in the tributary watercourses upstream of Lake Echo by the Citizens for Responsible Development in Lake Echo.

2.3 Visions of Future Development

Potential future development within the Study Area was investigated by:

- Reviewing the HRM Regional Municipal Planning Strategy;
- Meeting with community representatives;
- Reviewing estimates of future population developed in recent studies in the area; and
- Assessing the desirability and suitability for development of various sections of the Study Area.

2.3.1 HRM Regional Municipal Planning Strategy

In the MPS, HRM has established Lake Echo as a Rural Commuter Centre. The Municipality's has established Comprehensive Development District (CDD) zoning in an area on the north side of Highway 7 located on the western side of Lake Echo, south of Thomas Street and east of Bell Street. The CDD zoning will protect the area as a focal point for transit-oriented design development by requiring new development to proceed by development agreement, except for the continuation and expansion of existing uses. The parameters of the development agreement are quite broad, allowing for mixed use and development controls related to building heights, signage, building massing, architectural design, parking facilities, etc.

The MPS proposes future land use in this area as low to medium density residential with a mix of commercial, institutional and recreational uses. Large scale as-of-right residential development is discouraged in this area. Provisions have been established to allow small scale infill development on existing roads or roads that were under consideration at the time of implementation of the plan and to allow limited development on new roads. Large-scale residential development may be considered through a development agreement if it is in some form of Open Space Design that protects important conservation areas. The Regional MPS outlines the issues that HRM shall consider in approving Open Space Design developments.

2.3.2 Meeting with Focus Group

Several local community and business leaders were identified to the study team by HRM and other members of the community and all were invited to a Focus Group Meeting. The meeting was held at the Lake Echo Community Centre on the evening of November 29th 2011 with fourteen of these representatives in attendance. Population forecasts, existing water quality in receiving waters, water use objectives and associated water quality objectives from the water quality survey were discussed as well as options for servicing future development in the community. The presentation included a discussion of the costs of servicing and typical problems with existing services.

The attendees were asked as groups to consider future development in the community and to answer the following questions based on their options of the information presented:

- Is there a centre of the community of Lake Echo and if there is, where is it?
- Where will future development be located? The groups at each table were asked to draw the locations on maps of the study area provided.

The discussions carried on as one large group. Summaries of the points covered are presented in the following bullets.

- It was generally agreed that:
  - Residential development will continue to occur in the area over the next 20 years;
  - It will likely be spread throughout the study area;
  - With the exception of areas within existing approved development plans, all areas should be developed as Open Space Subdivisions;
  - It should provide a mix of housing types;
- There was no agreement reached on where the centre of new development might be located but a number of possible areas for future development were identified. These were identified on a map of the study area at the meeting and a copy of the map is attached for reference. The map shows:
  - Locations of several on-going and planned sub-divisions in the study area;

- Locations of future development centers in the community suggested by two groups, both are shown on the map of the study area:
  - The first group pointed to the areas where the retirement village development is proposed northeast of Lake Echo;
  - The second group suggested a new interchange be built on Highway 107, east side of Lake Echo, close to the lake, that would allow development on either side of the highway and improve access to existing development in Lake Echo. A community centre (core area) could be developed near the interchange; and
  - It was agreed that the impacts on lake water quality of suggested development areas shown on Figure 2.3.2 would be assessed.

Figure 2.3.2: Focus Group's Alternatives for a Community Centre

A summary of discussions was prepared following the meeting with the Focus Group and is included in Appendix A.

2.3.3 Demographics and Potential Development Densities

Population allocations prepared for the HRM Regional Plan for the period of 2006 to 2026 allow for a population increase of 1,000 people within the community of Lake Echo[8]. This is a growth of 25% although the document says "17%" and "grow fairly slowly". Because of downward trends in household size from 2.87 people per unit in 2001 to 2.37 people per unit in 2026 (generalized across HRM's rural commuter-shed) the HRM Regional MPS anticipated that there would be at least 650 new housing units created in the community.

To determine a range of possible future development scenarios, growth projections related to the Transit Plan[9] were reviewed and alternate projections related to "straight-line" extrapolations from the Nova Scotia Community Counts web site[10] and Statistics Canada[11] were developed. Based on this range of possible growth scenarios, the projections from the Transit Plan are selected as the high growth scenario; calculations using data obtained from the Nova Scotia Community Counts website are used to create the low growth scenario. A medium growth scenario mid-way between the high and low growth scenarios is also provided. Potential changes in population and housing units are summarized in Table 2.3.3.

Table 2.3.3: Population Projections for the Lake Echo Study Area

Year	Low (Community Counts)	High (Transit Plan)	Mid-Range (between NS Community Counts and Transit Plan)
2010 population	2,800	4,200	3500
2010 units	1,000	1,600	1300
2030 population	2,300	5,200	3,700
2030 Units	1,000	2,300	1,600
Population growth 2010-2030	-500	1,000	200
Unit growth 2010-2030	-100	700	300

Note: High and low scenarios selected on basis of population change

In addition to these generalized assessments, assessments were completed for a specific development planned for the northeast corner of the Study Area (Case 01278). The development is ultimately planned to accommodate a total of 315 new units (with an expected population of 746) in a mix of classic open space design and hybrid open space design sub-divisions. Included in the overall project is a "retirement village". Details of the assessment are provided in Chapter 6.

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[8] Marcus Garnett, Planner, HRM, personal communication 12 July 2010.
[9] Entra Consultants. 2007. Halifax Regional Municipality Regional Transit Plan – Park and Ride Express and Rural Transportation Services.
[10] Nova Scotia Community Counts, http://www.gov.ns.ca/finance/communitycounts/, accessed on 8 September 2010.
[11] Statistics Canada. 2006 Census Tract and Dissemination Area Population Data.

2.3.4 Population to be Serviced

Based on discussions at the Focus Group meeting, it is expected that only a portion of the new residents in the study area would choose to move into the Community Centre. The remainder will either choose to locate in existing sub-divisions that have been developed as estate lots or in new developments in the study area that will be developed under current requirements. For planning purposes, it has been assumed that one third of those moving to the community in the next 20 years will move to the Community Centre, the remainder will be distributed in the Study Area outside of the Community Centre.

Areas required for the expected development generated by the three growth scenarios are presented in Table 2.3.4(a). The Terms of Reference for this study specify that a central water system may be considered in the community but not a central wastewater system. In this case, property sizes for all future development areas (inside or outside of the Community Centre) will be determined by lots sizes prescribed by Nova Scotia Environment for onsite wastewater treatment and/or the lot size required to supply sufficient groundwater to meet demands in the study area. These issues are investigated in later sections of the report. For this assessment it is assumed that the minimum lot size will be 4,550 square metres for all new development whether in the community centre or outside.

Table 2.3.4(a): Population Projections for the Community Centre

Growth scenario	33 Percent of Growth in Community Centre			67 Percent of Growth Outside of the Community Centre		
Additional	People	Units(1)	Hectares(2)	People	Units(1)	Hectares(2)
High	333	233.1	132.6	670	469	266.7
Medium	66.6	99.9	56.8	134	201	114.3
Low	-166.5	0	0.0	-335	0	0.0

Note: Assumes 2.37 persons per unit

Assume a development density of 2.5 persons per hectare or 4550 square metres per lot.

Of those that move to areas outside of the Community Centre, it is assumed that half will build in existing sub-divisions and the remainder will build in new sub-divisions.

Table 2.3.4(b): Population Projections for Areas Outside of the Community Centre

Growth scenario	33.3 Percent of Growth in Existing Sub-divisions			33.3 Percent of Growth in New Sub-divisions		
Additional	People	Units(1)	Hectares(2)	People	Units(1)	Hectares(3)
High	333	233.1	132.6	333	233.1	132.6
Medium	66.6	99.9	56.8	66.6	99.9	56.8
Low	-166.5	0	0.0	-166.5	0	0.0

Using an average size requirement of 4550 square metres per unit the total area required for new development in the Study Area over the next 20 years will be 400 hectares for the high growth scenario and 170 hectares for the medium growth scenario.

CHAPTER 3 COMPONENT STUDIES

Studies were conducted to determine the following:

- Groundwater availability and quality and the potential for using groundwater to supply water to the community;
- Existing water quality in local water bodies;
- Desired water uses for the streams, lakes and costal inlets in the community;
- Assimilative capacity and opportunities for stormwater and wastewater treatment effluent discharge to surface waters;
- Potential sources of contamination for surface and groundwater;
- Opportunities for improving existing water quality, including stormwater best management practices most applicable in Lake Echo;
- Valuable environmental functions in the Study Area and opportunities for retaining them through the development process; and
- Constraints on development exerted by natural conditions and existing uses, including a limited survey of existing on-site wastewater treatment systems and wells.

Descriptions of the studies conducted and generalized results considered in isolation are summarized in this section. Where extensive studies have been completed, details of these component studies are presented in Component Study Reports in the appendices. Results of these studies are synthesized in subsequent chapters to develop results and recommendations.

3.1 Groundwater Availability and Quality

The full groundwater component study can be found in Appendix B. The groundwater resources evaluation of the Lake Echo area is summarized as follows:

Incoming precipitation in the study area is assumed to recharge primarily the surficial aquifer; components of recharge to deeper groundwater regimes could occur in upland areas to the north of the study area, and in the central, uninhabited part of the study area, between Lake Echo and Porters Lake.

3.1.1 Existing Wells

Drinking water needs in the Lake Echo Study Area are supplied by individual water wells in the surficial and bedrock aquifers of the area. Dug wells draw water from deposits of till, sandy lenses, and local pockets of gravel, providing yields sufficient for single household use. Selected wells drilled into the surficial deposits reported yields adequate to supply light industry and small commercial developments. The bedrock unit is composed of metamorphic rock with an upper weathered zone and limited fracture partings at greater depths. Flow in the bedrock aquifer is assumed to be regional, with gradients primarily horizontal or upward.

3.1.1.1 Surficial Material

Surficial aquifers in lowland areas are composed primarily of granular deposits within quartzite and slate tills. Thicknesses of granular deposits commonly reach 6 metres, with a maximum reported overburden thickness of 69 m. Wells installed in surficial deposits are capable on average of providing 9 to 84 L/min. Wells installed in surficial aquifers are expected to be capable of supplying clusters of 10 homes or more.

3.1.1.2 Bedrock

Individual wells are on average drilled 33 to 69 m into the bedrock. The depth and yield of drilled wells is variable. Many bedrock wells likely rely on single or discrete sets of fractures near the base of the well and provide water at 7 to 32 L/min. Most wells installed in the bedrock should be capable of supplying clusters of up to 10 homes. The bedrock transmissivity and storativity are low, indicating that drawdown cones will be deep with a moderate radius of influence, attention to proper well spacing during the design of well fields or lot layout is required.

3.1.1.3 Groundwater Quality Potential of Bedrock Aquifers

The inferred quality of water that could by supplied by wells installed in bedrock was investigated at a screening level in the “Onsite and Small Scale Wastewater Management Study” completed for HRM by Land Design Engineering Services in March 2005. Figure 3.1.1.3 was developed with information presented in the report for that study. It suggests that bedrock underlying most of the Study Area is Class B, (Potentially Good). There are bands of bedrock underlying the study area, including the existing Community Centre of Class D, (treatment to address water quality issues is likely to be required).

Actual treatment requirements will be determined through a Hydrogeological Assessment, as part of a subdivision application.

Arsenic concentrations were above Canadian Drinking Water Quality Guidelines (CDWQG) in a number of the samples taken from bedrock wells. Iron and manganese concentrations exceeded the taste and odour guideline in a sample of raw water from the community centre. Arsenic, iron and manganese treatment could be required for some groundwater supplies in the study area.

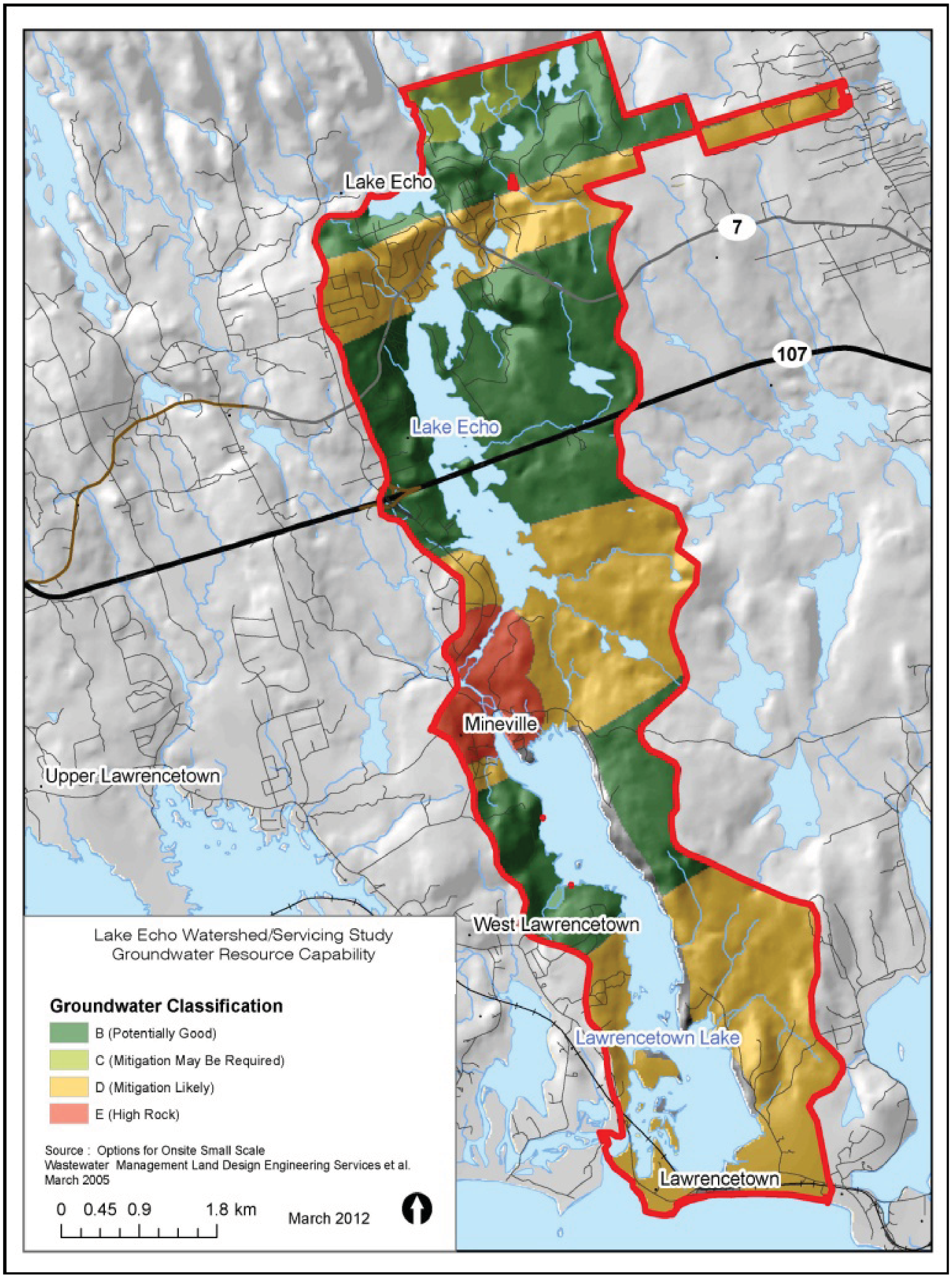


Figure 3.1.1.3: Groundwater Resource Potential of Bedrock (from Land Design Engineering Services et al. March 2005)

3.1.2 Effects of Groundwater Yields on Future Development

Projected demands were compared to the available water budget for the Lake Echo Study Area. Under current conditions approximately 4% of potential recharge is pumped for water supply in the Lake Echo area. The calculation assumes that all water is drawn from infiltrating precipitation falling within the Study Area, which implies a focus on withdrawals from surficial aquifers. Additional components of regional flow may be available in the bedrock aquifer. Under a high growth scenario up to 9% of potential recharge would be pumped as drinking water. An analysis of potential servicing scenarios indicates that all approaches could be sustained at the projected rate of growth. Over 90% of recharge local to the Study Area would remain available as base flow to streams, lakes, coastlines, and regional recharge.

Existing high-yield water supplies suggest that the yields of selected aquifers in the Lake Echo area are adequate to provide central servicing. Additional investigation would be required to locate an extensive deposit of granular material, preferably in a remote area where a Well Head Protection Area (WHPA) could eventually be designated. If future development is to encourage growth of a centralized urban area, a detailed hydrogeological investigation is recommended.

A high density of shallow wells could cause a decline in the local water table, potentially interrupting the supply to the shallowest wells. Careful lot planning is required to minimize potential interferences between wells and onsite wastewater treatment systems. Under increasing population density, surficial aquifers will be vulnerable to bacterial inputs, nutrient loading (septic effluent), pharmaceuticals / metabolites (septic effluent), and water table depletion. The bedrock aquifer receives some protection from the overlying tills, particularly in upland areas and where drumlins are present.

The scenario most likely to succeed under increasing development pressure would be to supply clusters of up to 10 homes on a single well. A balanced approach would include wells drawing water from both the bedrock and surficial aquifers. This option has several advantages from a supply and aquifer vulnerability standpoint including the following:

- Yields are generally adequate;
- Bedrock wells can be incorporated, providing better protection of water quality; and
- Well spacing is improved, reducing drawdown and interference effects.

3.2 Existing Surface Water Quality

The full surface water quality component study can be found in Appendix C.

3.2.1 Background

The field sampling program was designed to cover a comprehensive suite of water-quality parameters (see Table 3.2.3) in wet and dry weather conditions during spring, summer and fall seasons of 2010. Additional samples were collected on one dry day in the summer of 2011. Sampling locations were strategically selected to provide baseline data for the locations in Lake Echo most likely to be impacted by existing and future development. General results were also used for validation of a phosphorus model (see section 3.4). Locations of the sampling sites are shown in Figure 3.2.3. These were developed with input from the Technical Steering Committee for this study.

In situ parameters of water temperature, pH and salinity were measured with a Horiba multi probe, Model W-21. The probe was lowered into the water column using a graduated cable for measurements at 1-m depth intervals where appropriate. Water samples for biological and chemical analyses were collected in sterilized sampling bottles and analysis was performed by laboratories according to recommended and accredited standard methods. All samples were stored on ice and delivered to the lab within six hours of taking the sample. Water samples for the determination of chlorophyll *a* were wrapped in metal foil to avoid degradation of pigment by sunlight.

3.2.2 Objectives

The sampling program was designed to capture water quality differences between sites, seasons and, importantly, capture peak pollution levels caused by runoff. Specifically it was intended to:

- Assess existing water quality of surface water bodies in the most developed sectors of the Study Area, around Lake Echo;
- Assess the existing trophic status of these water bodies; and
- Contribute to the development of a baseline of water quality against which to compare future measurements.

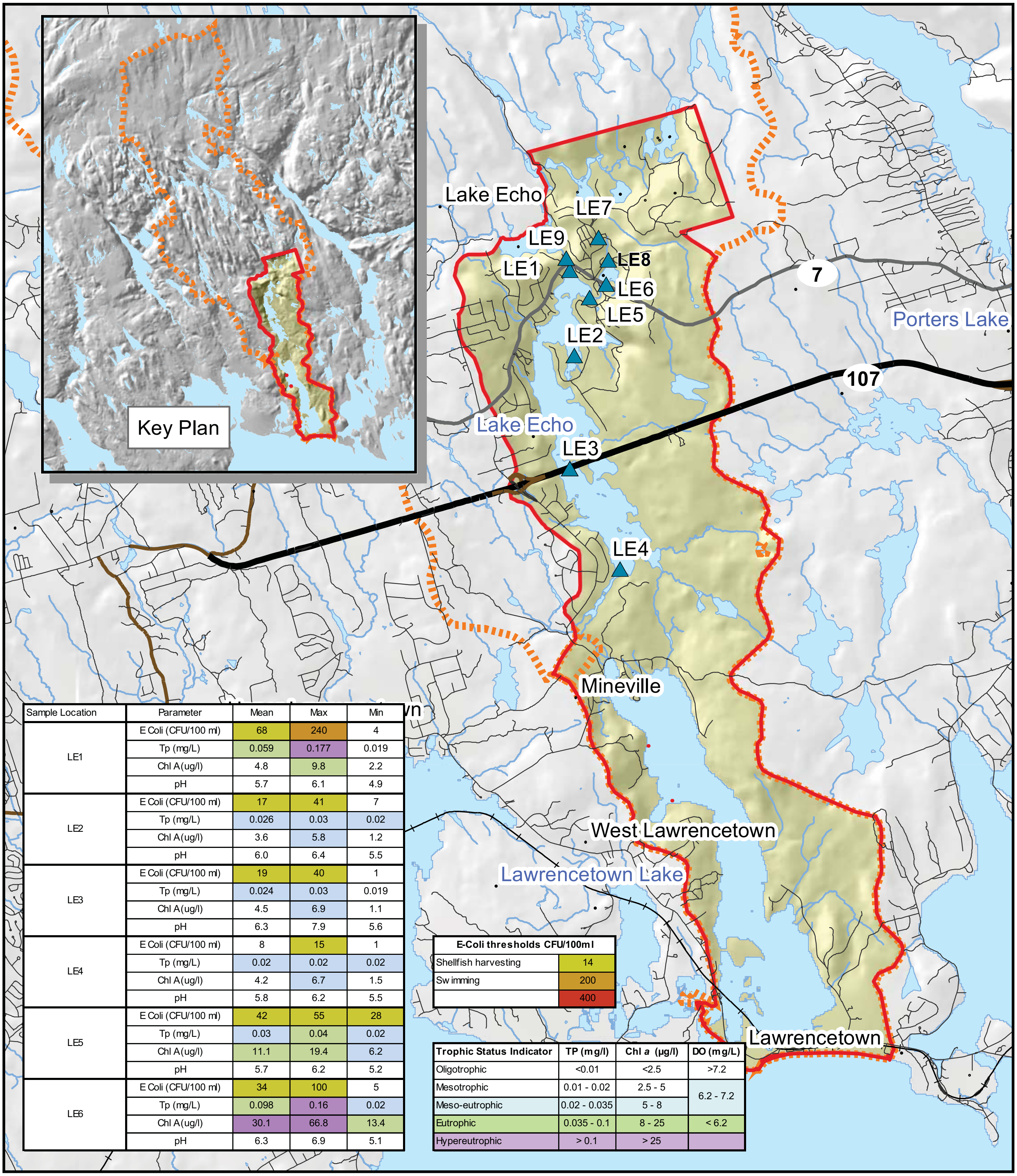
3.2.3 Water Sampling and Analysis Program

Surface water samples were collected at the locations shown on Figure 3.2.3. Fourteen (14) water quality parameters were measured for each sample; these are listed in Table 3.2.3.

Table 3.2.3: Water Quality Parameters

Parameter	Symbol	Units	Detection Limit Applied	Description
Dissolved Oxygen	DO	mg/L		Measured *in situ*
Water temperature		°C		Measured *in situ*
pH	pH			Measured *in situ*
Salinity		%		Measured *in situ*
Concentration of *Escherichia coli*	E. coli	CFU/100 mL	1	CFU (Colony Forming Units): the number of colonies on the incubation plate
Concentration of fecal coliform bacteria*	FC	MPN/mL	100	MPN (Most Probable Number): an approximation of the number of bacteria from a count of the number of colonies.
Total Phosphorus	TP	mg/L	0.02	Laboratory measurement
Carbonaceous Biological Oxygen Demand	C.BOD	mg/L	5	Laboratory measurement
Chlorophyll *a*	Chl *a*	µg/L		Laboratory measurement
Nitrate	Nitrate	mg/L	0.05	Laboratory measurement
Nitrate + Nitrite	Nitrite	mg/L	0.05	Laboratory measurement
Ammonia	Ammonia	mg/L	0.05	Laboratory measurement
Total Kjeldahl Nitrogen	TKN	mg/L	0.1	Laboratory measurement
Total suspended solids	TSS	mg/L	2	Laboratory measurement

*Fecal Coliform (FC) and E-Coli have been traditionally used in most jurisdictions as the primary bacterial indicators. Recently E-Coli (a subgroup of FC) was established as the preferred indicator (CCME 2004), because it is reported to correlate best with bather illnesses in sewage impacted recreational waters (Noble et al. 2003). For this study the samples were analysed for both E-Coli and FC.



Sample Location	Parameter	Mean	Max	Min
LE1	E Coli (CFU/100 ml)	68	240	4
	Tp (mg/L)	0.059	0.177	0.019
	Chl A (ug/l)	4.8	9.8	2.2
	pH	5.7	6.1	4.9
LE2	E Coli (CFU/100 ml)	17	41	7
	Tp (mg/L)	0.026	0.03	0.02
	Chl A (ug/l)	3.6	5.8	1.2
	pH	6.0	6.4	5.5
LE3	E Coli (CFU/100 ml)	19	40	1
	Tp (mg/L)	0.024	0.03	0.019
	Chl A (ug/l)	4.5	6.9	1.1
	pH	6.3	7.9	5.6
LE4	E Coli (CFU/100 ml)	8	15	1
	Tp (mg/L)	0.02	0.02	0.02
	Chl A (ug/l)	4.2	6.7	1.5
	pH	5.8	6.2	5.5
LE5	E Coli (CFU/100 ml)	42	55	28
	Tp (mg/L)	0.03	0.04	0.02
	Chl A (ug/l)	11.1	19.4	6.2
	pH	5.7	6.2	5.2
LE6	E Coli (CFU/100 ml)	34	100	5
	Tp (mg/L)	0.098	0.16	0.02
	Chl A (ug/l)	30.1	66.8	13.4
	pH	6.3	6.9	5.1

E-Coli thresholds CFU/100ml	
Shellfish harvesting	14
Swimming	200
	400

Trophic Status Indicator	TP (mg/l)	Chl *a* (µg/l)	DO (mg/L)
Oligotrophic	<0.01	<2.5	>7.2
Mesotrophic	0.01 - 0.02	2.5 - 5	6.2 - 7.2
Meso-eutrophic	0.02 - 0.035	5 - 8	
Eutrophic	0.035 - 0.1	8 - 25	< 6.2
Hypereutrophic	> 0.1	> 25	

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Lake Echo Watershed/Servicing Study
Figure 3.2.3 Surface Water Sample Location

May 2012

0 750 1,500 3,000 Meters

Surface Water Sample Location

Study Area

CBCL Project # 101015
Data Sources: HRM, NSDNR
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

CBCL LIMITED

File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Surface Water Sample Location.mxd

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3.2.4 Results

Results of the measurements and analysis of the water samples are presented in Table 2.3 in Appendix C. Pertinent results include:

3.2.4.1 Water Temperature

Water temperatures at the sampling sites ranged between 9 and 24°C over the sampling season. The warmest temperatures at all stations were measured on August 18, 2010 during a period of dry weather. Stations showed mostly uniform temperature through the water column. Temperature is a key physical parameter affecting life in marine and freshwater environments as it influences numerous other properties such as the solubility of gases in water, ionization constants, and the intrinsic growth rates of single celled organisms. Because temperature varies naturally in lakes both temporally and spatially CCME Guidelines, which are concerned about anthropogenic changes in ambient water temperature, are not relevant for this study's context.

3.2.4.2 pH

The pH in Lake Echo shows relatively little variability with values typically between 4.8 and 6.9. Variations of pH with depth are not systematic and do not demonstrate conclusive increasing or decreasing patterns. The CCME Guidelines recommend a pH range of 6.5 to 9. Lake Echo waters generally do not meet this general criterion. Slightly acid water is not unusual for Nova Scotia, where most watersheds have an environment with acidic soils, because of acidic precipitation and humic material. Values of pH less than 6.0 have been observed for similar studies in other watersheds with various levels of development.

Local residents completed measurements of pH in streams tributary to Lake Echo, north of the community (see section 2.2 for reference).Their findings showed low pHs. Figure 3.1.1.3 indicates that this area is underlain by Halifax Formation slate bedrock. When runoff comes in contact with this bedrock the pH is lowered.

3.2.4.3 Carbonaceous Biological Oxygen Demand (C.BOD)

C.BOD values were below the detection limit of 5 mg/L in all samples in Lake Echo. These low values indicate that there is little loading of lakes with dissolved organic matter. This has minimal effect on the oxygen levels, as confirmed by uniformly high values of dissolved oxygen concentrations in surface samples (see next section). BOD values between 4 and 5 mg/L were detected in the samples collected downstream of the wastewater treatment plant serving the Wonderland Mobile Home Park, at the STP Pond outlet and further downstream in McCoy's Pond which drains into Lake Echo.

3.2.4.4 Dissolved Oxygen

All vertical profiles of dissolved oxygen showed relatively uniform oxygen concentration with depth, including down to 8 m deep on 20 May 2010. The CCME Dissolved Oxygen Guidelines for freshwater aquatic life are 5.5 to 9.5 mg/L. The measured concentrations of dissolved oxygen (DO) in Lake Echo meet the guidelines. However, DO concentrations in the pond receiving effluent discharge from the wastewater treatment plant are in a range consistent with hypereutrophic conditions in July 2011, with a DO value of 0.7 mg/L (see the lists of indicator values for various water quality parameters in Table

3.2.4.6). Downstream of McCoy's Pond there was a measured DO value below the recommended minimum on one occasion (5.3 mg/L on 29 September 2010).

3.2.4.5 Total Suspended Solids (TSS)

The concentration of total suspended solids in all water samples was low, typically less than 5 mg/L. Measured TSS concentrations were not found to be of concern in the water bodies sampled at the times sampling was conducted.

3.2.4.6 Eutrophication Status (Phosphorus, Nitrogen, Chlorophyll A)

The process of eutrophication is defined as the loading of inorganic and organic dissolved and particulate matter, including nutrients, to waterbodies at rates sufficient to increase the potential for high biological production, decrease basin volume and deplete dissolved oxygen (Cooke *et al*., 2005). For the purpose of this report the trophic status of each lake has been assessed by examining the concentrations of nutrients: total phosphorous (TP) and total Nitrogen (TN), the levels of algal biomass (as chlorophyll a present in the lake, and the state of oxygenation of the water column. The results allow for the classification of the lakes into oligotrophic, mesotrophic, meso-eutrophic, eutrophic or hypereutrophic (see Table 3.2.4.6).

Table 3.2.4.6: Indicators of Trophic State

	TP (mg/L)	Chl a (µg/l)	DO (mg/L)	TN (mg/L)
Oligotrophic	<0.01	<2.5	>7.2	<0.35
Mesotrophic	0.01 - 0.02	2.5 - 5	6.2 - 7.2	0.35 – 0.65
Meso-eutrophic	0.02 - 0.035	5 - 8		
Eutrophic	0.035 - 0.1	8 - 25	< 6.2	0.65 – 1.2
Hypereutrophic	> 0.1	> 25		> 1.2

Note: Values in Table3.2.4.6 are based on the following sources:

- *Range indicator values for TP and Chl A are from Vollenweider and Kerekes (1982) as recommended by Brylinski (2004) for NS Lake Phosphorus Loading Models;*
- *There are no Federal or Nova Scotian guideline values for these parameters, below which nuisance algae can be avoided. The Province of Ontario suggests an annual average of less than 0.020 mg/L. For the purposes of this assessment, a Chl A concentration of greater than 5 µg/L, indicates nuisance algae;*
- *Range indicator values for DO and TN are from Cooke et al. (2005);*
- *Phosphorous and nitrogen are required in specific ratios for plant growth. TP and TN concentrations are of concern if the particular nutrient is limiting. Typically P is the limiting nutrient in freshwater, and therefore a TN concentration in the eutrophic range is not as much of a concern as a TP concentration in the eutrophic range (the opposite is typical in marine water); and*
- *Total nitrogen can be calculated from the parameters measured in this study as the sum of TKN and Nitrate+Nitrite.*

Phosphorus

The findings indicate that total phosphorus concentrations in the lake are generally in the mesotrophic to meso-eutrophic range. On several occasions phosphorus levels in the summer and fall are close to the lower range for eutrophication (0.035 mg/L). Measurements indicate that the watercourse and ponds receiving the trailer park's STP effluent and discharging into Lake Echo are hypereutrophic most likely due to nutrient loads discharged in the effluent.

In terms of a water quality guideline, an annual mean guideline is typically used because concentrations of the key parameters vary from season to season and from wet days to dry days. Eutrophic conditions typically occur in the summer, when the annual mean value would be lower than actual concentrations. There is no Federal or Nova Scotia guideline on recommended annual mean values. The Province of Ontario recommends an average value of 0.020 mg/L for the ice-free period to avoid nuisance algae, while a high level of protection against aesthetic deterioration is provided by a TP concentration less than 0.010 mg/L, which should apply to all lakes naturally below this value (Source: Ontario 1994).

Nitrogen

Nitrogen concentrations in Lake Echo varied between 0.2 and 0.5 mg N/L (recorded at station LE5 on October 28 2010). Nitrate, nitrite and ammonia were almost always below 0.1 mg N/L, often even below 0.05 mg N/L (detection limit), however, TKN values range between 0.2 and 0.5 mg N/L. This indicates that most of the nitrogen in the water is in organic form. Ammonia levels were generally less than 0.05 mg N/L. However, on August 18 and September 28 2010, ammonia levels were detectable (between 0.006 and 0.12mg/L). This indicates that generally, current nitrogen loads do not exceed the uptake capacity of freshwater plants, except during dry seasons and intense usage of the watershed during the peak vacation season.

The ratio TN/TP can be used to assess which nutrient is controlling plant biomass growth due to its lower concentrations (Brylinski 2004). The ratio TN/TP is greater than 10 at almost all sites, indicating that phosphorus is the limiting nutrient. On occasions where the ratio is less than 10, TP is in the hypereutrophic range and nitrate concentrations are also high, indicating no nutrient limitation. At other times TN concentrations in the mesotrophic range have no impact on plant growth because TP concentrations limits. This is typical of large watersheds where nutrient loadings are predominantly from non-point sources.

The tributary to McCoy's Pond (LE7 and LE8) was found to have euthrophic to hypereutrophic levels of both nitrogen (TKN of 5.1-10.8 mg/L) and phosphorus (1.61-2.4 mg/L) on July 29 2011. Nitrate contributes about 60% to the TKN, suggesting products of bacterial decomposition and organic matter as the source of the nutrient. The nitrogen and phosphorus level at the outflow of McCoy's Pond (site LE6), are also elevated. Comparison of inlet to outlet concentrations suggests that a significant portion the nutrients are assimilated in the pond.

Chlorophyll

Chlorophyll levels in the waters of the lakes give a measure of the size of their resident phytoplankton populations, and provide one of the best indicators of eutrophication status. For 5 sampling days in seven, measured chlorophyll levels for all stations were in the meso-eutrophic range or higher. McCoy's Pond had chlorophyll levels in the hyper-eutrophic range on three occasions.

3.2.4.7 Bacterial Indicators

The samples were analyzed for two bacterial indicators, fecal coliform (FC) and *Escherichia coli* (E. coli). The fecal coliform bacteria group is indicative of contamination from the intestinal tract of humans and other animals and includes other, more definite groups such E. coli.

The units of measurement for bacteria reported in this study are based on different methods to estimate the number of bacteria in a sample. Colony Forming Units (CFU) is the number of colonies on an incubation plate determined by direct count. Most Probable Number (MPN) is the result of a calculation based on a statistical model using the number of colonies as an input and yields an estimate of the actual number of bacteria. At low concentrations, i.e. less than 100 cells, CFU and MPN methods yield very similar results. At high cell concentrations, the MPN method yields higher counts compared with CFU, because the MPN calculation takes into account the probability that there are more than one bacterium per colony. In addition, the results for FC bacteria reported in this study were determined by analysing the sample on large filters (ISOGRID) capable of detecting large numbers of FC, including those that grow poorly or ferment lactose slowly (source: Maxxam Analytics). This technique further contributes to the trend towards high values from the MPN method.

There is a vast spread in the measured FC range (and often questionably high values) reported by Maxxam Analytics for the 2010 samples using the MPN-Isogrid method. Results for E-Coli using the CFU method exhibit less variability and are within a range that is consistent with other local studies. For this dataset, the E-Coli measurements are likely a more reliable indicator. A commonly used guideline based on E-Coli bacteria is 200 MPN/100 ml for primary recreational contact and 14 MPN/100 ml for shellfish harvesting.

Ecoli -

Measured E-Coli concentrations in the lake render the lake waters unsuitable for primary recreational contact on three occasions. Highest concentrations were observed during wet weather in the fall, including near the dock at the canoe club. The source of these high values could not be identified. While measured bacteria levels were very high in the pond receiving the trailer park's STP effluent (>500/100 mL on 29 July 2011 at LE7), further downstream, the outlet of McCoy's Pond into Lake Echo did not indicate excessive bacterial levels. This suggests the residence time in McCoy's Pond may be large enough for sufficient bacteria die-off before its waters enter Lake Echo. The range of measured E. coli concentrations is consistent with data collected by HRM at Upper Lake Echo.

3.2.4.8 Comparison of Results with the HRM Lakes Water Quality Sampling Program

The Halifax Regional Municipality (HRM) has reported on three sampling events per year, spring, summer and winter, in Lake Echo since 2007. The HRM sampling site is located near CBCL site LE1, in the northern section of the lake. Several water quality parameters were measured by HRM, including those determined in this study. Comparison of results obtained in HRMs program to the data collected as part of this study indicates that there are no great discrepancies between the values of water quality parameters measured by HRM and those found in this study (from site LE1).

Total phosphorus concentration was determined to a lower detection limit in the HRM study (0.002 mg/L) and the **mean concentration of total phosphorus is 0.016 mg/L** which is somewhat lower than levels measured during this study; oscillating between 0.02 and <0.02 mg/L (except for an unexplained peak on

29 July 2011 at 0.177 mg/L for which measurement or analysis error cannot be ruled out). There was one event measured on 17 May 2010 (TP = 0.048 mg/L) in which the total phosphorous concentration was in the range indicating eutrophic conditions. This high concentration of phosphorous was observed at many lakes in the HRM in the same period. The sample collected nearby at LE1 three days later on 20 May 2010 as part of this study indicated 0.02 mg/L; a total phosphorous concentration of 0.03 mg/L was measured on 20 May further downstream at LE3.

3.3 Surface Water Use Objectives

The full surface water use objectives component study can be found in Appendix D.

3.3.1 Summary of Water Quality Questionnaire

A water quality questionnaire was created to find out how residents of the area use water bodies now and how they want to be able to use them in the future (A copy of the questionnaire used in the survey is available as part of the component report in Appendix D).The questionnaire was available online from **July 18 to September 16, 2011**. The survey was publicized through email distribution lists, posters, and a notice in the Eastern Gazette in the Municipal Councillors newsletter. There were **111 responses** to the online survey.

3.3.2 Respondents Water Use Objectives

The survey presented a list of water bodies in the area and respondents were asked to indicate the ways in which these water bodies were important to them. Overall, the most responses were provided for Lake Echo and Lawrencetown Lake. For all lakes, visual enjoyment, swimming and wildlife habitat were generally the highest choices, while boating and recreational fishing was also popular. Lake Echo and Lawrencetown Lake are used for drinking water more often than the other lakes.

Figure 3.3.2 shows the most important water use objectives provided by respondents for each water body in the study area, the height of each colour band indicates the portion (%) of the respondents that felt each water use objective was the most important to them.

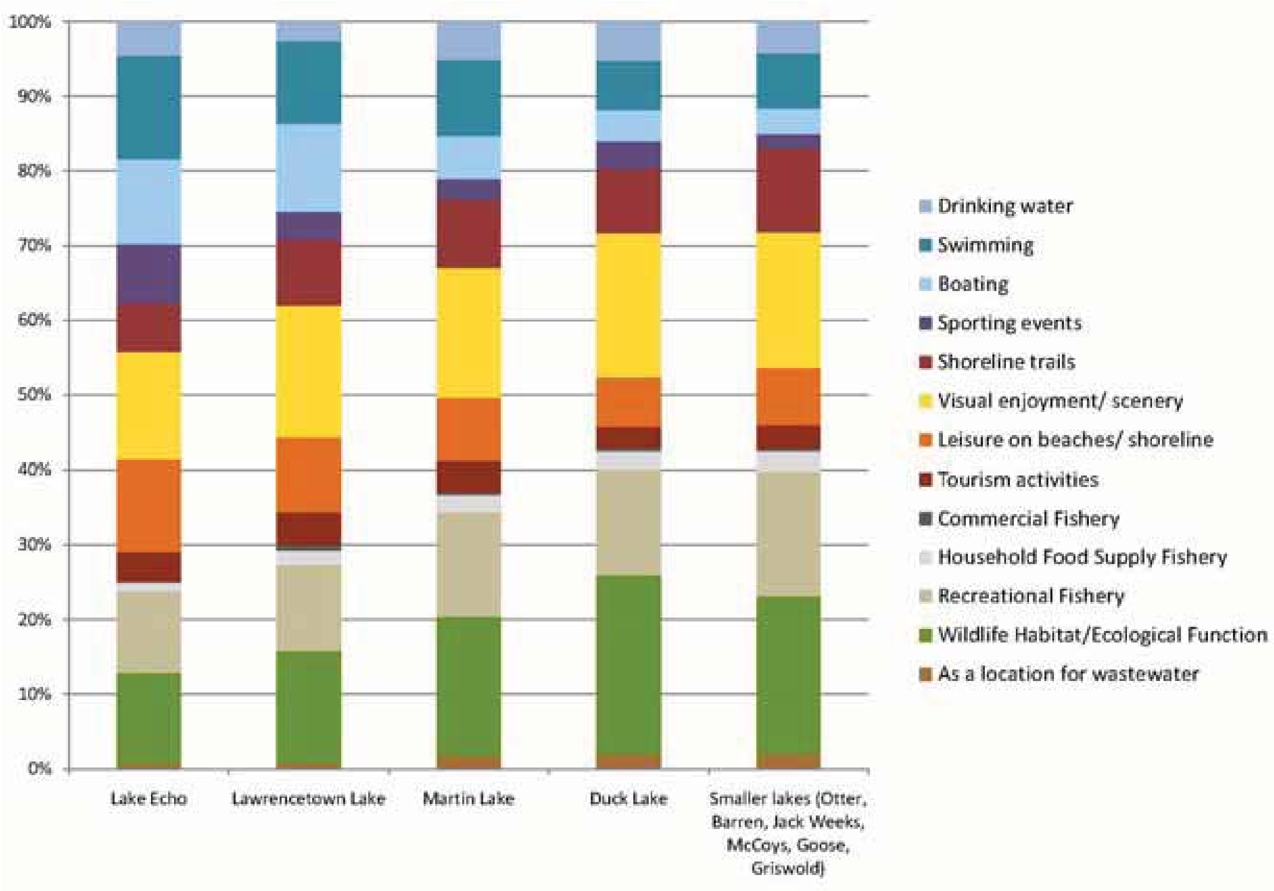


Figure 3.3.2: Water Use Objectives Indicated for Each Water Body

HRM, through the Regional MPS, has two applicable water use objectives:

1. As a minimum, all waterbodies should be safe for primary contact recreation including swimming.
2. Future development of a watershed should not change the trophic status of a waterbody; if it is currently oligotrophic, it should remain oligotrophic after development is completed.

3.3.3 Water Quality Objectives

Respondents were asked what level of water quality they desired for each water body. The questionnaire showed respondents a scale with a movement from the LEAST stringent water quality requirements (left) to the MOST stringent water quality requirements (right). Respondents were asked to indicate the level of water quality they would be satisfied with in the future.

Figure 3.3.3 shows the responses for each water body. Respondents identified Lake Echo and Martin Lake as water bodies that require the most stringent water quality requirements. For all lakes, 85% or more respondents indicated a desire for very good water quality for fresh water bodies (Level 4 and 5). Very few respondents indicated that they would be satisfied with low water quality requirements (Level 1 and 2).

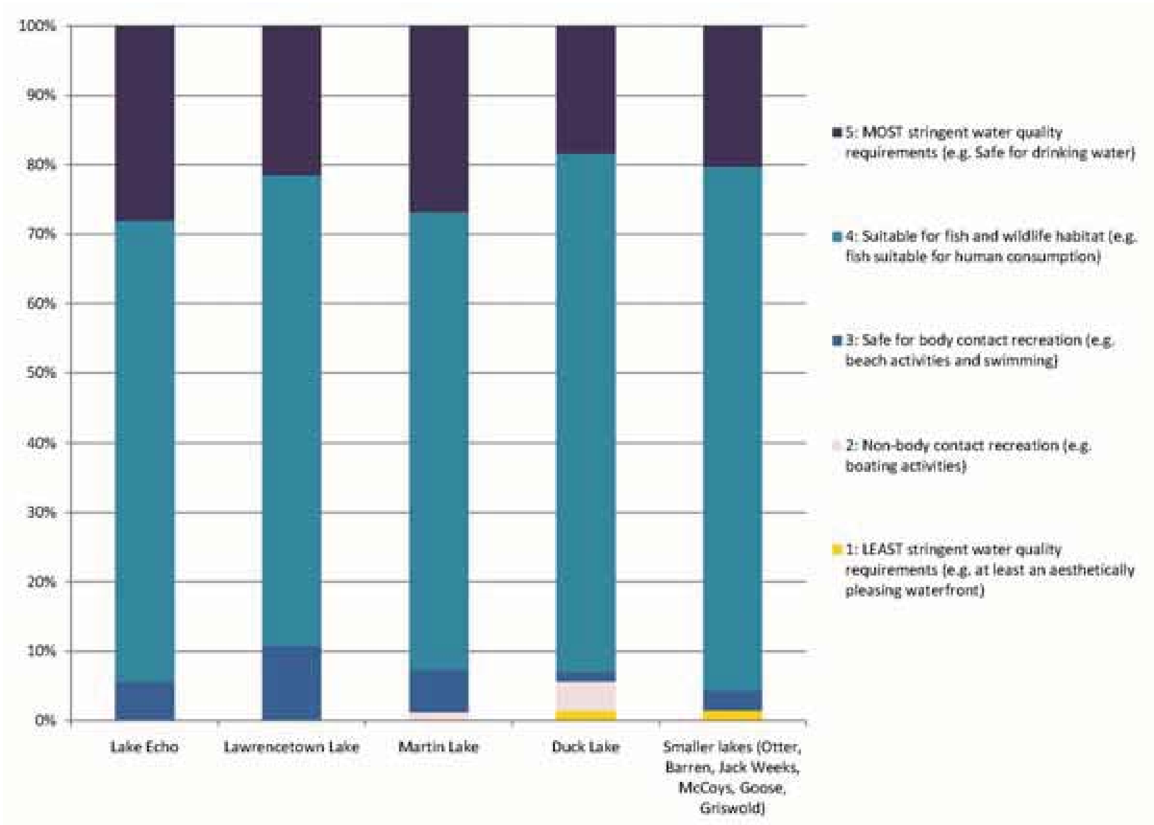


Figure 3.3.3: Respondents Desired Future Water Quality for Each Water Body

In water bodies near urban development, there are typically two areas of paramount interest:

1. Public health and habitat - E coli concentrations are used to assess conditions with respect to public health and potential for habitat.
2. Aesthetics - Concentrations of nutrients (nitrogen and phosphorous), algal biomass (chlorophyll A), dissolved oxygen, silt and organic matter are used to assess the trophic status of a water body.

There are CCME guidelines for concentrations of E coli below which experience has shown that use of the water has a relatively low probability of causing illness.

Although one of the essential parameters in the production of algae, there are no federal or Nova Scotian guidelines related to total phosphorous concentration limits *below which nuisance algae can be avoided.* Guidelines from Ontario were presented in section 3.2.4.6. However, these guideline concentrations do not preclude algae growth; as algae growth depends on many parameters that can vary significantly during the ice free period. Experience has shown that by limiting phosphorous, the amount of algae that can be produced is limited.

The following table outlines the water quality objectives recommended for desired uses for water bodies in the Study Area.

Recommended water quality objectives for all of the waterbodies in the Study Area include:

- As a minimum, E. coli concentrations should not exceed a MPN of 200 in any lake. As a long term objective, mean annual E coli concentrations should be below 14 per 100 mL sample for all waterbodies in the study area: for freshwater and brackish water;

- All waterbodies that are currently not impacted by development should be Oligotrophic or better. To achieve this requires compliance with the stipulated values for the parameters listed in Table 3.3.3; and
- Any water body that is currently impacted by development including Lake Echo and Lawerencetown Lake should be Mesotrophic or better to be considered for habitat or as aesthetically acceptable. To achieve this requires compliance with the stipulated values for the parameters listed in Table 3.3.3.

Table 3.3.3: Water Quality Objectives for Desired Water Uses

Use	Water Quality Required to Sustain the Water Use
Health	Concentration of E coli
Drinking Water	*Guidelines for Canadian Drinking Water Quality (GCDWQ)* should be met. To allow consumption of water it must have an E coli count of 0 per 100 mL sample. All water used for water supplies must be treated to meet GCDWQ guidelines by current Provincial requirements.
Fishing	To preserve habitat, CCME Guidelines should be met. To allow consumption, an E coli count of <14 per 100 mL sample is suggested
Shellfish Gathering	To preserve habitat, CCME Guidelines should be met. To allow consumption, a long term median an E coli count of <14 per 100 mL sample is required by Environment Canada
Swimming	To allow primary contact associated with this activity, an E coli count < 200 per 100 mL sample is required
Boating	To allow secondary contact associated with this activity, an E coli count < 1000 per 100 mL sample is required
Habitat and Aesthetics	Trophic Status
Oligotrophic	TP < 10 micrograms/L; Chl a<2.5 micrograms/L;TN<35 mg/L; DO>7.2 mg/L; pH> 5.5
Mesotrophic	TP < 20 micrograms/L; Chl a<5 micrograms/L; 35<TN<65 mg/L; 7.2<DO<6.2 mg/L; pH> 5.5

3.4 Assimilative Capacity of Surface Waters

Assimilative capacity of surface waters is discussed in the component report in Appendix C.

Assimilative capacity is an indication of the amount of additional loads of various pollutants a water body may receive without exceeding water quality objectives. Assessment of the assimilative capacity of the lakes and streams in the Study Areas was completed by comparing existing water quality to the recommended water quality guidelines presented in Table 3.3.3. Two conditions exist:

- Concentration of measured water quality parameter is below the guideline level for the desired use, the water may be used as desired and there is some assimilative capacity available; or
- Concentration of measured water quality parameters is at or above the guideline level, the water is not suitable for the desired use and there is no assimilative capacity available in the water body for the limiting pollutant(s).

3.4.1.1 Objectives

Objectives of this assessment included:

- Assess the assimilative capacity of Lake Echo as well as other waterbodies in the study area; and
- Identify waterbodies currently impacted by development, those that receive stormwater runoff and potentially receives septic tank effluent.

3.4.1.2 Phosphorous loading Models

Assessments of assimilative capacity based on current trophic status of the lakes were completed using a standard phosphorous loading model, Brylinski (2004), developed with Nova Scotia Environment for use in Nova Scotia. This model was used to simulate average annual Total Phosphorous concentrations in each waterbody. The model uses information on land-uses in the tributary areas and typical phosphorous generation rates for each land-use to estimate the flow of phosphorous into each waterbody, the amount retained in each waterbody and the amount discharged to the downstream based on typical values that have been developed based on experience gained in this region.

Phosphorous concentrations measured in Lake Echo as part of HRM's 2006 - 2011 Sampling Program and concentrations measured as part of this study were used to confirm that the estimated parameters were reasonable. The sampling data collected as part of the ongoing lake monitoring completed by HRM provided the best information for calibration of the models as it is:

- Multi-year, long-term;
- Low P detection limit; and
- Several lakes are included.

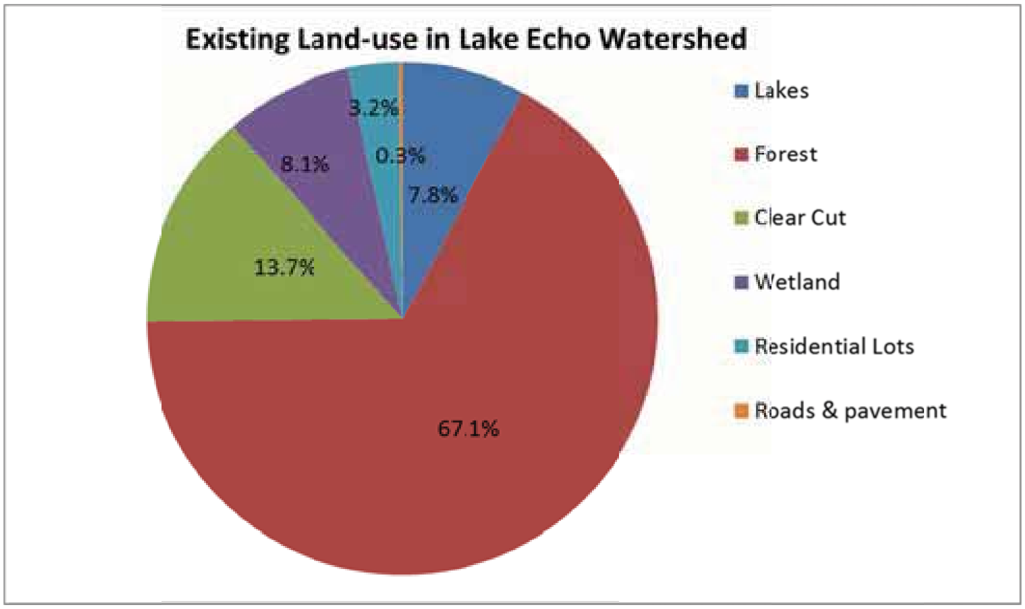
The information collected as part of this study was used to assess:

- Conditions in several locations in Lake Echo and a tributary to the lake that are not included in the long term monitoring program; and
- Differences that result from varying weather conditions

3.4.1.3 Phosphorous Loading Model Results

Results of the land use and phosphorous loading assessments for the lakes in the Study Area are presented in Appendix C.2. This information is summarized for Lake Echo in Figure 3.4.1.3. The pie chart on the left-hand side of this figure indicates the portion of various lands-uses in the Lake Echo watershed. The pie chart on the right indicates the amount of phosphorous these land uses contribute to Lake Echo.

Currently developed areas cover slightly more than 4% of the watershed but contribute approximately 42% of the annual phosphorous load to the lake. It was estimated that this load is contributed by a combination of point sources (including partially treated septic tank effluent and wastewater treatment plant effluent) and non-point sources such as runoff from landscaped areas and road rights of way. Another significant contributor is clear cutting of the forest. Clear cutting accounts for 13% of the watershed area but contributes 35% of the phosphorous load to Lake Echo. On the other hand, forests cover 74% and wetlands make-up 9% of the watershed but contribute 22% and 1% of the annual phosphorous loads.



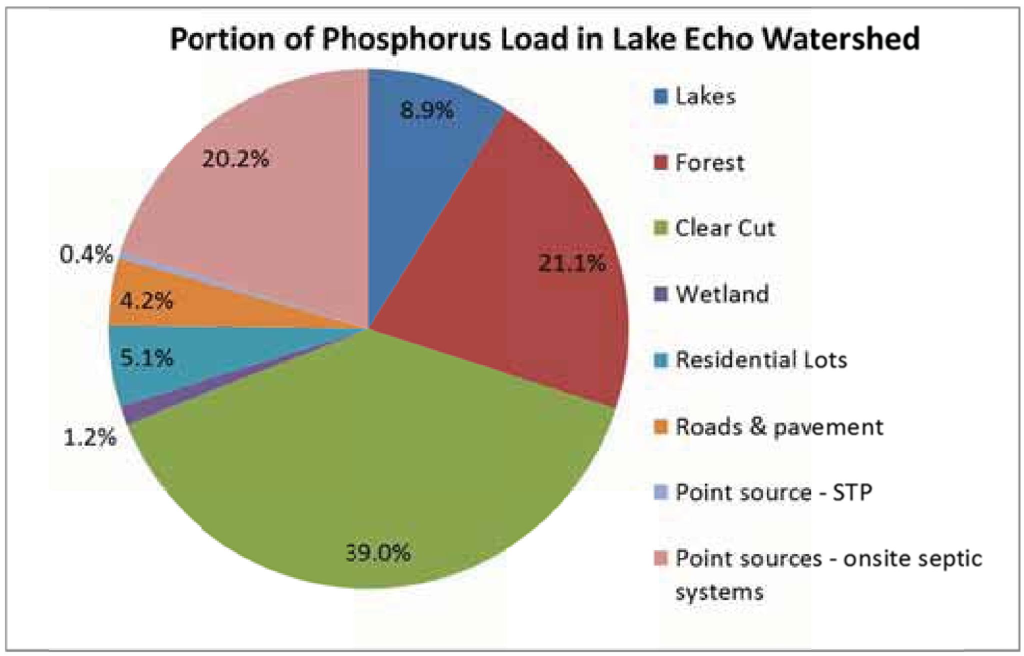


Figure 3.4.1.3: Land-use and Estimated Total Phosphorous Loads Generated in Lake Echo

3.4.1.4 Assessment of Existing Assimilative Capacity

Based on water quality sampling results, there are several water quality concerns in the Lake Echo watershed:

- Trophic status of Lake Echo and McCoy's Pond;
- pH in the lakes (Jack Weeks and Lewis Lake) and tributaries at the upper end of the lake; and
- E coli concentrations at the upper end of Lake Echo and in McCoy's Pond and its main tributary.

These water quality concerns are discussed further in the following paragraphs:

Trophic Status

Figure 3.4.1.4 presents a summary of measured phosphorous and chlorophyll A concentrations for the upper end of Lake Echo, with HRM's data from 2007 to 2011. The average phosphorous concentration in Lake Echo measured between 2007 and 2011 by the HRM sampling program was 0.016 mg/L (this is in the mesotrophic range), in 2010 and 2011 it was in the order of 0.020 mg/L (at the upper end of the mesotrophic range), mostly due to a large peak in 2010. Average concentrations in any given year ranged from 0.010 to 0.030 mg/L (from oligotrophic to meso-eutrophic) and individual measurements ranged from 0.004 to 0.048 mg/L.

The average Chlorophyll A concentration was 4.96 ug/L for the same period, at the upper end of the mesotrophic range and at times into the meso-eutrophic range. Average concentrations in any given year ranged from 2.54 to 8.11 ug/L and individual measurements ranged from 2.04 to 18.55 ug/L.

Based on the water quality objectives set in Table 3.3.3 for a lake with existing development in the watershed, the average annual concentration of total phosphorous should be below 0.020 mg/L and Chlorophyll A concentrations should be below 5 ug/L. Measured concentrations for both parameters at times exceed these guidelines. Although the average total phosphorous concentration for the past five years was below the recommended guideline to avoid nuisance algae of 0.020 mg/L, conditions were such that nuisance algae was still produced in the Lake, at times algae is above the nuisance levels. Based on this assessment the average annual concentration to avoid naissance algae should be below 0.016 mg/L. In this case, there is no assimilative capacity for additional phosphorous loads in Lake Echo.

It is estimated that phosphorous loads from the existing Wonderland Mobile Home Park wastewater treatment plant are responsible for 0.0023 mg/L of phosphorous in Lake Echo. It is interesting to note that the treatment plant services approximated 13.7% of the existing population in the community and contributes approximately 13 % of the total phosphorous load to the lake. Although the annual input from the treatment plant is in the same order (on a load per capita basis) as the net input from others in the community tributary to Lake Echo, it has a dramatic impact on the waterbodies from the treatment pond, through McCoy's Pond to Lake Echo and in the immediate vicinity of the discharge from McCoy's Pond in Lake Echo. This system is at times hyper-eutrophic and is in effect part of the wastewater treatment system for the mobile home park. There is no assimilative capacity available in this system and in fact, significant reductions in phosphorous loads to this system are required in order that it may be considered mesotrophic.

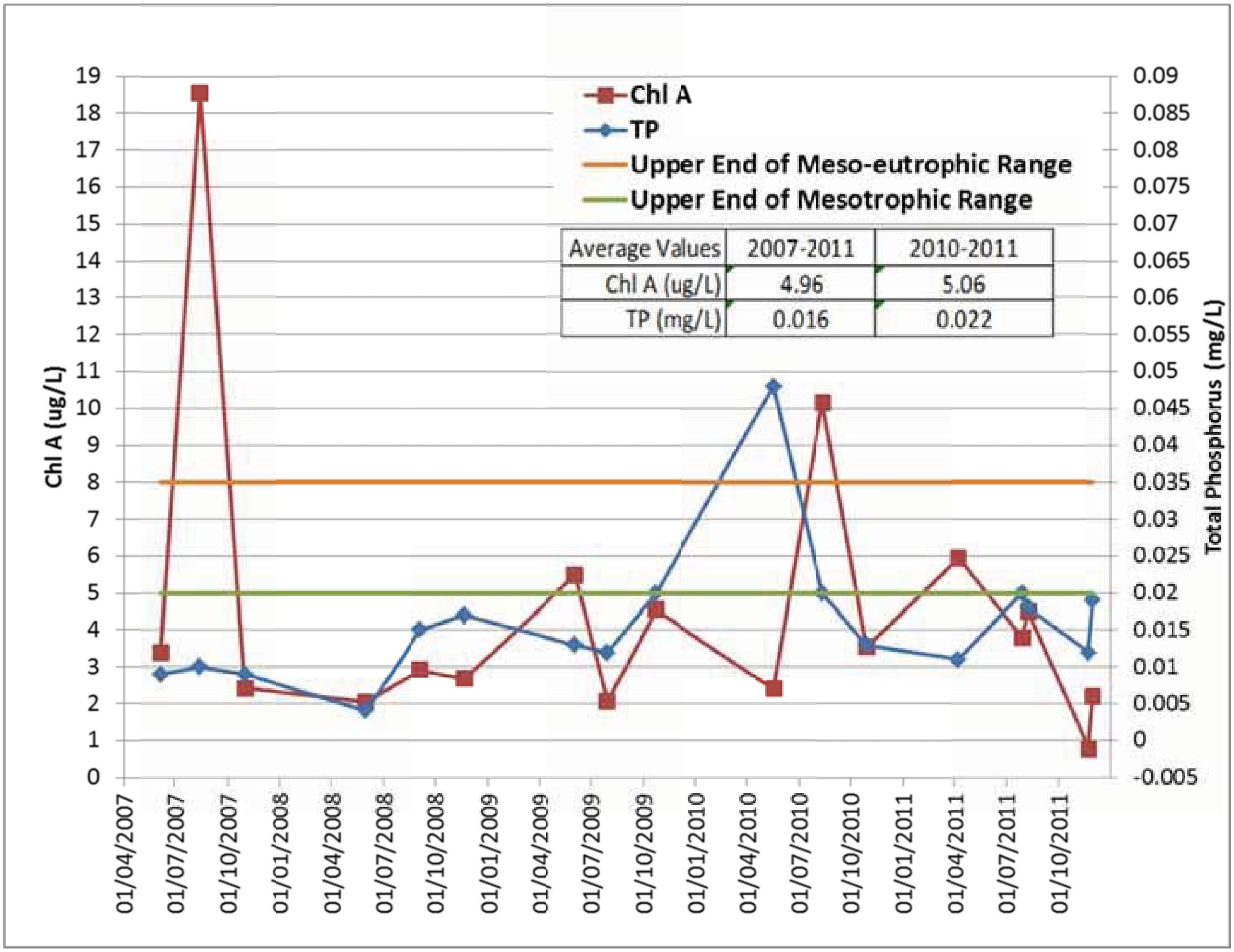


Figure 3.4.1.4: Trophic Status Indicators Measured in Lake Echo by HRM: 2007 to 2011

pH

Measured pH values in Lake Echo during this study were typically below the CCME Guidelines range of 6.5 to 9. The lowest pHs were measured following rainfall events. They were typically lowest at the upper end of the lake (ranging from 4.8 to 5.9) and increased downstream in the lake. However most pH measurements completed for this study in 2010 were above the objective set for this watershed of 5.5.

pH measurements made as part of HRM's 2006 – 2011 sampling program in 2010 averaged 6.55. This was the highest yearly average of the 5 year program with an overall average of 5.58 and a low of 4.99 in 2007. The five year average is slightly higher than the minimum pH objective and there were no measured values above the objective in 2007, 2008. Based on this assessment, there is no assimilative capacity in Lake Echo for additional acid loads.

pH measurements completed by the citizens group indicated similarly low pH in the tributaries to Jack Weeks Lake and Lewis Lake. These should be considered to have no assimilative capacity for additional acid loads. On-going pH measurements in these lakes are advised to confirm the results of limited testing to date.

E coli

Measured bacteria (E-Coli) concentrations were above 200 counts/ 100 mL sample on 2 occasions near the inflow to Lake Echo from Martins Lake and once near the discharge point from McCoy's Pond making the local area unsuitable for recreational contact (see Table 3.3.2). Measured concentrations in other areas of the lake were typically below 50 counts/ 100 mL sample.

Ecoli concentrations have only been measured for the past two years (2010 and 2011) in Lake Echo. During this period the Ecoli objective of 14 counts for habitat was exceeded at the inlet end of the lake for 2 of the 6 measurement occasions and at the lake outlet for 3 of the 6 measurement occasions. Average concentrations for the limited data available are above the water quality objective for safe habitat (14 counts/ 100 mL sample).

The bacterial water quality objectives are compromised on occasion in Lake Echo and in the system tributary to McCoy's Pond, during all three sampling seasons. On this basis, there is no assimilative capacity for additional E coli loads to McCoy's Pond or Lake Echo.

3.4.1.5 Assessment of Available Assimilative Capacity for Future Development

Projections for future development of the Lake Echo study area were presented in Table 2.3.3. Table 3.4.1.5 presents predicted annual average phosphorus concentrations in the main lakes in the Lake Echo watershed for existing development conditions as well as for the three growth scenarios considered in this study. The assessment makes the following assumptions:

- New urban development was assumed to:
    - Be distributed as follows:
        - 40% to Lake Echo;
        - 30% to Lawerencetown Lake;
        - 10 % each to Martin, Lewis, and Jack Weeks watersheds;
    - Replace existing land uses as follows:
        - Forest areas: 50% of new development;
        - Clear cut areas: 50% of new development;
        - Wetlands are to be protected and not developed;
- Phosphorus loads from developed areas were assumed to be generated by 3 sources:
    - Runoff from developed areas including residential lots and roads & pavement;
    - Known point sources for phosphorous, including the existing wastewater treatment plant at the Wonderland Mobile Home Park. The existing treatment plant discharges to what appears to be a polishing pond that discharges to a natural channel into McCoy's Pond. The outflow from McCoy's Pond discharges to a channel into Lake Echo adjacent Ponderosa Drive. This downstream system provides additional treatment including phosphorous removal. Sample results obtained at various points in this system were used to estimate the actual phosphorous load that is discharged from this system to Lake Echo (in the order of 10 kg phosphorous per year from the existing STP, if phosphorous removal was to be included at the treatment plant the load would be reduced to 0.3 kg/year);
    - 800 g/cap/year for all existing residents with a 0.5 retention coefficient from existing on-site treatment/septic systems. The retention coefficient for modern systems was estimated to be 0.9; and

Table 3.4.1.5 Predicted Annual Average Total Phosphorous Concentration in Study Area Lakes with Existing STP Effluent and On-site Systems

		Sub-watershed												
Development Scenario		McKay Lake	Lake Williams	East Lake	Byron Lake	Tittle Lake	Loon Lake	Salmon River Long Lake	West, Granite Lakes	Brown, Jack Weeks Lakes	Lewis Lake	Martin Lake	Lake Echo	Lawerencetown Lake
Existing Conditions														
Drainage Basin Area (Excl. of Lake Area)	Ha	4019.4	638.3	277.0	453.5	928.4	167.3	420.0	926.4	608.1	139.0	1145.8	1332.8	1021.2
Percent Clear Cut	%	15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	19.4%	17.0%	34.0%	16.9%	24.7%
Percent Developed	%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	2.9%	22.0%	11.6%
Number of Residences Directly Draining to Lake	# Units	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	400.0	100.0
Average Annual Total Phosphorous Concentration	mg/L	0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0124	0.0166	0.0145
Trophic Status Based on Total Phosphorous		Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
Growth Scenarios Considered														
Assumed Portion of Development in Each Sub-watershed		0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	40%	30%
Low Growth Scenario														
Percent Clear Cut	%	15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	19.4%	17.0%	34.0%	16.9%	24.7%
Percent Developed	%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	2.9%	22.0%	11.6%
Number of Residences	# Units	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	400.0	100.0
Average Annual Total Phosphorous Concentration	mg/L	0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0123	0.0159	0.0139
Predicted Increase	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	-4%	-4%
Trophic Status Based on Total Phosphorous		Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
Medium Growth Scenario														
Percent Clear Cut	%	15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	18.0%	11.1%	33.3%	14.4%	22.3%
Percent Developed	%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	24.3%	4.3%	26.9%	16.4%
Number of Residences	# Units	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	90.0	520.0	190.0
Average Annual Total Phosphorous Concentration	mg/L	0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0126	0.0082	0.0122	0.0160	0.0141
Predicted Increase	%	0%	0%	0%	0%	0%	0%	0%	0%	5%	-7%	-2%	-4%	-3%
Trophic Status Based on Total Phosphorous		Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
High Growth Scenario														
Percent Clear Cut	%	15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	16.2%	3.2%	32.3%	11.2%	19.1%
Percent Developed	%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	40.1%	6.2%	33.5%	22.8%
Number of Residences	# Units	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	70.0	130.0	680.0	310.0
Average Annual Total Phosphorous Concentration	mg/L	0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0135	0.0101	0.0126	0.0166	0.0146
Predicted Increase	%	0%	0%	0%	0%	0%	0%	0%	0%	13%	15%	2%	0%	1%
Trophic Status Based on Total Phosphorous		Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic

Assumptions:

50% of new development occurs in areas that are currently forests, and 50% occurs in areas that are currently clear cut
Shading indicates a change in trophic status
Estimated using the phosphorous loading model - should be validated with sampling
Average Annual Total Phosphorous concentration based on on-going HRM Sampling Program

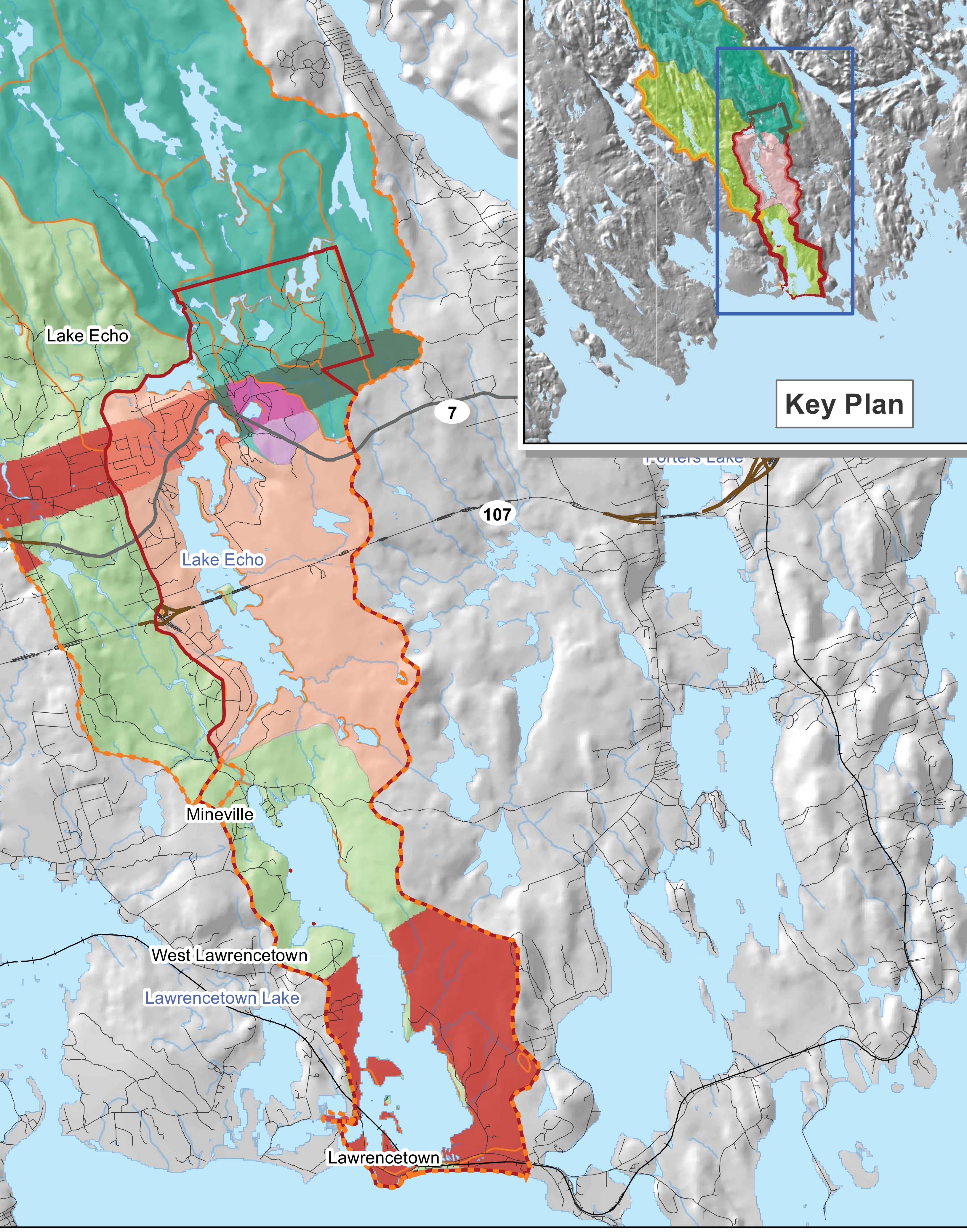
- The number of residents per residential unit for existing conditions is 2.87 and for the three growth scenarios it is assumed to be 2.37.

Model results for Lake Echo are generally in line with the annual average phosphorous results measured in HRM's 2006 – 2011 sampling program. Model results for the other lakes are estimates that should be confirmed by completing additional water quality monitoring in the lakes upstream of Lake Echo where additional development might be located and in Lawrencetown Lake.

Predictions of the impacts of future development scenarios indicate that due to the decrease in population per unit, the annual average total phosphorous concentration for Lake Echo is expected to decrease slightly for watersheds with existing development in the low growth scenario. It is expected that future development should produce less impacts than existing systems due to a combination of reduced phosphorous loads from the land and use of modern onsite wastewater treatment systems that retain phosphorus in the groundwater regime much more effectively than older on-site systems. In the medium and high growth scenarios, the watersheds with no current development will experience increases in the annual average phosphorous concentration where new development is expected, but the trophic status is not expected to change in any lake, provided the assumed distribution of new growth is realized.

In reality, the annual average phosphorous concentrations in Lake Echo are expected to increase as development continues and then decrease as the population in each residential unit decreases over time (from 2.87 to 2.37 persons per unit). Although the measured annual average phosphorous concentrations are generally lower than the objective of 0.020 mg/L, nuisance algae is experienced, existing phosphorous loads are significant contributors to the algae. To limit nuisance algae, measures to reduce existing phosphorous loads should be considered.

Additional development anywhere in the watersheds tributary to Lake Echo has potential to generate larger nutrient loads to Lake Echo and increase the risk of algae in the lake. From a watershed perspective, development for the near future (until the phosphorous loads generated upstream can be reduced) would be best suited in watershed lands that discharge downstream of Lake Echo into Lawerencetown Lake, see Figure 3.4.


Key Plan
Lake Echo
7
107
Lake Echo
Mineville
West Lawrencetown
Lawrencetown Lake
Lawrencetown

In order to meet water quality objectives for Lake Echo and allow additional development to occur in the areas tributary to Lake Echo, measures to reduce current pollutant loads from existing development should be considered. For every kilogram of phosphorous generated by future development, an equivalent amount (or more) must be removed from the contributions generated by existing development to maintain existing lake water quality. Efforts should be made to reduce typical phosphorous loads generated by various land-uses for future development. Sources of pollutants and appropriate measures to reduce them in these receiving water bodies are considered in subsequent sections.

For planning purposes the following should be considered regarding assimilative capacity of the lakes in the study area:

- McCoy's Pond and its tributaries have no assimilative capacity for additional development due to its trophic status (phosphorus and chlorophyll A concentrations) and E coli concentrations;
- There is no assimilative capacity in Lake Echo due to its trophic status (phosphorus and chlorophyll A concentrations) or E coli at the upper end of the lake as a result of the loads from existing development. Low pH is also a concern; and
- Low pH in the upstream tributaries to Lake Echo, including Lewis Lake and Jack Weeks Lake indicate that there is no assimilative capacity for additional acid loads to these lakes. Additional development in the watersheds to these lakes will reduce their capacity to assimilate addition phosphorous loads as well.

3.5 Sources of Contamination

Potential sources of surface water pollution and/or contamination of groundwater were investigated. Those which may be of concern, include the following:

- Malfunctioning and failing sewage disposal systems, constructed on lots that are considered undersized for local site conditions by current standards, of particular concern are the small lots around Lake Echo, described at the Focus Group meeting as the original development in the area;
- Wastewater treatment plant effluent;
- Runoff and leachates from a variety of potential sources that are periodically washed off the land and discharged to the surface water systems as well as potentially infiltrate into the groundwater. Potential contributors to some of the most significant water quality issues observed include:
  - Phosphorous and nitrogen from fertilizers; and
  - Pet wastes.

Other potential sources of contamination were identified by respondents to the water quality survey and by a windshield survey of the Study Area. These are described in the following paragraphs.

3.5.1 Surface Waters

Respondents were asked to describe any potential past or current sources of contamination in each water body. Responses were received for Duck Lake, Martin Lake, Lake Echo, Lawrencetown Lake and McCoy's Pond. Respondents described the following potential sources of contamination of surface waters:

- Construction/excavation/development too close to the water;
- Septic systems in general (domestic and school) and old or failed;
- Automotive mechanic land use / scrap yards;
- Chemical fertilizers and pesticides;

- Mineral extraction;
- Roads / salt;
- Gas and oil leaks - domestic and from boats;
- Landfills / informal “dumps”;
- Tree cutting;
- McCoy’s Pond - Contaminated from sewer from the existing trailer park; and
- Lakes in Upper Salmon river watershed near Halifax International Airport - acid runoff from runway construction.

3.5.2 Groundwater

Sources of contamination are discussed in Chapter 4.4 of the component report in Appendix B. Figure 3.5.2, illustrates locations and land uses that could be potential sources of contamination within the Study Area. Relative risks to source water are ranked from least risk to greatest risk, based on the *Nova Scotia Environment’s - Developing a Municipal Source Water Protection Plan: A Guide for Water Utilities and Municipalities, Step 3 Identify Potential Contaminants and Assess Risk*.

Development and potential sources of contamination in the community are concentrated along main roads. Low density housing and the absence of industrial activity leads to generally local potential sources of contamination. Two potential fuel storage and handling facilities, up to four private sewage treatment facilities, one potential chemical handling and storage facility, and three active or abandoned quarries in Lake Echo centre pose the most concentrated threats to water quality in the study area. Potential threats to groundwater quality in the Lake Echo study area appear to be generally minor and dispersed.

Agricultural Areas

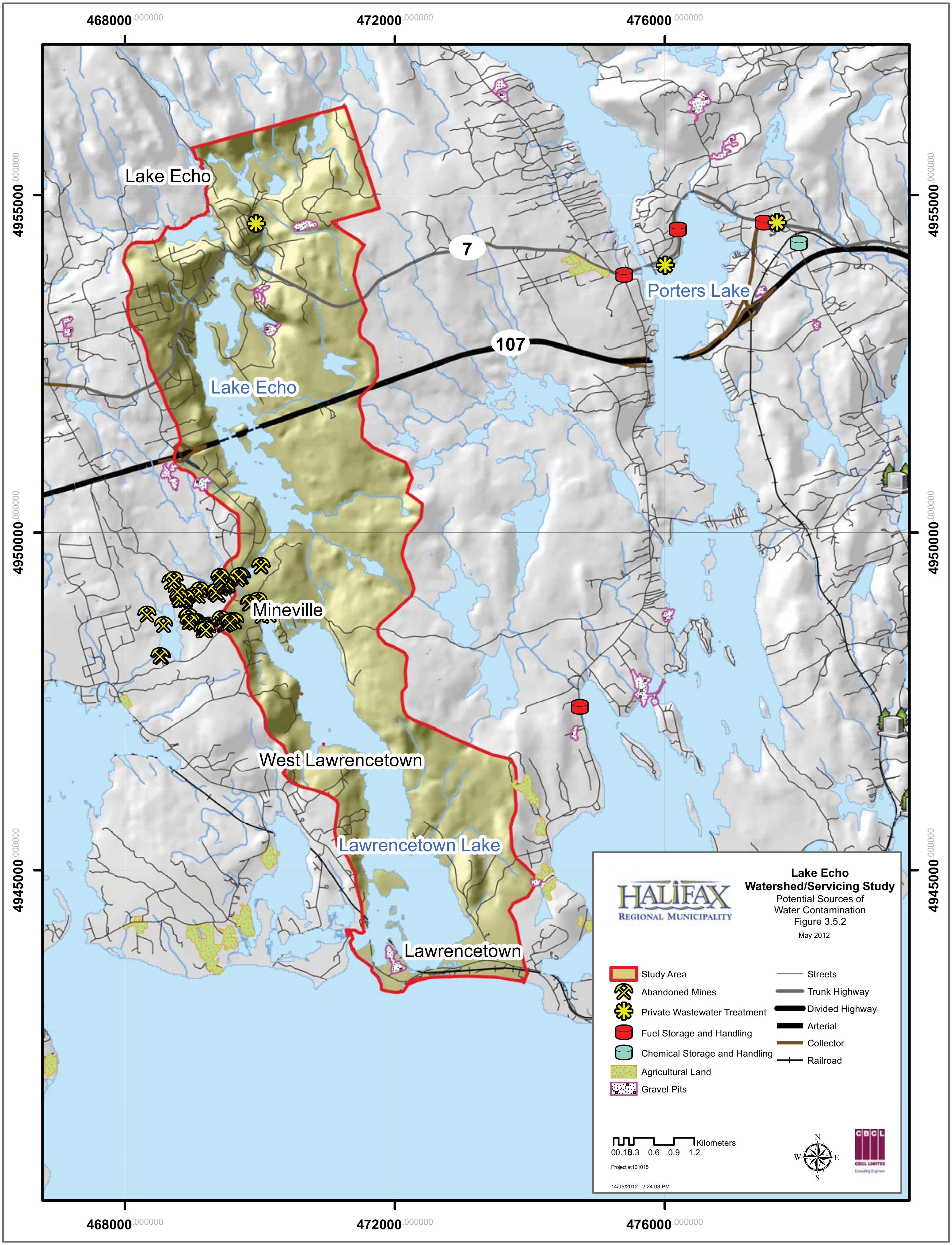
There are five farms in the southeast corner of the study area and one farm to the west of Porter’s Lake centre. Hobby farms and livestock are the most likely uses of farms in the area. The requirement for irrigation and/or spraying is unknown, but storage and handling of manure is likely. If water supply wells were to be located near farms, more detailed on-site reconnaissance would be required. Each of the farms could under specific conditions propose a threat to local shallow groundwater supplies under the direct influence of surface water (GUDI wells).

Pits and Quarries

Provincial mapping shows three small quarries near Lake Echo Centre, two small pits or quarries on the northeast arm of the study area and a larger pit/quarry to the west of Lawrencetown Beach. One of the quarries in Lake Echo Centre was active and operating above the water table. A second quarry was inactive and filled with water, indicating that the excavation was terminated below the water table. Contaminants released at the floor of pit/quarry excavations can short-circuit into adjacent aquifers. High risk land uses should be prohibited near pits and quarries.

Light Industrial Activity

Three sites in the study area were observed and classified as potential chemical storage and handling facilities. Individual site uses included a welding shop on the northeast arm (solvents, plating solutions, and degreasers), a plant nursery near Lake Echo Centre (fertilizers and pesticides), and a site storing refuse and abandoned or poorly maintained shacks adjacent to Highway 7.



L:\101015 Tantallon Porters Lake Watersheds\101015_GIS\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Potential Sources of Water Contamination.mxd

Cemeteries

There are three known cemeteries in the study area, all located on main routes. Cemeteries were identified in Mineville, to the west of Porter's Lake, and on the northeast arm of the study area. Cemeteries in the study area have the potential to affect local shallow groundwater supplies.

Abandoned Mines

Mineville is host to a historically significant gold mining district of Nova Scotia. There are over 50 abandoned mine shafts, open cuts, and pits at and to the west of Mineville. Many of these shafts are located outside the western boundary of the study area. Gold deposits are commonly associated with elevated concentrations of arsenic.

Tailings deposited near the shafts and at gold ore processing sites can generate significant source zones of arsenic and other metals. Process streams are also associated with elevated concentrations of cyanide. Arsenic originating in flooded tailings ponds or flooded shafts may be present in its reduced form (AsIII), which is relatively mobile in aquifers. This mining district could present an obstacle to obtaining a reliable groundwater supply in the area.

Fueling and Service Stations

Three active service facilities were identified along Highway 7, including a service station, a used car dealership, and a heavy equipment contractor on Harmony Way. An abandoned garage was also noted on Highway 7. Three sites adjacent to the northern part of Porter's Lake included a smaller service station, a marina, and a truck servicing/tractor trailer storage lot. A heavy equipment refuelling station (three above-ground storage tanks) was identified near Lawrencetown.

Fuelling stations are equipped with one or more underground storage tanks (UST) for gasoline and diesel fuel. Older tanks can deteriorate and develop perforations, releasing fuel to the subsurface environment and generating significant source zones for groundwater contamination. Garages may use and store lube oil, degreasers, and paint. Older garages often have oil change pits and sumps excavated directly into the underlying soil, creating a direct conduit for flow of contaminants into the subsurface.

Private Sewage Disposal Systems

The Mountainview Wonderland Mobile Home Park operates a classified private sewage treatment system in Lake Echo Centre. Other likely locations for on-site sewage disposal systems serving larger facilities included two schools near Lake Echo Centre, and closer to Porter's Lake, the Lake Echo Community Centre. Facilities at or adjacent to Lawrencetown Beach included the teahouse and surf shop, a bed and breakfast, the beach canteen, and a group of outhouses on the beach parking lot.

Sewage treatment systems can impart elevated concentrations of bacteria, viruses, dissolved organic carbon, biological oxygen demand, chloride, nitrogen compounds, phosphates, pharmaceuticals, and personal care products (e.g., acetaminophen, caffeine, codeine, nicotine, antidepressants, antibiotics, and estrogenic steroids). High rates of groundwater extraction in areas where the density of sewage treatment systems is relatively high could impart contaminants to drinking water. Discharges of sewage effluent to salt water systems could help to alleviate this effect.

Seawater Intrusion
Development outside of Lake Echo Centre is focused largely along coastal routes including Mineville Road, Highway 207, and West Porter's Lake Road. Large scale use of groundwater in these coastal areas could lead to intrusion of brackish lake water or seawater. High pumping rates in coastal areas draw the freshwater-seawater interface inland. This effect could compromise existing wells closer to the coastline and eventually compromise the pumping well itself.

Location of Past Spill Events
In order to determine the location of past spill events within the study area, an Environmental Registry Search must be requested from Nova Scotia Environment and Labour. A Search must be requested for each property in question at a cost of $21.30 per civic address. This Search can also provide information on:

- Approvals issued under the *Environment Act;*
- Certificates of qualification issued under the *Environment Act;*
- Certificates of variance issued under the *Environment Act;*
- Orders, appeals, decisions and hearings made under the *Environment Act;*
- Notices of designation given pursuant to the *Environment Act;*
- Notices of a charge or lien given pursuant to the *Environment Act;* S.132;
- Policies, programs, standards, codes of practice, guidelines, objectives;
- Directives and approval processes established under the *Environment Act;*
- Convictions, penalties and other enforcement actions brought under the *Environment Act;*
- Information or documents required by the regulations to be included in the registry;
- Annual reports;
- Petroleum storage tank registration information; and
- Well log information.

When potential areas for groundwater supply are confirmed it will be necessary to request a search for registered storage tanks and other point sources. The results of each Environmental Registry Search are available two to four weeks after the request is made.

3.6 Stormwater Management

HRM's stormwater management guidelines describe stormwater best management practices to improve water quality in the water bodies in the Study Area affected by existing development as well as to minimize the risk of further degradation of water quality by future development.

3.6.1 Measures to Improve Existing Water Quality

Receiving water assessments indicated that E. coli concentrations in Lake Echo and McCoy's Pond are periodically above objective levels. Maximum measured results are well above the objective levels for most desired uses. Sources of these bacteria are typically failing onsite wastewater treatment systems and stormwater from urban development as well as direct deposits from local lake residents such as ducks and other waterfowl. While there is not much that can be done to deter the waterfowl; investigations can be undertaken to locate the other sources.

A second water quality concern is eutrophication of these lakes. Sources are typically nutrients (nitrogen and phosphorous) associated with:

- Failed onsite wastewater systems;
- Surface runoff that has come in contact with lawn fertilizers etc.; and
- Decaying brush and other organic material in clear cut areas.

The following measures are required to identify the sources:

- Sampling and analysis of tributary drainage systems;
- Identification of point sources of the pollutants in suspect areas; and
- Testing of onsite wastewater systems as well as local water supply wells, see results of a limited investigation completed as part of this study in section 3.11.

Once point sources are located, failed or not fully functional onsite systems may be replaced or reconstructed with systems designed to meet current standards for these system. Non-point sources may be reduced by:

- Education of residents and property owners in the community at large and in particular residents in the areas with significant sources of bacteria or other pollutants;
- Development of stewardship programs for local residents and property owners to encourage them to identify the sources and work to remove them; and
- Design and implementation of comprehensive stormwater management best management practices including treatment systems to remove the remaining pollutants to a level that can be assimilated by the lakes and still meet the receiving water objectives. Locating facilities to accomplish treatment of stormwater is very difficult in areas where development has already occurred; some innovation is typically required.

3.6.2 Measures to Reduce the Risk of Further Degradation of Water Quality

Given current water quality in these lakes, stormwater management plans should include measures to minimize additional pollutant loads to these receiving waters and to reduce the current loads. This requires the following measures from any new development prior to discharging to the environment:

- Attenuation of peak runoff flows; and
- Minimizing exposure of pollutants and treatment of stormwater from areas where the potential for release of contaminants is greatest.

These objectives can be achieved by:

- Implementing low impact site development, minimizing the affected footprint, and providing measures to:
  - Attenuate flows from individual properties and developments;
  - Maintain dispersed stormwater systems, minimize the concentration of stormwater;
  - Decrease the efficiency of stormwater collection systems on private properties;
  - Minimize exposure of pollutants and erosion potential of soils;
  - Provide treatment to remove pollutants;
- Decreasing the efficiency of local stormwater collection systems;
- Treating runoff; and

- Enacting current guidelines requiring deep storm sewers or clear water sewers be provided where sanitary sewers are provided. In Lake Echo, central wastewater collection systems are not envisioned but if they are provided to service buildings with basements, clear water sewers to convey foundation drainage away from each property will be required.

Groundwater is currently the main source of water in the community and is expected to play a significant role in water supply for future development in the community. Groundwater quantity and quality must not be compromised. This requires maintenance of areas with permeable soils (recharge areas) and protection of “clean” sources of runoff. Stormwater best management practices including, treatment of stormwater with potential contaminants and infiltration of the cleanest water to recharge the surficial aquifer should be included in the drainage plans submitted for any new development. Recommended best management practices include:

- Rain gardens and rain barrels on every property, existing and proposed;
- Permeable pavements;
- Sediment, oil and grease separators; and
- Infiltration systems.

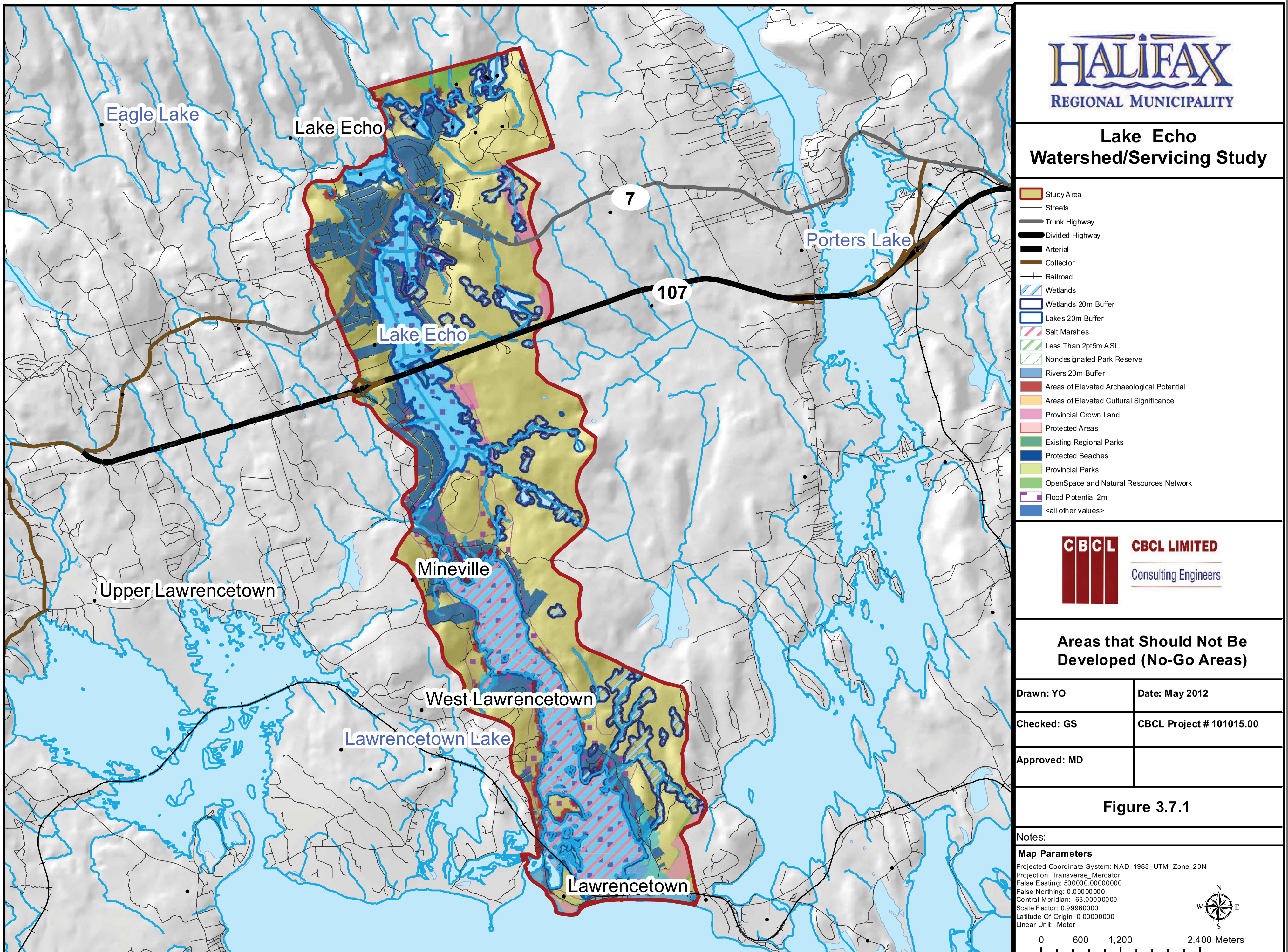
3.7 Means to Reduce and Mitigate Important Environmental Functions

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 are considered at two levels: the overall watershed planning and detailed site planning.

3.7.1 Planning

There are areas that should not be developed. Figure 3.7.1 illustrates these “no go” areas based on the following criteria adapted from *A Guide to Open Space Design Development in Halifax Regional Municipality* (HRM, 2007) and other sources:

- Water bodies, watercourses and designated wetlands;
- Watercourse, wetland, coastal buffers and other low lying areas that can contribute to stormwater detention and treatment;
- Provincial parks, reserves, and provincial crown lands;
- Cemeteries;
- All lands below elevation 2.5m;
- Significant wildlife habitat and endangered species as per map 5 of the Regional Municipal Planning Strategy;
- Areas of elevated archaeological potential as per map 11 of the Regional Municipal Planning Strategy; and
- Lands of high cultural significance as per category 5 on map 10 in the Regional Municipal Planning Strategy.


Eagle Lake
Lake Echo
7
Porters Lake
107
Lake Echo
Mineville
Upper Lawrencetown
West Lawrencetown
Lawrencetown Lake
Lawrencetown
HALIFAX
REGIONAL MUNICIPALITY
Lake Echo
Watershed/Servicing Study
Study Area
Streets
Trunk Highway
Divided Highway
Arterial
Collector
Railroad
Wetlands
Wetlands 20m Buffer
Lakes 20m Buffer
Salt Marshes
Less Than 2pt5m ASL
Nondesignated Park Reserve
Rivers 20m Buffer
Areas of Elevated Archaeological Potential
Areas of Elevated Cultural Significance
Provincial Crown Land
Protected Areas
Existing Regional Parks
Protected Beaches
Provincial Parks
OpenSpace and Natural Resources Network
Flood Potential 2m
<all other values>
CBCL LIMITED
Consulting Engineers
Areas that Should Not Be Developed (No-Go Areas)
Drawn: YO
Date: May 2012
Checked: GS
CBCL Project # 101015.00
Approved: MD
Figure 3.7.1
Notes:
Map Parameters
Projected Coordinate System: NAD_1983_UTM_Zone_20N
Projection: Transverse_Mercator
False Easting: 500000.00000000
False Northing: 0.00000000
Central Meridian: -63.00000000
Scale Factor: 0.99960000
Latitude Of Origin: 0.00000000
Linear Unit: Meter
N
E
S
W
0 600 1,200 2,400 Meters
File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Areas that should not be developed (No_Go).mxd
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Developing at a higher density will reduce the geographical area to be impacted by development. If an area in the Lake Echo Study Area is found to be suitable for denser development with the implementation of appropriate sanitary and stormwater systems, this denser development will limit the impact of development. Denser development can be achieved in a more rural form though the use of open space subdivisions serviced with clustered water supply and sanitary sewerage systems. To limit impacts on less disturbed ecosystems and to respect the existing centre of the community, it is recommended that the denser urban development should be associated with already developed areas and open space subdivisions be designed, as intended, to preserve important ecosystems and other valuable features of development sites (see Section 3.7.2).

3.7.2 Detailed Site Planning in Open Space Subdivisions

It is recommended that open space subdivision designs be used to keep a significant portion of the area free of development. Within an overall development site, development may occur in the areas outside the "No Go" areas defined above. Where available within an overall site, the "No Go" areas may accommodate all or a portion of the site that is to remain undeveloped (see Figure 3.7.2(a)), except where the area is Federal or Provincially owned land.

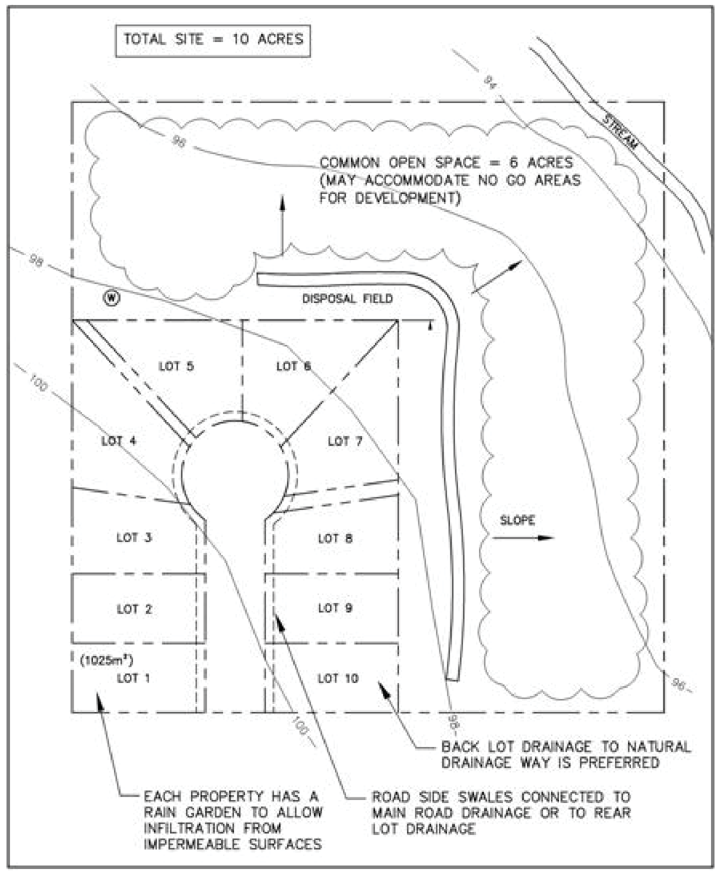


Figure 3.7.2(a): Schematic Drawing of an Open Space Subdivision Design

Land development should be done through responsible design –a process that takes into consideration and addresses the environmental functionality of the landscape. There are many references to this concept; three well known texts include McHarg's, *Design with Nature (1969)*; Hough's, *City Form and Natural Process (1984)*, and Forman and Godron's, *Landscape Ecology (1986)*. All three texts refer to the idea that design, in order to be successful, must acknowledge, understand and respond to the ecological processes of the land. More recent texts include Randall Arendt's *Growing Greener (1999)* and *Envisioning Better Communities (2010)*. These works provide guidance for site planning and design approaches that will assist in reducing and mitigating the loss of permeable surfaces, native plants and native soils, groundwater recharge areas, and other important environmental functions.

Responsible site planning and design can mitigate the loss of permeable surfaces (such as paved driveways, rooftops) through a variety of approaches such as the provision of multiuse land areas for recharge. Lawn areas, for example, can be designed to act as surface runoff detention areas, as well as aesthetic and recreational areas. Driveways can be designed to be more permeable through the use of unit pavers, and roof drains can be designed to discharge into soft landscaped areas or "rain gardens". In other cases, it may be more desirable to have impermeable surfaces directing runoff to recharge areas depending on the situation. The point is that in each case the question of recharge needs to be addressed at the community level as well as on each property in the community.

Good design should incorporate the use of native landscape, topography and native vegetation into the site development (see Figure 3.7.2(b)). Rather than stripping a site bare and completely reforming the topography, buildings should be placed in the landscape and the areas disturbed for construction should be limited to the smallest reasonable area. Open space or conservation subdivision design should make this easier to achieve because the smaller footprint of development will allow development areas to be placed strategically within the site enabling the preservation of important natural and cultural features.

Figure 3.7.2(b): Schematic of Development that Reflects Natural Conditions

Using the natural landscape and vegetation reduces the requirement of artificial irrigation, maintains natural infiltration and stormwater detention areas and helps to conserve native soils, the wildlife and its habitats that all help to define the place. Since the permeability of the surrounding landscape is directly related to groundwater recharge and well water, homeowners, and developers alike, should be aware of the potential impacts associated with unnecessarily large construction footprints. Clearing a lot for ease of construction purposes does nothing to conserve the surrounding environment. Landscaping to re-establish the vegetation once lost after construction further mystifies the very intention of the development in the first place. Through responsible design, however, successful land development can be both conscientious of the environment and at the same time provide safe and healthy communities in which to live, work and play.

3.8 Methods to Reduce Cut and Fill and Overall Grading

To reduce cut and fill and overall grading of development sites, developers should be encouraged to work with the land to strategically place developed portions of the site in areas where cut and fill can be minimized. Respect should be given to slopes. Contour development should be practised in roadway design to reduce cuts and fills and steep grades.

Attention should be paid to the design of individual structures. Each structure should be suitable for the topography of the site where it is to be located. Structures should be designed to fit the land, not the land graded to fit the structures.

The use of open space subdivision designs enables a significant portion of the site to remain undisturbed. Lower areas of the site and drainage-ways should be preserved. Development should be placed on higher ground where run-off can be directed to these natural drainage-ways. Run-off does not always have to be directed to the street. Where appropriate, run-off can be directed to the backs of lots where slopes enable this and natural drainage-ways exist. To reduce its erosive force as much as possible, run-off should be dispersed and not concentrated.

3.9 Identify and Recommend Measures to Protect and Manage Natural Corridors and Critical Habitats

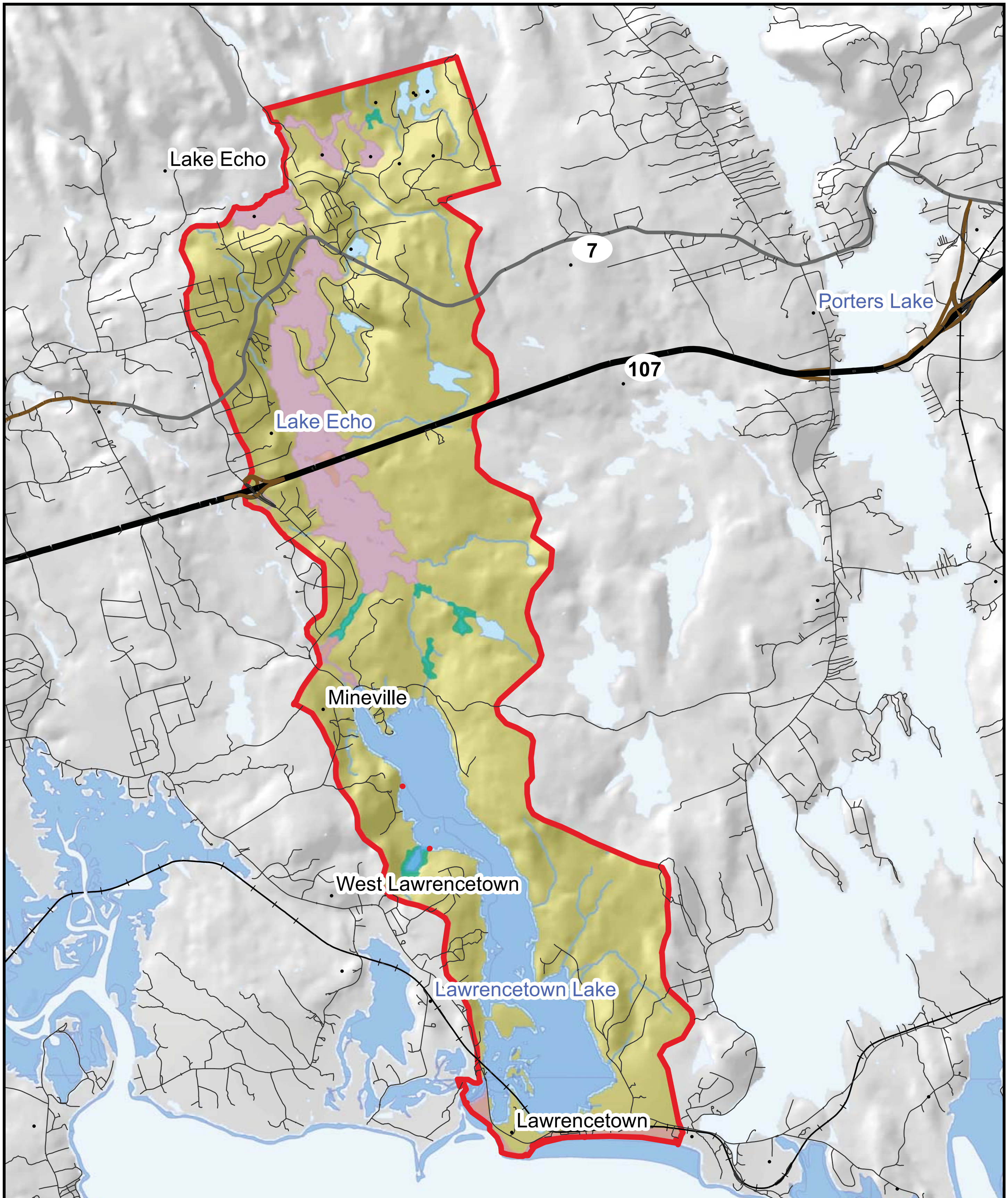
Habitats and species at risk are described in Appendix E.

As mentioned above, the use of open space subdivision designs should more easily enable the preservation of undisturbed areas and the establishment of the upland buffers along watercourses and wetlands. The “No Go” areas identified on Figure 3.7.1 include natural corridors and critical habitats as identified though the HRM Regional Plan. During detailed site design, development should be setback from identified critical habitat areas and buffers appropriate to the species being protected need to be established. For example, certain birds may need buffers of up to 100 m from road noise to preserve nesting habitat, while a stationary plant could have a much smaller buffer. Habitat fragmentation can have a major impact on species viability. It is therefore recommended that as far as possible during detailed site design, contiguous blocks of undisturbed lands be preserved across multiple properties and that only extremely limited road crossings of these areas be allowed. This is especially critical for Red Species and Yellow Species areas identified on Map 5 of the Regional Municipal Planning Strategy (see Figure 3.9).

Erosion and sedimentation can also have a significant impact on habitat. In addition to preserving undisturbed portions of the site, specific building sites should only be cleared when construction is ready to proceed. Large swaths of land should not be cleared months or years in advance and left without groundcovers, unprotected from erosion.

3.10 Identify Appropriate Riparian Buffers and Recommend Other Methods for Protection of Critical Habitats

It is recommended that, during detailed site design, buffers along all watercourses, lakes, ponds, and wetlands over one hectare be brought in line with the Nova Scotia Department of Natural Resources *Wildlife and Watercourses Protection Regulations*, which states that for watercourses with channel widths over 50 centimetres, upland buffers are to be a minimum of 20 metres on either side of the watercourse and where average slopes within that area exceed 20%, the width is to be increased by one metre for each 2% of slope, up to a maximum of 60 metres in width either side of the watercourse. Measurements of the upland buffers should start at the top of bank or edge of lakes ponds or wetlands. In all other conditions, it is recommended that a continuous strip of natural vegetation, a minimum of 20 metres wide, is provided on both sides of all water courses and around all lakes and wetlands.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study
Figure 3.9 Significant Habitats and Endangered Species in the Study Area
May 2012

0 750 1,500 3,000 Meters

- Rare Plant
- Old Forest
- Wetland
- Yellow Species
- Red Species
- Salt Marshes
- Study Area

CBCL Project # 101015
Data Sources: HRM, NSDNR
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

CBCL LIMITED Consulting Engineers

N W E S

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Specific concerns in the study area include:

- Acid runoff and inflows to Lake Echo from the upper reaches of the Salmon River watershed; and
- Erosion from potential construction sites along the lake fronts as well as in the areas being considered for additional development in Lake Echo.

Measures to reduce contact with pyritic slates have been implemented at the airport in the upper reaches of the Lake Echo Watershed. Measures to minimize potential for disturbance of additional areas in the watershed should be implemented where any development is considered in the vicinity of pyritic slate. Figure 3.10 shows the general locations of slate bedrock in the Study Area.

Stormwater management and the maintenance and improvement where possible of existing flow conditions including quantity, quality, temperature, time of concentration, etc. are critical to the protection of aquatic habitats. Erosion and sedimentation controls as per Nova Scotia Environment requirements must be implemented and monitored to ensure that they function as required. Limiting of areas to be cleared and only clearing sites when construction is imminent will also serve to reduce run-off and erosion issues that could affect water quality.

The use of open space subdivision designs should more easily enable the preservation of undisturbed areas and the establishment of the upland buffers.

3.11 Sanitary Survey

A sanitary survey was completed in the study area to assess the make-up and performance of existing on-site wastewater treatment and dispersal systems as well as onsite water supply systems. Details of the assessment and the findings are provided in the component study report in Appendix H.

The sanitary survey was not intended to be an all-inclusive program, only a sampling program of onsite systems in the study area. Locations for the survey were selected based on the findings of the surface water quality assessments. These assessments determined that the greatest concerns with water quality were at the upper end of Lake Echo. These areas (see Figure H.1.2) became the focus of the sanitary survey; to determine how much the onsite wastewater systems might be contributing to the water quality issues in Lake Echo.

Onsite systems are considered to have failed when they discharge untreated or partially treated wastewater to surface waters or groundwater. Factors such as the type of system, the slope of the land, the nature and depth of surficial soils were considered in the generation of the onsite suitability mapping for HRM. Figure 3.11, reproduced from the onsite study completed by Land Design Engineering in 2005[12], indicates that in general the soils in the Study Area are considered most suited for onsite systems, exceptions include some low areas along the east side of Lake Echo between Highways 7 and 107 and on both sides of the southern portion of Lawerencetown Lake. Other factors, including the size of the lot and the arrangement of the system on the lot, affect the capacity of an onsite system to successfully treat sewage before it is released to the environment. Discussions with local installers indicated that the failed systems they have replaced have been in pockets of unsuitable soils and on lots that do not meet current Nova Scotia Environment standards for the design of onsite wastewater systems.

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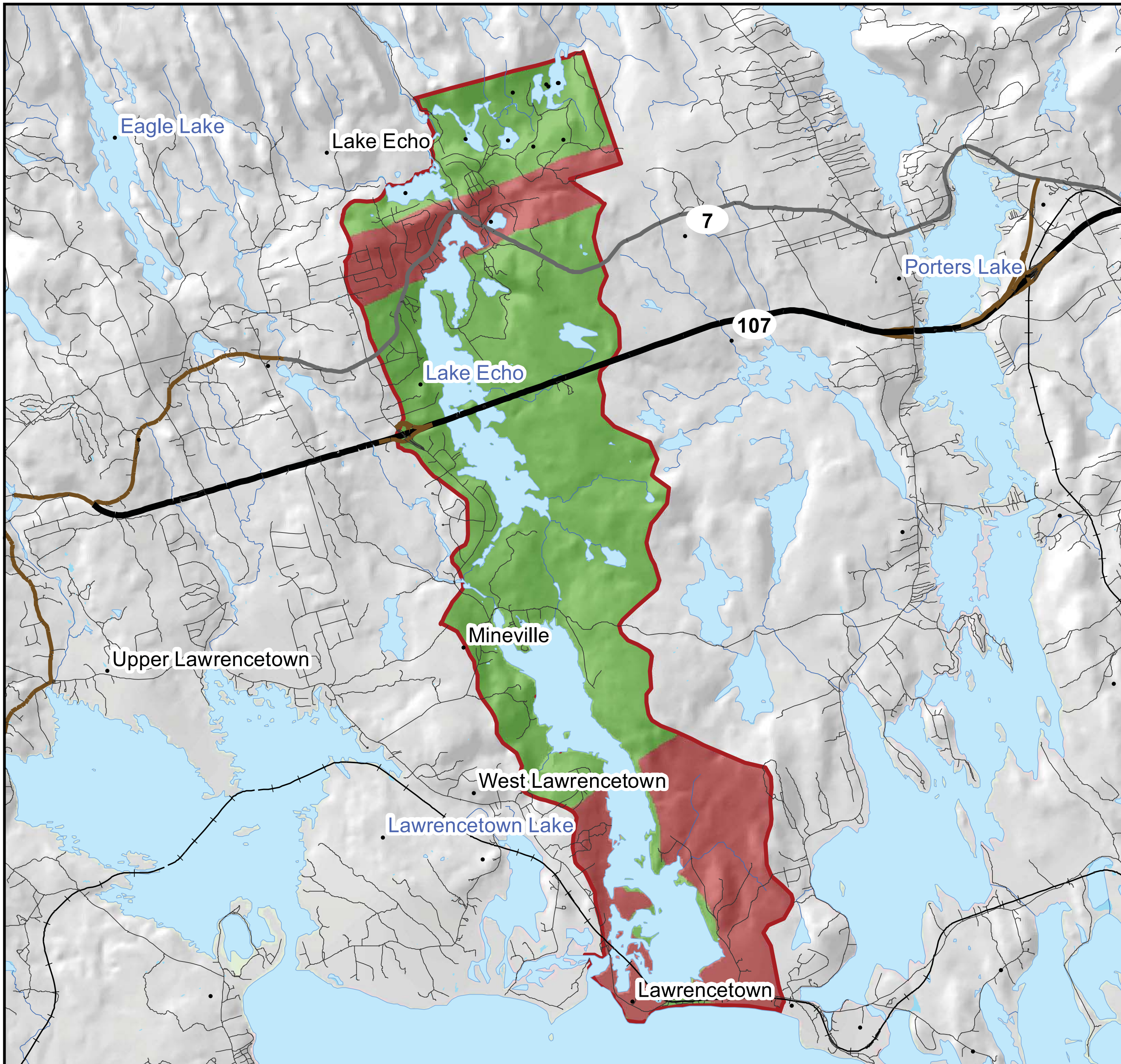
[12] Land Design Engineering Services et al. March 2005. Options for Onsite & Small Scale Wastewater Management.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area
- **Pyretic Slates**
- Absent
- Present
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Locations of Slate Bedrock in the Study Area

Drawn: YO	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure 3.10

Notes:

Map Parameters
Projected Coordinate System: NAD_1983_UTM_Zone_20N
Projection: Transverse_Mercator
False Easting: 500000.00000000
False Northing: 0.00000000
Central Meridian: -63.00000000
Scale Factor: 0.99960000
Latitude Of Origin: 0.00000000
Linear Unit: Meter

0 550 1,100 2,200 Meters

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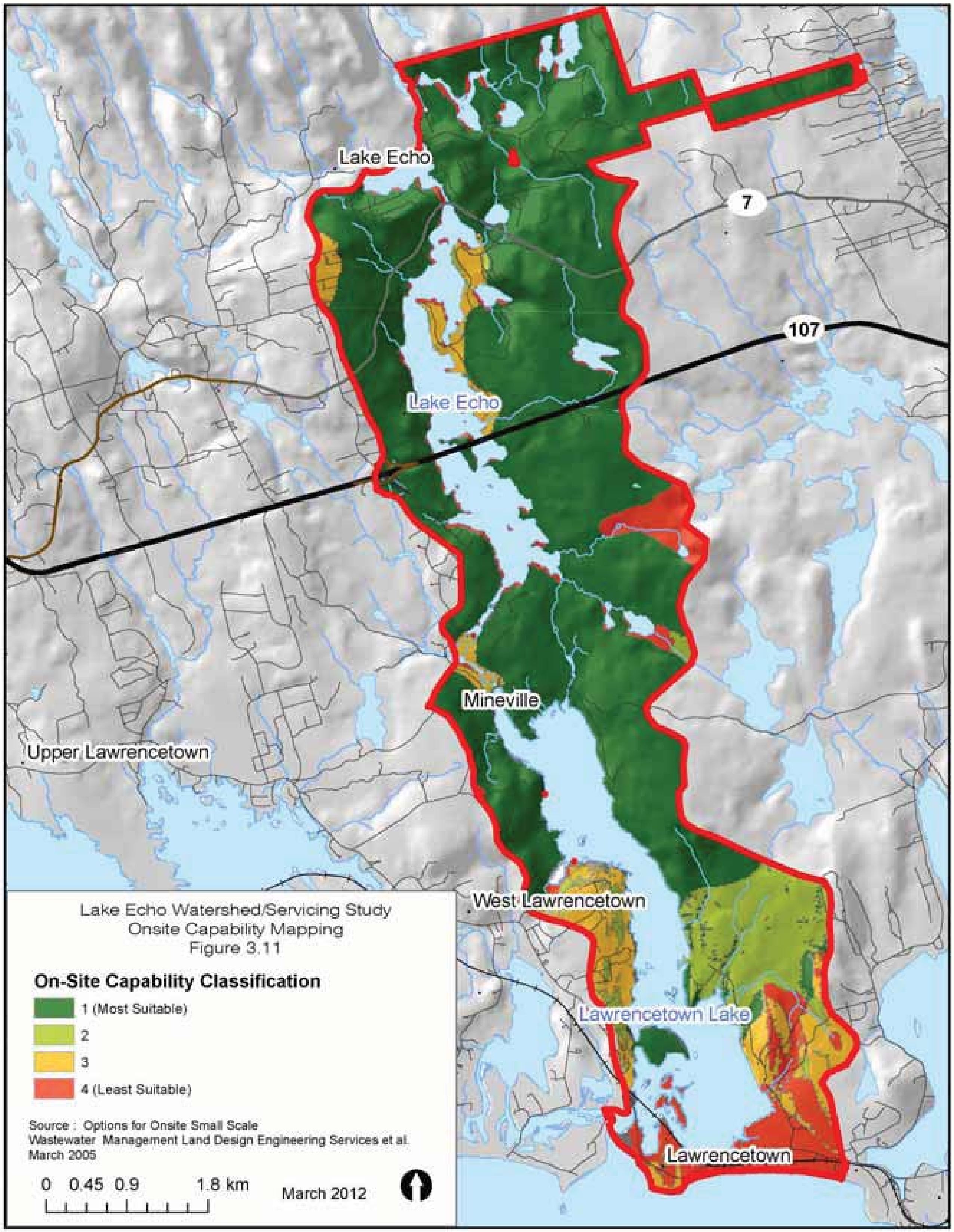

Lake Echo
7
107
Lake Echo
Mineville
Upper Lawrencetown
West Lawrencetown
Lawrencetown Lake
Lawrencetown
Lake Echo Watershed/Servicing Study
Onsite Capability Mapping
Figure 3.11
On-Site Capability Classification
1 (Most Suitable)
2
3
4 (Least Suitable)
Source : Options for Onsite Small Scale
Wastewater Management Land Design Engineering Services et al.
March 2005
0 0.45 0.9 1.8 km
March 2012

Properties with the greatest potential for onsite wastewater systems to fail were visited in an effort to confirm suspicions that these were the systems that generated pollutant loads to the receiving waters. Residents were asked to voluntarily participate in the survey at the level where they felt comfortable. Some agreed to fill out a questionnaire with the survey team. Each property owner that completed this phase was asked to allow the team to complete a dye test on the wastewater system (dye is flushed and the area monitored for a two week period for signs of the dye at the surface). Survey results are summarized in Table 3.11.

Table 3.11: Summary of the Sanitary Survey Findings

Survey Results	Number	
Total Visits	176	
Surveys Completed	72	40.9%
Dye Tests Completed	23	31.9%
Suspect or Inadequate Systems	19	26.4%
Systems that Failed the Dye Test	0	
Onsite Wastewater System Types		
Area Bed	54	75.0%
Contour	9	12.5%
Chambers	3	4.2%
Mound	2	2.8%
Unknown	2	2.8%
Sloping Sand Filter	1	1.4%
Holding Tanks	1	1.4%
Water Source		
Drilled Well	54	75.0%
Dug Well	17	23.6%
Lake Water	1	1.4%
Do not Drink Water	8	11.1%
Water Treatment	46	63.9%

There were 23 dye tests completed in November 2011, out of 72 surveys completed. Although assured that the results would remain confidential, many property owners were reluctant to participate, fearing that neighbours would observe the dye and know that their system failed as well as the financial repercussions of a failed system. No failed systems were identified by the dye testing program. This is not proof that the existing systems provide suitable treatment only that at the time the dye tests were completed none of the wastewater flows came to the surface. Additional survey is required to identify inadequate and failed onsite systems in the study area.

Well water samples were also collected at each property that agreed to participate in the dye testing, as an incentive. These well water samples were analysed for concentrations of parameters that may affect the health of the users as well as parameters that determine the aesthetic quality of the water. Results of these assessments are provided in Appendix H.

Survey respondents did not indicate that drilled well yields were a concern. Water quality issues with drilled wells included incidences of elevated concentrations of:

- Coliform bacteria and in one case *E. Coli* above the respective Maximum Acceptable Concentration (MAC), commonly associated with poor well construction;
- Colour;
- Iron and manganese;
- Lead and copper, likely related to the plumbing system; and
- Arsenic above the respective Maximum Acceptable Concentration (MAC).

One respondent indicated that yield was a concern with their dug well. Water quality issues with dug wells included incidences of elevated concentrations of:

- Coliform Bacteria and in one case *E. Coli* above the respective Maximum Acceptable Concentration (MAC);
- Colour; and
- Iron, manganese, and aluminum.

CHAPTER 4 ALTERNATIVES FOR SERVICING THE STUDY AREA

Wastewater, stormwater and water needs in the community were investigated and the results are summarized in this chapter. Details of the contributing assessments may be found in the Servicing Study Report in Appendix F.

4.1 Services in the Study Area

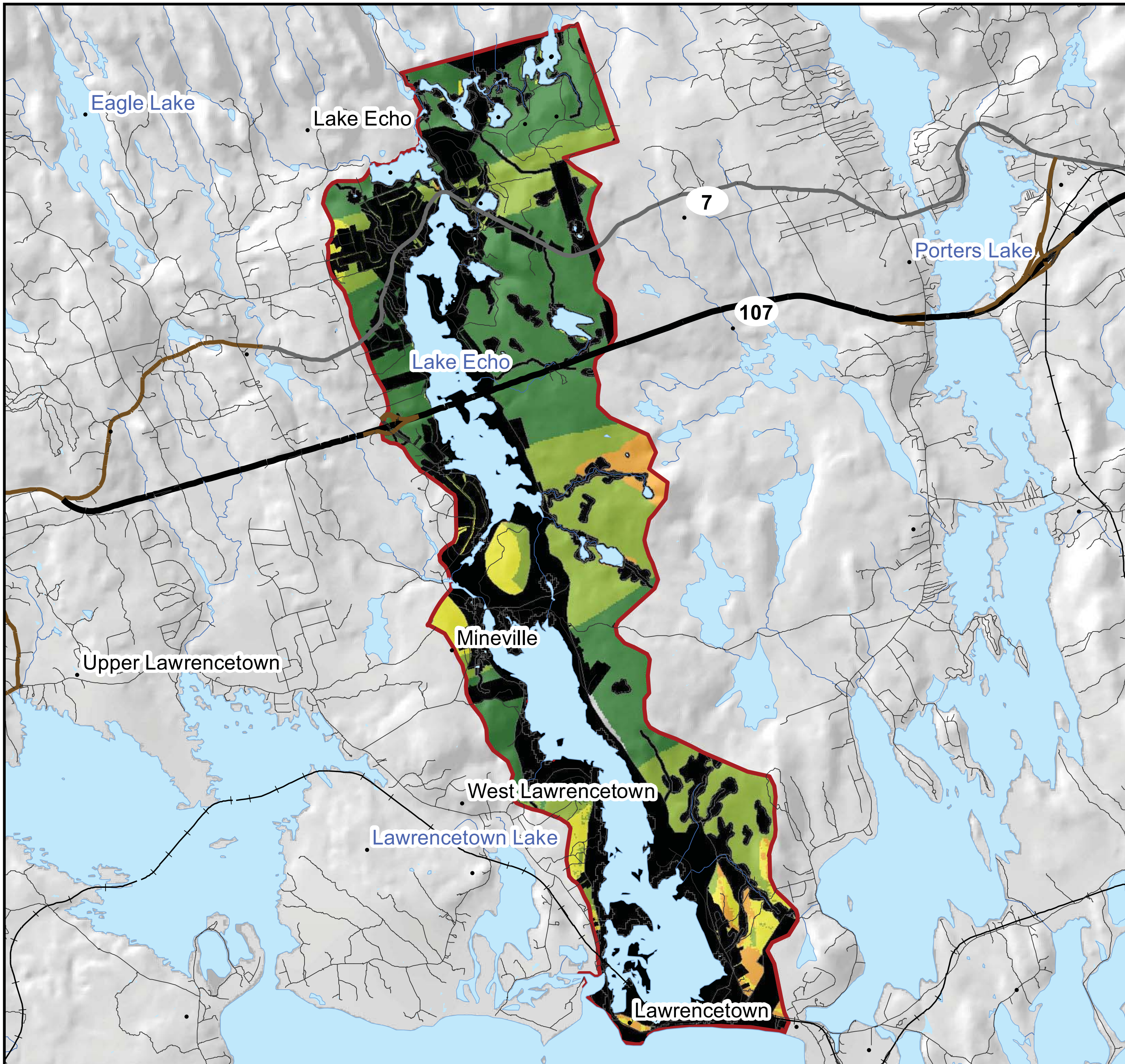
Services considered include:

- Wastewater collection and treatment;
- Stormwater management; and
- Water supply, treatment and distribution.

The Request for Proposals (RFP) for this study states that "The objective of the Lake Echo Centre Servicing Study will be to assess in greater detail, options for the servicing of land within the Lake Echo Centre and surrounding area with on-site and / or cluster septic systems". Potential areas considered for the community centre were identified by community representatives at the Focus Group meetings, see Figure 2.3.2. In addition to these suggested locations for new development, the study team assessed expansion of the community around the existing Lake Echo Community Center.

Assessments of these potential community centre locations included comparing the ability of the land to provide wastewater treatment and supply water in each location to determine if one was better suited than the others. Figure 4.1 combines the information on Figure 3.1.1.3, the groundwater resource potential of bedrock, with the onsite capability presented in Figure 3.11. It shows the ability of the land to provide water for domestic use as well as wastewater treatment. When this capability is compared to the locations of potential community centres it is evident that if the community is to be serviced with onsite systems, neither the existing community centre nor the southern portion of the proposed development in the northeast corner of the study area are as suitable as the area identified adjacent Highway 107. This is primarily due to the pyritic slate bedrock that underlies these areas. This bedrock poses two difficulties:

- Well yields from the slates are lower and the water quality is not as good, it requires higher levels of treatment to be suitable as a water supply; and
- Runoff from areas with exposed slate bedrock can be more acidic (lower pH) than runoff from other areas. A stormwater management plan that addresses management of acidic runoff is recommended for all areas with underlying pyritic slate bedrock.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area Boundary

Relative Suitability - Onsite Services

Most Suitable

Least Suitable

Streets

Trunk Highway

Divided Highway

Arterial

Collector

Railroad

CBCL LIMITED Consulting Engineers

Land Suitability for Onsite Services

Drawn: YO	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure 4.1

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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0 550 1,100 2,200 Meters

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Areas outside of the community centre should be serviced with onsite systems for individual residences or commercial properties as well as small clusters of properties in new sub-divisions. The most suitable areas for provision of onsite services are shown in green on Figure 4.1. Development should be encouraged to locate in these areas where land is available and offered for development. Onsite wastewater and water systems must be designed and constructed to meet current standards. Minimum lot sizes for both onsite wastewater and onsite water supply by wells should be compared for each property and the larger lot size used as the minimum lot size.

4.1.1 Wastewater Treatment

4.1.1.1 Upgrading of Existing Systems

All wastewater treatment systems are potential point sources of nutrients, E coli and other pollutants. Each system in the study area should be reviewed to ensure that discharges from these systems can be assimilated in the receiving environments. The phosphorous loading models were used to estimate the impacts on lake water quality of improving the performance of existing wastewater treatment systems in the study area including:

- Addition of phosphorous removal to the treatment plant at the mobile home park; and
- Upgrading or replacement of existing septic tanks and soil dispersal systems to meet current Nova Scotia Environment requirements.

Results of this assessment are presented in Table 4.1.1 for existing development as well as for the three growth scenarios considered. The results indicate that, if the upgraded systems are able to perform as well as a new system, then all of the planned growth can be accommodated while lowering the total annual phosphorous loads to McCoy's Pond and Lake Echo.

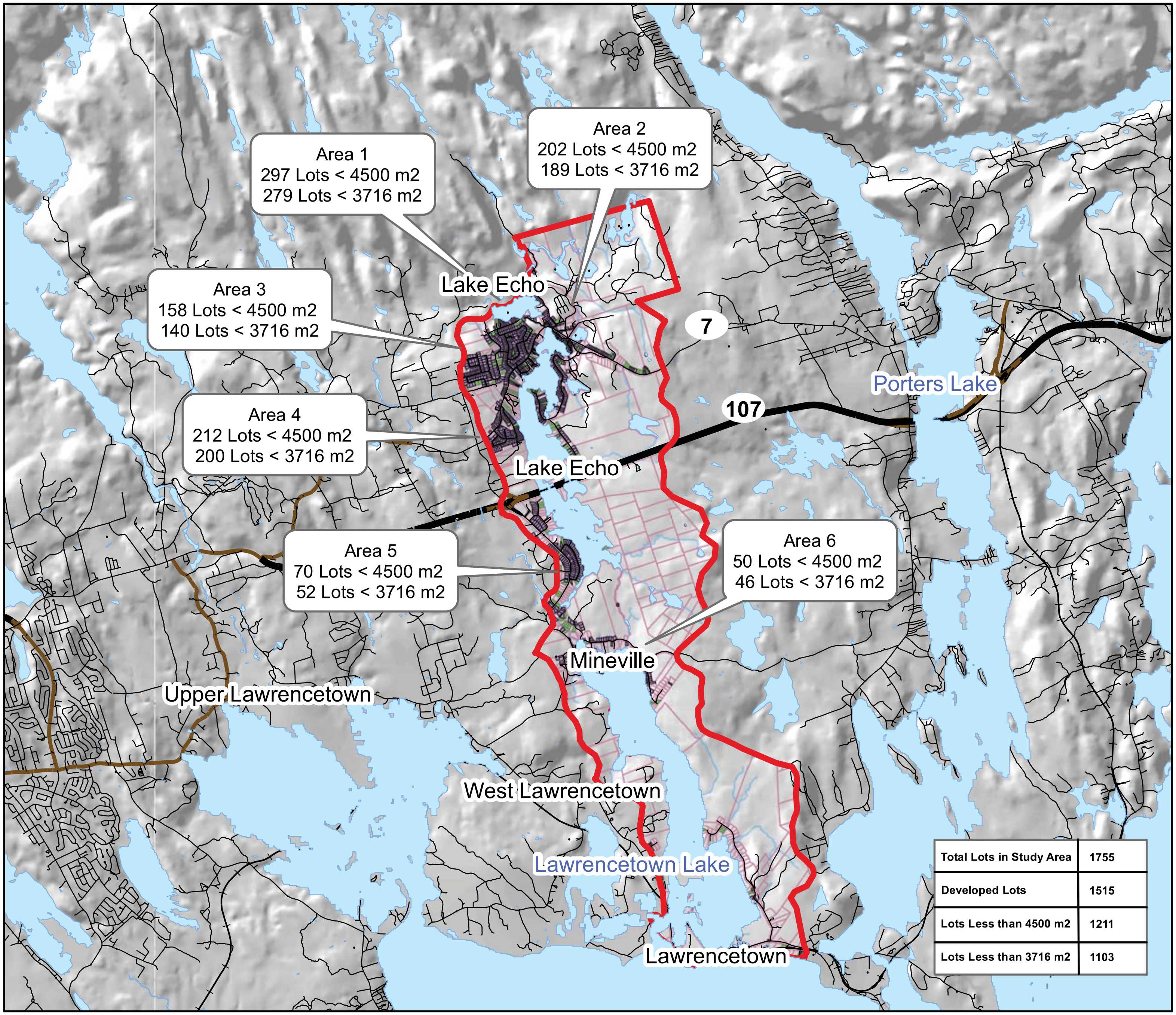
Onsite systems for individual properties as well as clusters of properties were considered for replacement of existing deficient onsite systems (not all of the required components meet current standards) or failed onsite systems (a portion of the septic tank effluent reaches the surface water systems) and to service proposed development in the community.

Within the overall Study Area, out of a total of 1,755 lots, 1,515 are currently developed. Of the developed lots, 1,211 lots are less than 4,550 square metres and 1,103 lots are less than 3,716 square metres, the minimum lot requirement for water frontage (see Figure 4.1.1(a)). Any lot that is currently developed in areas that are not well suited for on-site systems (lots in areas that are not green on Figure 4.1) may be considered as potential sources of wastewater pollutants. In order to identify all on-site wastewater systems that do not function as required, a comprehensive sanitary survey of all lots with potential for deficient onsite wastewater systems will need to be completed. This should help to locate the sources of the elevated levels of nutrients in Lake Echo and define the areas where upgrades of onsite wastewater systems are needed.

Where systems on individual properties are found to be deficient or failed, the existing soil dispersal system may be replaced by a new soil dispersal system if the required land is available and separation distances can be achieved. Otherwise a recirculating textile filter (RTF) system may be used to replace the failed soil dispersal system.

Table 4.1.1 Predicted Annual Average Total Phosphorous Concentration in Study Area Lakes with Improved Phosphorous Removal for Existing Wastewater Systems

			Sub-watershed												
Development Scenario			***McKay Lake***	***Lake Williams***	***East Lake***	***Byron Lake***	***Tittle Lake***	***Loon Lake***	***Salmon River Long Lake***	***West , Granite Lakes***	***Brown, Jack Weeks Lakes***	***Lewis Lake***	***Martin Lake***	***Lake Echo***	***Lawerencetown Lake***
Existing Development - Tertiary Level of Treatment at the STP															
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0124	0.0165	0.0145
Predicted Increase	%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%
Existing Development - Tertiary Level of Treatment at the STP and On-site Wastewater Systems Upgraded to Meet Current Standards															
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0116	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0118	0.0132	0.0118
Predicted Increase	%		0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	-5%	-20%	-19%
Low Growth Scenario with Both Wastewater Treatment Upgrades															
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0116	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0118	0.0131	0.0117
Predicted Increase	%		0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	-5%	-21%	-19%
Medium Growth Scenario with Both Wastewater Treatment Upgrades															
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0116	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0126	0.0094	0.0120	0.0134	0.0120
Predicted Increase	%		0%	-1%	0%	0%	0%	0%	0%	0%	5%	7%	-3%	-19%	-17%
High Growth Scenario with Both Wastewater Treatment Upgrades															
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0116	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0135	0.0101	0.0122	0.0138	0.0124
Predicted Increase	%		0%	-1%	0%	0%	0%	0%	0%	0%	13%	15%	-2%	-17%	-14%



Total Lots in Study Area	1755
Developed Lots	1515
Lots Less than 4500 m2	1211
Lots Less than 3716 m2	1103

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Property Area<3,716m2
- Property Area<4,500m2
- High Density Areas
- Property Boundary
- Study Area
- County Lines
- Rivers
- Other Roads
- Highway
- Collector
- Railroad

CBCL LIMITED
Consulting Engineers

Lots Size Assessment in the Study Area

Drawn: YO	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure 4.1.1 (a)

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
Projection: Transverse_Mercator
False Easting: 500000.00000000
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Linear Unit: Meter

0 750 1,500 3,000 Meters

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Cluster wastewater treatment systems may be considered for servicing small groups of failed systems where land is not available for replacement systems on the individual properties. Septic tanks (and effluent pumps where required) on each property, a small diameter septic tank effluent collection system and central septic tank effluent treatment using recirculating filters and disinfection are the most suitable types of systems. Designs were generated for typical clusters that might be considered in the study area.

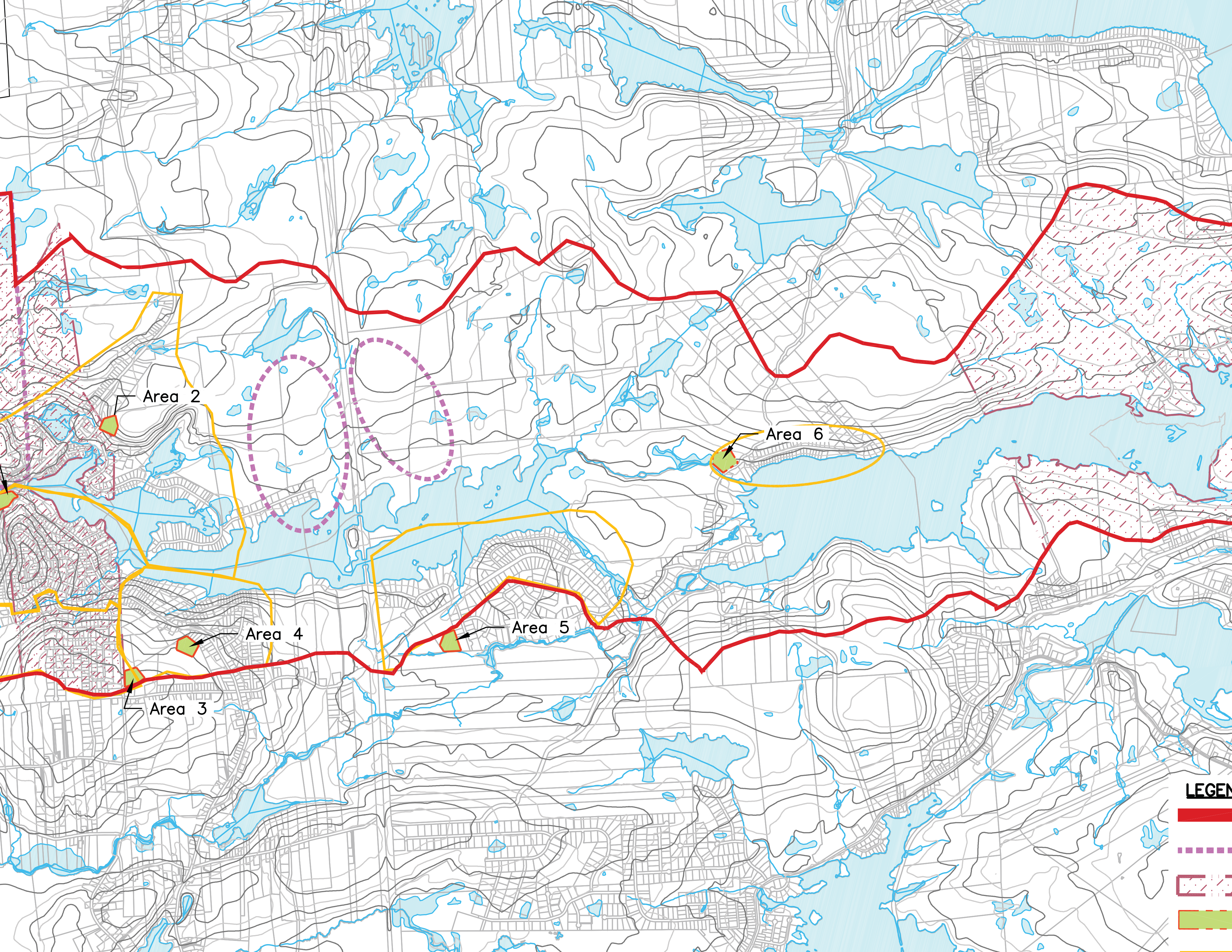
Designs were also generated for the option of treating septic tank effluent from larger groups at a single site with a recirculating filter system. It is expected that land dispersal from this type of system may be feasible and is preferred to reduce nutrient loads to the lakes. Soil characteristics at each site must be determined by site specific, in situ infiltration testing. The information obtained from these tests will be used to determine the area required to achieve effective soil dispersal with minimum risk of breakout. Effluent flow to groundwater is limited to the infiltration capacity of the soil. When this is exceeded a portion of the effluent will flow laterally and may reach the surface water system, where it can affect the water quality in local drainage systems as well as in Lake Echo. Potential locations for these community based septic tank effluent treatment plants are shown on Figure 4.1.1(b).

4.1.1.2 New Development

Options for onsite systems presented in section 4.1.1.1 may also be used for infilling development or development in sub-divisions that are already approved. Cluster wastewater treatment systems may also be considered for future development in new open space sub-divisions. All onsite systems should be designed with site specific information for each sub-division. Where the soil hydraulic characteristics, depth and slope are suitable, contour systems would be used. Recirulating filters with land dispersal of effluent may also be considered.

4.1.2 Stormwater Management

Assimilative capacity assessments indicated phosphorous concentrations and E coli concentrations are concerns closest to existing development in Lake Echo. Stormwater management plans should aim to minimize increases in the concentration of these pollutants in Lake Echo and reduce the concentrations where possible while maintaining peak flows through the system at current levels. This requires minimizing potential contact of runoff with pollutants as well as attenuation of peak flows and treatment of stormwater from any development site prior to discharging to the environment, surface waters and/or groundwater.



Area 2
Area 6
Area 4
Area 5
Area 3
LEGEN

These objectives can be achieved with:

- Low impact site development, utilizing stormwater best management practices such as:
  - Rain gardens and rain barrels;
  - Porous pavements;
  - Low slope swales along the property perimeter complete with vegetated filter strips adjacent impermeable areas. These should be directed to undeveloped back lots where this is possible without affecting neighbours;
- Local stormwater collection swales with flow limiting culverts between them to encourage detention and infiltration rather than piped stormwater collection systems;
- Treatment of remaining runoff in centralized wet ponds and constructed wetlands with built in detention capacity;
- Detention storage in natural low lying areas. These areas should be preserved where possible by locating all development on the highlands. Where there is no naturally occurring low land and detention storage must be constructed, co-use of stormwater detention with other public use lands such as parkland or recreation fields will lower the overall costs of this requirement as the costs of land can be significant; and
- Current guidelines require that deep storm sewers or clear water sewers are included where sanitary sewers are provided. Clearwater sewers to convey foundation drainage away from each property will need to be included if central wastewater collection systems are considered. These will discharge relatively constant clean flows directly to the receiving waters with minimal impact.

These and other best management practices available at the time should be considered in the development of a site specific stormwater management plan for each development.

4.1.3 Water Supply and Treatment

Water supply options and water treatment requirements for individual and cluster systems were assessed by reviewing well records for wells in the study area. Wells constructed in the surficial soils yield 9 to 84 L/min and are able to provide water for individual units as well as clusters of more than 10 units. Wells constructed in bedrock yield less, 7 to 32 L/min and are able to provide water for individual units as well as clusters of up to 10 units. These are the ranges of yields for existing wells, yields of individual wells may be different and will need to be confirmed on a site by site basis through a hydrogeological investigation for each development.

Sampling and testing of existing wells was completed as part of the sanitary survey. Water quality parameters of concern included iron, manganese, and arsenic as well as lead and copper in the wells drilled into bedrock (typically from the plumbing), as well as Aluminum and E coli in the wells in the surficial soils.

The hydrogeological assessment completed as part of this study indicated that the percentage of water taken to service existing development is relatively small (4% of groundwater recharge) compared to the flow through the tributary aquifers. This will more than double (9% of groundwater recharge) to supply water to the community under the high growth scenario for future development in the community. Withdrawal to supply this type of development is not expected to negatively affect existing wells and reduce their ability to supply water to current users if minimum lot sizes for water supply and well separation distances are considered in the placement of new sub-divisions and wells.

For general planning purposes, a minimum of 5,854 square metres of permeable area is required for every cubic metre of daily water demand, based on the groundwater suitability mapping and an assumption that ground cover has a low demand for water. Generally, for planning purposes, one cubic metre per day of water can supply one dwelling unit. The actual land area required for water supply will be determined during the hydrologic assessment required as part of HRM's subdivision approval process.

4.2 Central Water Supply, Treatment and Distribution System

The RFP also states that "If the analysis reveals that there is a significant problem with water quantity and/or quality in the Lake Echo Centre, the consultant shall examine options for the provision of central water to the Lake Echo Centre". Bedrock underlying the existing community centre and a large portion of the proposed development to the northeast is pyritic slate. The available quantity of water from this type of bedrock is typically low and poor water quality means that treatment will likely be required.

If the existing community centre and/or the proposed development in the northeast corner of the study area are to be considered as a centre of the community for future development, a central water system complete with treatment should be considered. A central water supply, treatment and distribution system was assessed for existing development and potential future development with underlying pyritic slate bedrock in the northern portion of the Study Area. In addition, residents attending the public meeting in Lake Echo on May 9th, 2012 indicated that the water supply for the existing Wonderland Mobile Home Park (Water Supply Lake) has had some recent problems, requiring residents to boil water. If a central water system is considered for the area, it should include supply of treated water to the mobile home park system.

4.2.1 Central Water Supply By Wells

Supply of water to the community by wells in deep surficial aquifers appears feasible in the Study Area, provided the well sites can be located and that undeveloped land that is separate from potential contaminants can be located and is available for this purpose. A well siting and development program is considered the next step if this is to be pursued.

4.2.2 Water Supply From Lake Echo

The surface water system with the greatest potential to provide water for a central water supply is the Lake Echo watershed. The feasibility of using this system to supply water for a central system was assessed by comparing maximum day water demands to low flows in local gauged water courses and prorating the results to the Salmon River - Lake Echo system. The maximum day demands for existing development in the potential water service area account for 25% of the estimated 1 in 50 year low flow in the Lake Echo system. Preliminary assessments indicate that future water demands for the Study Area under the high growth scenarios are 45% of the drought flows. Withdrawal of water for a central water supply system for the entire Study Area would require withdrawal of a significant portion of the low flows, resulting in lower lake levels than occurs under existing conditions.

Although the change in water levels due to withdrawal for water supply may be considered minor, (2 mm lower for the low growth, 3 mm lower for the medium growth and 4 mm lower for the high growth scenario) it may impact fish habitat. This may not be acceptable for all stakeholders. It is recommended that the acceptability of such changes be investigated as part of a water withdrawal permit application, prior to proceeding further.

4.2.3 Water Treatment

4.2.3.1 Design Flows

For the purposes of determining adequate design sizes for centralized water treatment a service rate of 50% total population has been assigned for each growth scenario. There would be 1,150; 1,850; and 2,600 serviced persons for the low, medium and high growth categories. The existing population of 1,750 is established by taking 50% of the median between two base population estimates between Community Counts (2,800) and Statistics Canada (4,200).

The anticipated average water use per day varies linearly with population, ranging from 1.4 million liters per day (MLD) in the low growth scenario to 3.1 MLD in the high growth scenario. Average water usage rates, however, do not take into account the variability in demand that occurs daily or seasonally. As a result, they are not used to design treatment processes, as this would underestimate the amount of water required on high demand days. The maximum daily water demand estimate is used in this study to size treatment systems and estimate the costs of treatment plant options for Lake Echo.

4.2.3.2 Source Water Quality

Lake Water Source

Water quality results from the lake water sampling program indicate that the surface water near the proposed intakes is acidic, high in organics, low in turbidity and alkalinity, and moderate in minerals. Metals, including iron, manganese, and aluminum are at or near the regulatory limit. Other municipal water treatment systems nearby, including Bennery Lake, have similar organic matter and metals source water characteristics as Lake Echo.

During the sampling program the lake water was assessed at two locations (North and South) for nutrients and metals relevant to water treatment. The results showed little variation between locations and consistent presence of organic matter in the absence of mineral content. The low measured pH of the lake (5.6) is not uncommon for surface water in Atlantic Canada. The low alkalinity (<5 mg/L as $CaCO_3$) indicates a low buffering capacity and additionally the low conductivity (40 µS/cm) demonstrates the lake is void of any effects due to seawater or brackish sources. This is typical of many source waters used for municipal drinking water supply in the region.

Well Water Source

Drilled wells (excluding dug wells, or improperly constructed drilled wells) in and around the Lake Echo area commonly have elevated levels of either iron, manganese, arsenic or some combination thereof. This is typical of many groundwater supplies in Nova Scotia. Hardness levels are moderate to elevated but other parameters such as pH, fluoride, TDS, chloride etc. appear to be within acceptable limits.

4.2.3.3 Summary of Water Treatment Options for Potential Lake Echo Water Supplies

The water treatment process for Lake Echo will have to provide for the removal of manganese (and likely iron) and disinfection by-product precursors. Thus, it will have to include some form of oxidation process combined with a process optimized to remove the organic molecules that react with chlorine to form THMs and HAAs. There are a number of alternatives for removal of non-organic molecules (NOM) including conventional sedimentation, or proprietary clarification systems. For this report dissolved air floatation (DAF) has been used based on past history of installations in Nova Scotia on similar water. More study is needed to optimize the NOM removal process.

Treatment processes for water from existing drilled wells includes a range of small-scale or point-of-use devices designed for removal of iron and manganese, or softening. These include ion exchange, media filtration, and reverse osmosis.

Three general categories of treatment were developed based upon the typical parameters of concern which may be encountered in the area. Each category ranges in complexity and cost and can be considered as follows:

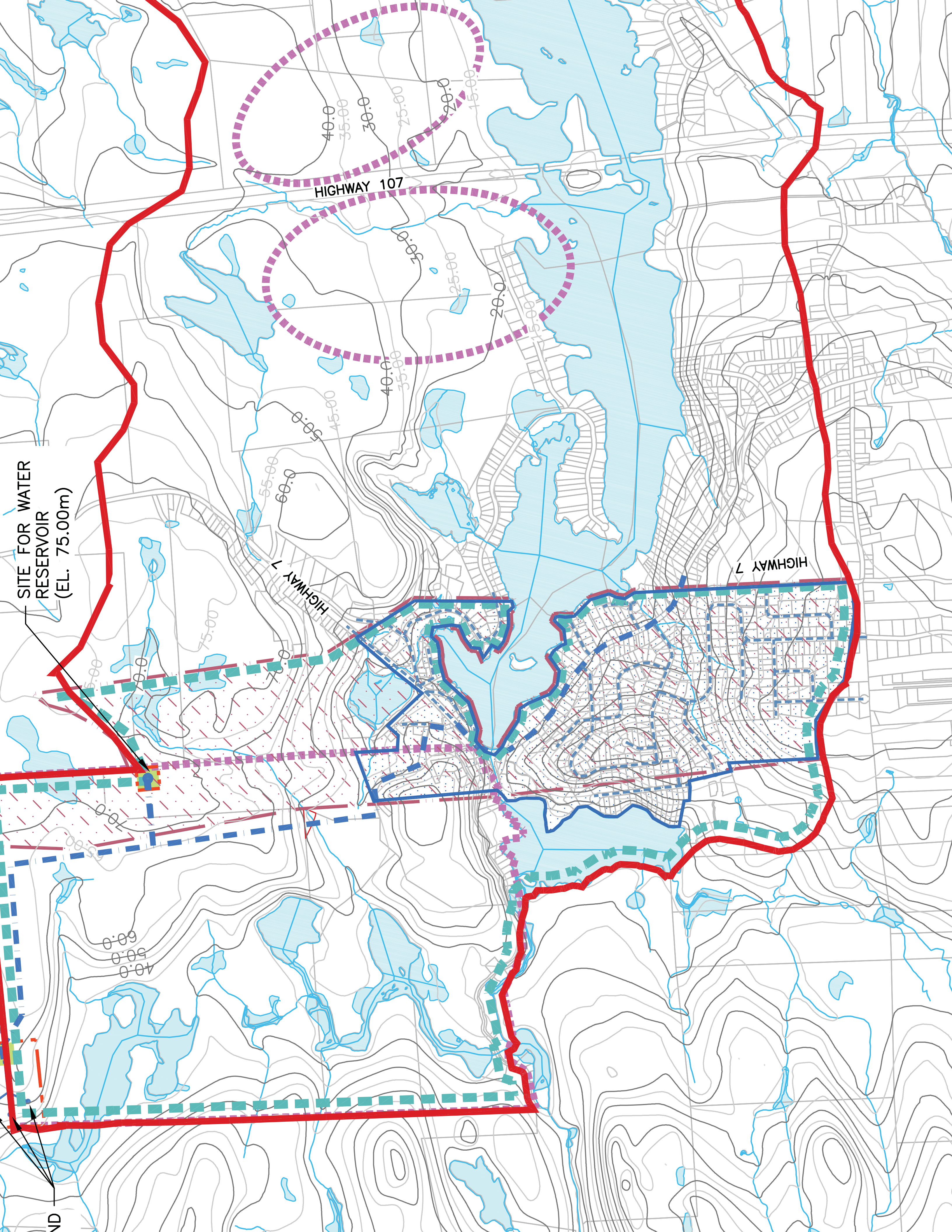
1. Chlorination/disinfection only – no additional treatment required.
2. Iron and manganese treatment plus chlorination/disinfection.
3. Iron and manganese treatment plus arsenic treatment plus chlorination/disinfection.

4.2.4 Water Distribution

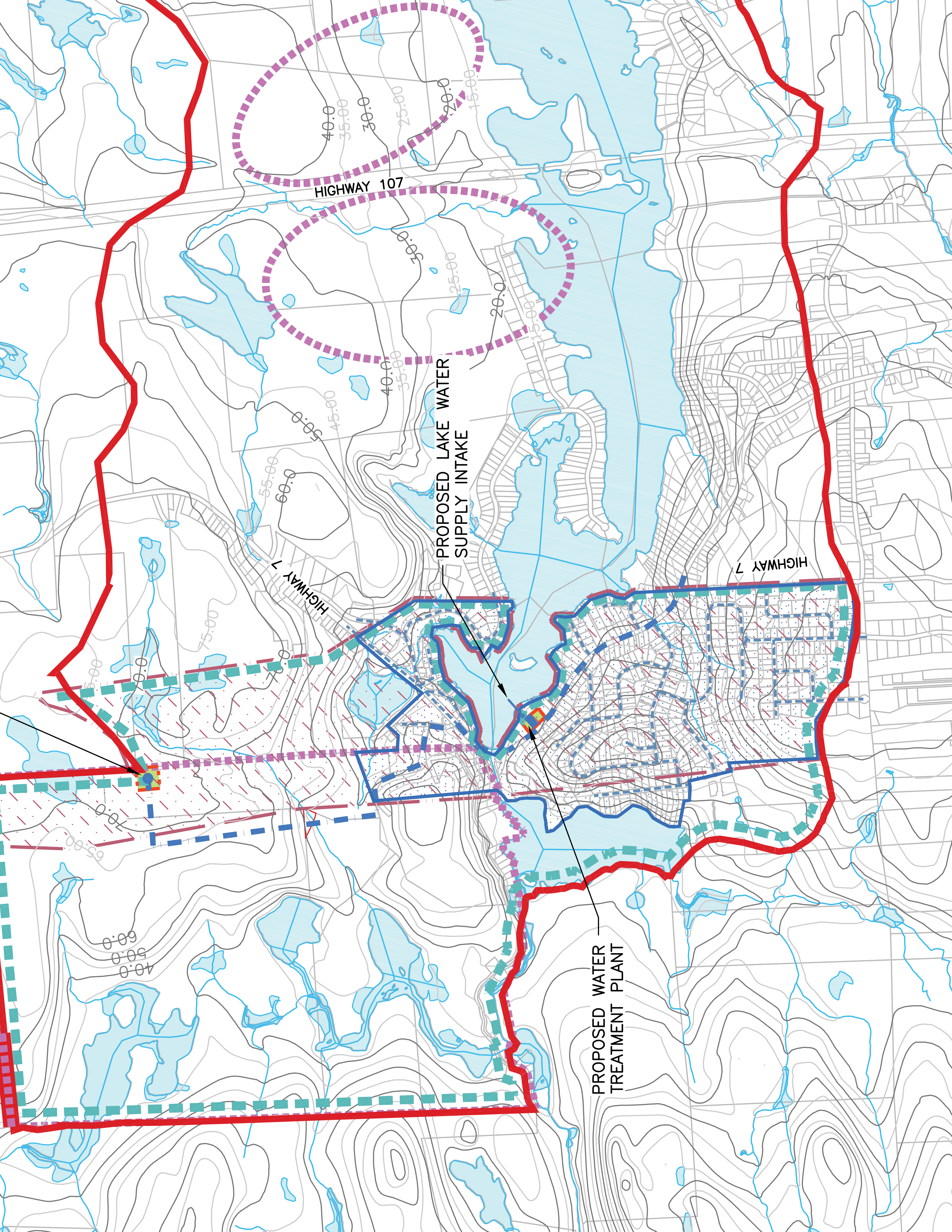
Trunk water distribution systems for the community associated with the two scenarios for central water supply are shown on Figures 4.2.4 (a and b). Based on discussions with the steering committee, the distribution watermains are sized only to provide water to existing and future domestic users as well as existing commercial and institutional users. The watermains shown have not been sized to provide fire flows.

The minimum system would include:

- Raw water supply from the source to the treatment plant:
  - Approximately 200 metres of water main from an intake in the lake, south of the Highway 7 bridge (see Figure 4.2.4(a)) to the water treatment plant; or alternatively;
  - Approximately 1,850 metres of water main from the wellfield at the treatment plant, tentatively located northeast of the proposed development at the north end of the study area, to the reservoir. At a preliminary level, the source water supply pipes and the transmission main from the well field to the reservoir would need to be in the order of 200 mm in diameter to supply the proposed water service area (all areas of existing and proposed future development that is located over the pyritic slate bedrock);
- A reservoir to accommodate peak demands on the maximum demand day. It should:
  - Be located in the vicinity of the highest point in the area to be serviced, at the highest point of land in the proposed development area, at an elevation in the order of 75 metres;
  - Have active capacity in the order of the maximum day demand;
  - Have a maximum water level in the order of elevation 85 metres and the minimum water elevation should be in the order of elevation 84 metres;
- Approximately 2,100 metres of water main from the reservoir to Highway 7;
- Approximately 1,500 metres of water main along Highway 7;



HIGHWAY 107
HIGHWAY 7
HIGHWAY 7
SITE FOR WATER RESERVOIR (EL. 75.00m)
40.0
35.00
30.0
25.00
20.0
15.00
50.0
45.00
55.00
60.0
75.00
70.0


HIGHWAY 107
HIGHWAY 7
HIGHWAY 7
PROPOSED LAKE WATER SUPPLY INTAKE
PROPOSED WATER TREATMENT PLANT
40.0
35.00
30.0
25.00
20.0
15.00
50.0
45.00
55.00
60.0
75.00
70.0
65.00

- Water distribution piping in the Water Service Area to service existing and proposed development:
  - East side of Lake Echo – 600 metres of watermain on Highway 7 as well as 1,200 metres on the side roads; and
  - West side of Lake Echo – 7,700 metres in the existing sub-divisions on both sides of Highway 7.

4.3 Costs of Servicing Alternatives

4.3.1 Wastewater

4.3.1.1 SINGLE UNIT AND SMALL CLUSTER SYSTEMS

A summary of requirements and probable construction costs for onsite wastewater systems is provided in Table 4.3.1(a). A range of development options serviced with traditional onsite wastewater treatment and effluent dispersal systems is presented in this table. The probable costs for the treatment systems to service clusters include engineering and contingency allowances.

Table 4.3.1(a): Requirements for Onsite Sewage Disposal Systems

	Design Flow (Lpd)	Septic Tank Capacity (L)	Probable Costs (C1 contour) ($)	Probable Costs (C2 contour) ($)
New single family	1,350	4,500	4,000 – 6,000	8,000 – 12,000
10 unit cluster system	11,500	20,500	$47,800	$114,400
20 unit cluster system	23,000	32,000	$91,900	$227,500

C1 contours may be used in the best soil conditions shown on the suitability mapping for new development (Figure 3.11). C2 contours may be assumed as a requirement for new developments in the areas shown in lighter green. These assumptions must be confirmed on a case by case basis using site specific information on soil type, depth, slope etc. Contour systems should only be considered for replacement of failed systems if there is sufficient land and setback distance available. In all other areas, a recirculating filter system will likely be required.

A summary of requirements and probable construction costs for Recirculating Textile Filters (RTF) technologies alternatives is provided in Table 4.3.1(b). Costs for the cluster systems include engineering and contingency.

Table 4.3.1(b): Requirements for RTF systems

	Design Flow (Lpd)	Septic Tank Capacity (L)	Probable Costs (RTF)
Existing single family	1,350	5,700	$15,000 – $25,000
10 unit cluster system	11,500	25,300	$112,400
20 unit cluster system	23,000	50,600	$199,700

4.3.1.2 Community Effluent Treatment Sites

For completeness and comparison purposes, effluent collection and treatment systems for servicing larger numbers of services were developed for the most densely populated areas in the community. Figure 4.1.1(b) shows the groups of services considered and a possible location for the treatment system. Each group of services would include the following:

- A septic tank at each unit with filters and pumps as required;
- Septic tank effluent collection piping comprising approximately 110 metres of 100 to 150 mm diameter pressure sewers per service; and
- A recirculating filter treatment system for the septic tank effluent for all properties in each group, complete with subsurface drip dispersal and treatment for phosphorus removal.

Estimates used to generate probable costs for all of the systems considered are presented in Table 4.3.1(c).

4.3.2 Stormwater

Typically the costs of the recommended measures on individual properties, including a portion of the costs of the roadside swales, may be incorporated into the costs of lot grading and landscaping for new construction. Similarly, the collection swales may be incorporated into the typical cross sections for new rural roads and be included in the costs of road construction. Inclusion of swales would require a change in the subdivision design standards.

Costs of typical measures used to mitigate existing problems are summarized in Table 4.3.2.

Table 4.3.2: Costs of Onsite Stormwater Remedial Measures

Stormwater Component	Size	Quantity	Estimate of Probable Costs per Service
All Residential Development - Inside and Outside of the Community Centre			
Rain Barrels for Each Residential Unit	0.2 m^3	5	\$500 – \$1,000
Rain Garden for Each Residential Unit	6 m^3	1	\$2,000 – \$2,500

Costs include 25% engineering fees and contingencies.

4.3.3 Water Supply

4.3.3.1 Single Unit and Small Cluster Systems

A well serving a single home in Lake Echo should be 50 metres deep on average with an average casing depth of 6 metres and a yield exceeding 7 to 9 L/min, which should satisfy a peak demand of around 3 L/min. The cost for a well like this should fall in the standard \$3000-\$6000 range for a domestic water well. In the bedrock that prevails in most of the lake Echo Study Area, individual well yields and depths will vary widely. Thus in some areas home owners could spend \$10,000 or more drilling a deep well in an attempt to find and store water, whereas others could happen upon an excellent fracture and pay only \$3000.

Table 4.3.1(c) Estimates of Probable Capital Costs of Alternatives for Wastewater Collection and Treatment for the Study Area

Component			For Existing Development			
		Existing Services	Ultimate Services	Estimate of Probable Cost	Cost / Existing Service	Cost / Ultimate Service
Community Treatment Systems for Replacement of Multiple Failed Onsite Systems - see Figure 4.1						
Community Area 1	**Martin Lake to Lake Echo**					
	Septic Tanks, Pumps and Service Connedtions	297	297	$ 3,411,501	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	297	297	$ 5,965,303	$ 20,085	$ 20,085
	Septic Tank Effluent Piping to Treatment Plant	297	297	$ 358,061	$ 1,206	$ 1,206
	Septic Tank Effluent Treatment	297	297	$ 3,485,758	$ 11,737	$ 11,737
	Sub- total Community Area 1	297	297	$ 13,220,622	$ 44,514	$ 44,514
Community Area 2	**East Side of Lake Echo**					
	Septic Tanks, Pumps and Service Connedtions	202	202	$ 2,320,280	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	202	202	$ 11,515,970	$ 57,010	$ 57,010
	Septic Tank Effluent Piping to Treatment Plant	202	202	$ 358,061	$ 1,773	$ 1,773
	Septic Tank Effluent Treatment	202	202	$ 3,074,488	$ 15,220	$ 15,220
	Sub- total Community Area 2	202	202	$ 17,268,800	$ 85,489	$ 85,489
Community Area 3	**Bell Park**					
	Septic Tanks, Pumps and Service Connedtions	158	158	$ 1,814,872	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	158	158	$ 3,545,131	$ 22,438	$ 22,438
	Septic Tank Effluent Piping to Treatment Plant	158	158	$ 681,887	$ 4,316	$ 4,316
	Septic Tank Effluent Treatment	158	158	$ 2,884,006	$ 18,253	$ 18,253
	Sub- total Community Area 3	158	158	$ 8,925,897	$ 56,493	$ 56,493
Community Area 4	**Mineville Road**					
	Septic Tanks, Pumps and Service Connedtions	212	212	$ 2,435,145	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	212	212	$ 4,303,182	$ 20,298	$ 20,298
	Septic Tank Effluent Piping to Treatment Plant	212	212	$ 358,061	$ 1,689	$ 1,689
	Septic Tank Effluent Treatment	212	212	$ 3,117,780	$ 14,707	$ 14,707
	Sub- total Community Area 4	212	212	$ 10,214,168	$ 48,180	$ 48,180
Community Area 5	**Dempster Cres**					
	Septic Tanks, Pumps and Service Connedtions	70	70	$ 804,057	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	70	70	$ 6,512,705	$ 93,039	$ 93,039
	Septic Tank Effluent Piping to Treatment Plant	70	70	$ 681,887	$ 9,741	$ 9,741
	Septic Tank Effluent Treatment	70	70	$ 2,503,041	$ 35,758	$ 35,758
	Sub- total Community Area 5	70	70	$ 10,501,690	$ 150,024	$ 150,024
Community Area 6	**Candy Mountain Rd**					
	Septic Tanks, Pumps and Service Connedtions	50	50	$ 574,327	$ 11,487	$ 11,487
	Septic Tank Effluent Collection Piping	50	50	$ 1,690,398	$ 33,808	$ 33,808
	Septic Tank Effluent Piping to Treatment Plant	50	50	$ 681,887	$ 13,638	$ 13,638
	Septic Tank Effluent Treatment	50	50	$ 2,416,458	$ 48,329	$ 48,329
	Sub- total Community Area 6	50	50	$ 5,363,070	$ 107,261	$ 107,261
On-site Systems - Individual Units and Typical Cluster Development						
	Individual Residential Unit					
	Septic Tank and Contour for Individual Property	1	1	$ 12,000	$ 12,000	$ 12,000
	Septic Tank and RTF for Individual Property	1	1	$ 25,000	$ 25,000	$ 25,000
	Wastewater Treatment for a 10 Unit Cluster					
	Services and Collection Piping for 10 Unit Cluster	10	10	$ 200,657	$ 20,066	$ 20,066
	Septic Tank and RTF for 10 Unit Cluster	10	10	$ 114,400	$ 11,440	$ 11,440
	Septic Tank and Contour for 10 Unit Cluster	10	10	$ 112,400	$ 11,240	$ 11,240
	Sub- total 10 Unit Cluster	0	0	$ 315,057	$ 31,506	$ 31,506
	Wastewater Treatment for a 20 Unit Cluster					
	Services and Collection Piping for 20 Unit Cluster	20	20	$ 376,449	$ 18,822	$ 18,822
	Septic Tank and RTF for 10 Unit Cluster	20	20	$ 227,500	$ 11,375	$ 11,375
	Septic Tank and Contour for 10 Unit Cluster	20	20	$ 199,700	$ 9,985	$ 9,985
	Sub- total 20 Unit Cluster	0	0	$ 603,949	$ 30,197	$ 30,197

Probable costs include 25%contingency allowance and 10% engineering allowance.

A well serving ten (10) homes would be required to produce 30 L/min. Records suggest that most wells should be able to satisfy this demand; the third quartile yield for a standard 150 mm diameter (6-inch) well was 36 L/min. It would be wise to budget at least $10,000 per well, but it could be $30,000 or more depending on site conditions. It is worth noting that if there are more than twenty-five (25) people on the well that it will need to be registered as a public drinking water supply.

A summary of costs of the alternative water supply schemes for individual properties or clusters of properties is presented in Table 4.3.3(a).

4.3.3.2 Water Service Area

For completeness and comparison purposes, a water service area was developed, servicing the areas in the vicinity of the existing Community Centre that have underlying pyritic slate bedrock. The two options for supplying water were developed in section 4.2. Estimates of the probable capital costs of both options are included in Table 4.3.3(a) for existing and planned development in the water service area. Table 4.3.3(b) presents a life cycle cost assessment of the water supply components, sized to service the populations associated with the low, medium and high growth scenarios for the study area. As shown in the table, the groundwater supply and treatment option has the lowest estimated life cycle costs for the range of populations serviced and should be considered further if a central system is to be considered for the centre of the community.

Table 4.3.3(a) Estimates of Probable Capital Costs of Alternatives for Water Supply and Treatment for the Study Area

Component		Existing Services	Ultimate Services	Capital Cost	Cost / Existing Service	Cost / Ultimate Service
Central Water Service Area - in the Existing Community Centre and Proposed Development Northeast of Lake Echo						
Water Supply Alt 1 - Ground Water with Treatment Plant to Remove Iron and Manganese						
	Interconnecting Piping in Wellfield	956	1288	$ 1,628,956	$ 1,704	$ 1,264
	Wells	956	1288	$ 200,000	$ 209	$ 155
Figure 4.1.3(a)	Well Pumps	956	1288	$ 250,000	$ 262	$ 194
	Water Treatment - Category 2 assumed	956	1288	$ 4,924,000	$ 5,151	$ 3,822
	Total Water Supply and Treatment	956	1288	$ 7,002,956	$ 7,325	$ 5,435
	Reservoir	956	1288	$ 3,791,416	$ 3,966	$ 2,943
	Watermain From: WTP to Reservoir Rd	956	1288	$ 1,180,993	$ 1,235	$ 917
	Reservoir Road to Highway 7 at Circle Drive	10	1288	$ 1,466,060	$ 146,606	$ 1,138
	Highway 7 to West Service Boundary	100	455	$ 1,126,266	$ 11,263	$ 2,475
	Road To Reservoir	0	1288	$ 244,343		$ 190
	Distribution Piping - East Service Area	101	101	$ 570,642	$ 5,650	$ 5,650
	Distribution Piping - West Service Area	355	455	$ 6,562,378	$ 18,486	$ 14,423
	Services	566	566	$ 1,516,988	$ 2,680	$ 2,680
	Total Distribution	956	1288	$ 12,667,670	$ 13,251	$ 9,832
	Total Water	956	1288	$ 23,462,043	$ 24,542	$ 18,210
Water Supply Alt 2 - Lake Echo with Surface Water Treatment Plant						
	Intake Structure and Piping	956	1288	$ 132,009	$ 138	$ 102
Figure 4.1.3(b)	Water Treatment	956	1288	$ 6,413,500	$ 6,709	$ 4,978
	Total Water Supply and Treatment	956	1288	$ 6,545,509	$ 6,847	$ 5,080
	Reservoir	956	1288	$ 3,791,416	$ 3,966	$ 2,943
	From WTP to Int Highway 7 and Circle Drive	956	1288	$ 440,030	$ 460	$ 342
	Reservoir Road to Highway 7	10	1288	$ 1,584,109	$ 158,411	$ 1,230
	Highway 7 to West Service Boundary	100	455	$ 814,478	$ 8,145	$ 1,790
	Road To Reservoir	0	1288	$ 264,018		$ 205
	Distribution Piping - East Service Area	101	101	$ 544,253	$ 5,389	$ 5,389
	Distribution Piping - West Service Area	355	455	$ 7,118,537	$ 20,052	$ 15,645
	Services	566	566	$ 1,516,988	$ 2,680	$ 2,680
	Total Distribution	956	1288	$ 12,282,414	$ 12,848	$ 9,533
	Total Water	956	1288	$ 22,619,340	$ 23,660	$ 17,556
On-site Systems - Individual Units and Typical Cluster Development						
	Individual Residential Unit					
	Well	1	1	$ 10,000	$ 10,000	$ 10,000
	Well Pump	1	1	$ 1,000	$ 1,000	$ 1,000
	Water Treatment	1	1	$ 2,000	$ 2,000	$ 2,000
	Total for Water Supply	1	1	$ 13,000	$ 13,000	$ 13,000
	Well Water Supply for a 10 Unit Cluster					
	Well	10	10	$ 38,000	$ 3,800	$ 3,800
	Well Pump	10	10	$ 2,000	$ 200	$ 200
	Distribution Piping	10	10	$ 163,179	$ 16,318	$ 16,318
	Water Treatment	10	10	$ 20,000	$ 2,000	$ 2,000
	Total for Water Supply	10	10	$ 223,179	$ 22,318	$ 22,318
	Well Water Supply for a 20 Unit Cluster					
	Well	20	20	$ 76,000	$ 3,800	$ 3,800
	Well Pump	20	20	$ 4,000	$ 200	$ 200
	Distribution Piping	20	20	$ 326,359	$ 16,318	$ 16,318
	Water Treatment	20	20	$ 40,000	$ 2,000	$ 2,000
	Total for Water Supply	20	20	$ 446,359	$ 22,318	$ 22,318

Probable costs include 25%contingency allowance and 10% engineering allowance.

Table 4.3.3(b) 100 Year Life Costs of Water Supply and Treatment Options for Lake Echo

Component	Growth Scenario	Capital Cost	Initial Installation Costs	Annual O&M Costs	Present Worth of 100 Year Life Cycle O&M Costs	Present Worth of 100 Year Life Cycle Replacement Costs	Present Worth of 100 Year Life Cycle
Wells and Connecting Piping, Ground Water Treatment Plant and Pipe to Reservoir Road	Low	$ 3,630,819	$ 3,830,819	$ 69,000	$ 2,230,365	$ 1,309,149	$ 7,045,256
	Medium	$ 6,240,969	$ 6,440,969	$ 111,000	$ 3,290,259	$ 2,137,287	$ 11,321,946
	High	$ 7,788,327	$ 7,988,327	$ 156,000	$ 4,341,824	$ 2,757,495	$ 14,409,771

CHAPTER 5 PREFERRED DEVELOPMENT IN THE LAKE ECHO STUDY AREA

The previous chapters summarize:

- Information related to the watershed study objectives set out in Policy E-17 in the HRM MPS regarding protection and enhancement of environmental functions in the Study Area;
- The extent of municipal services required in various development scenarios and the options available to provide these services in a cost effective manner; and
- Constraints to development including assimilative capacity of surface waters.

This chapter integrates the results of these studies and analyzes this information to develop the most suitable options for development in the Study Area.

5.1 Development Considered

Populations and development densities were discussed in section 2.3. Based on those discussions it is expected that future development in the Lake Echo Study Area over the next 20 years will be as follows:

- The population may decrease by 500 people or up to 1000 people may move into the Study Area;
- Because of decreasing population per dwelling, the number of occupied dwelling units in the study area may decrease by up to 100 or there may be up to 700 additional dwelling units;
- This study has assumed that one third of the proposed development will be infilling in the vicinity of the community Centre; and
- The remaining development will be split between existing approved sub-divisions and new sub-divisions designed to meet current standards.

5.2 Areas Available for Development

5.2.1 Desirability for Residential Development

Desirability does not imply it is technically feasible to develop the lands; factors such as slopes and soil conditions could make building difficult or prohibitively expensive. Soil types and their condition determine ease of building and the ability to install onsite septic systems. Residential development can built on slopes up to 30%. Preferred aspects are southeast, southwest, south, and west. Generally, areas with mature vegetation are more desirable to purchasers, although it may be desirable for the Municipality to encourage redevelopment of disturbed or clear cut areas as a means of preserving less-disturbed areas and controlling erosion. Lands on the oceanfront or lakefront or with ocean views tend to be more valuable than inland areas. Assuming that most development will not be serviced by a central water supply system, it is also important that the area is able to supply sufficient good-quality groundwater.

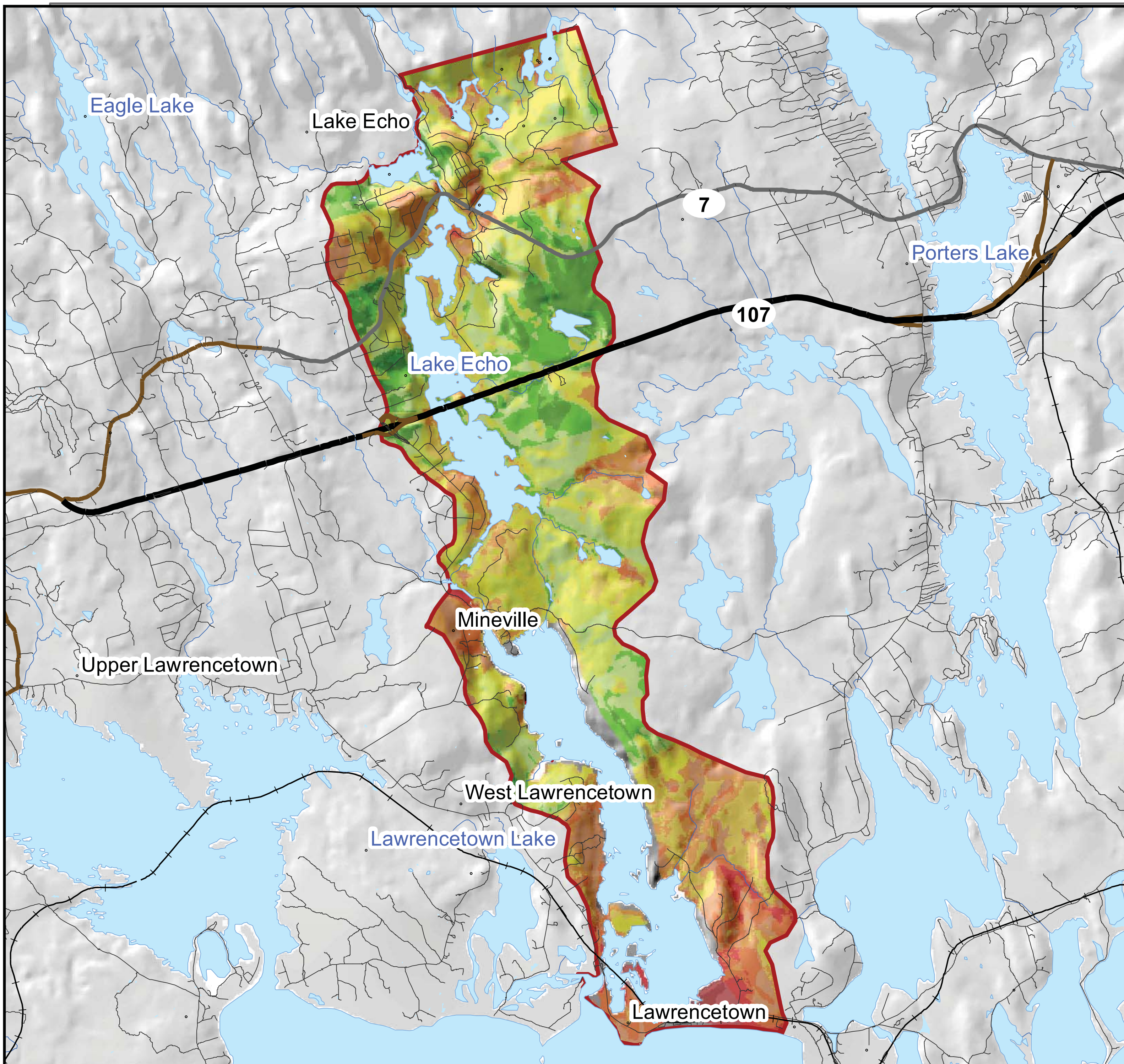
The amalgamation of suitability and desirability information from the component maps (see Appendix G) creates a relative scale with the dark green areas on the plan denoting areas that can be considered more suitable and desirable, the yellow areas are less suitable and desirable and the red areas are considered the least suitable and the least desirable for residential development.

Table 5.2.1: Suitability and Desirability Criteria

	Best	Middle	Worst
Soil Type	Dry Soil	Imperfectly Drained	Wet and Wet Organic
Soil Conditions	Thick Till	Thin till	Disturbed and Bedrock
Slope	0-8%	8-20%	>20%
Vegetation	Mature	Immature	Other
Aspect	South, southwest	Southeast, west	Other
School Access	within 1 km	1-2 km	>2 km
Views	Oceanfront/lakefront	ocean/water view or riverfront	No water views
Groundwater Resource Potential of Bedrock	Class B (potentially good)	Class C and D (may require mitigation)	Class E (high risk of contamination)
Acid Slate Potential	No	-	Yes

Note: These factors affect the suitability for on-site wastewater systems.

New development should occur on the lands considered most suitable for development. This land is considered desirable **and** has the ability to be serviced in a cost-effective manner. Figure 5.2.1 shows the relative suitability and desirability for development of the land within the Study Area that may be available for residential development. Suitability and desirability is based on the criteria outlined in Table 5.2.1 and includes all areas outside of the “No Go” areas as defined in Section 3.7.1. Figure 5.2.1 is similar to Figure 4.1 but includes desirability criteria in the rating of undeveloped lands as well as the rating of the lands ability to support onsite wastewater and water systems.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area Boundary

Relative Desirability

Most Desirable

Least Desirable

Streets

Trunk Highway

Divided Highway

Arterial

Collector

Railroad

Rivers

CBCL LIMITED Consulting Engineers

Relative Desirability of Land for Residential Development

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure 5.2.1

Notes:

Map Parameters
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Projection: Transverse_Mercator
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Linear Unit: Meter

0 550 1,100 2,200 Meters

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5.2.2 Development Pattern

The Focus Group indicated that there is not really a community centre. Denser development to justify central services did not seem to be desired. Two possible community centres or centres for additional development in the community were considered:

1. In the proposed development to the northeast of the community associated with the existing community centre. There are issues with the underlying pyritic slate bedrock that affect water quality for wells servicing the existing sub-divisions as well as reported surface water issues that affect the quality of water supplied to the residents of the Wonderland Mobile Home Park and downstream habitat. These issues raise concerns regarding further development in this area.
2. In a new development on the east side of Lake Echo, adjacent Highway 107. Most of the land in the proposed location is generally the more desirable areas for development and is well suited for onsite water and wastewater systems. The most significant issues at this site are land ownership and access.

The assessments lead to the conclusion that, if a new community centre is desired, location 2 is preferred from a servicing perspective.

Based on the findings of the investigations reported in Chapter 3, **classic open space subdivisions** are the preferred pattern of development for residential areas outside of the Community Centre. New subdivisions should be fashioned to place residences in desired developable areas while preserving lands that provide significant environmental functions.

5.2.3 Potential Development Locations

The low growth scenario indicates decreases in population and a reduction in the number of residential units over the next 20 years.

The medium growth scenario requires approximately 170 hectares (9.1% of the area within the Study Area that is not in “No Go” areas, and approximately 43 % of the area best suited for development) and the high growth scenario requires approximately 400 hectares (43% of the area within the Study Area that is not in “No Go” areas, and all of the area best suited for development). A portion of this planned development will be in existing sub-divisions, the remainder will be in new sub-divisions. Given that these new developments will be open space subdivisions serviced by clustered onsite wastewater systems and wells, they can be located anywhere within the Study Area but should be encouraged to develop in the green areas shown on Figure 5.2.1.

The assumption that growth in the area will be based on the use of cluster systems creates a large degree of flexibility in the location of future development. Unlike central systems that require a certain level of density to be concentrated in one area to make the systems cost effective, cluster systems can be cost-effectively developed separately in a variety of areas allowing developments throughout the Study Area to come on-line as desired.

The development pattern created by the use of open space subdivision designs are unlikely to enable the creation of sufficient population density to support a viable walk-able transit-oriented centre as outlined in Policy S-10 of the Regional Municipal Planning Strategy. Therefore, if transit use is to be encouraged, people in the community will need to drive their cars or catch a local bus to a bus rapid transit terminal.

5.2.4 Constraints on Development Locations

The assimilative capacity assessment concluded that because nuisance algae concentrations in Lake Echo exceed the range indicative of mesotrophic conditions, there is no assimilative capacity for additional loads of the inputs needed to produce algae including nutrients (nitrogen and phosphorous) and heat in any area tributary to Lake Echo.

There is zero assimilative capacity in the tributary to McCoy's Pond that accepts the Wonderland Mobile Home park wastewater treatment plant effluent based on E coli concentrations as well as total phosphorous concentrations. Existing overall loads to this system must be significantly reduced in order for this system to be considered suitable as habitat.

Lake pH values and the pH of waters in the upstream tributaries are low making Lewis Lake and its tributaries as well as Lake Echo at times less suitable habitat for species at risk. Any development in the areas tributary to these waterbodies (particularly areas with underlying pyritic slate bedrock) must be done with caution, making sure that actions taken do not lower the pH.

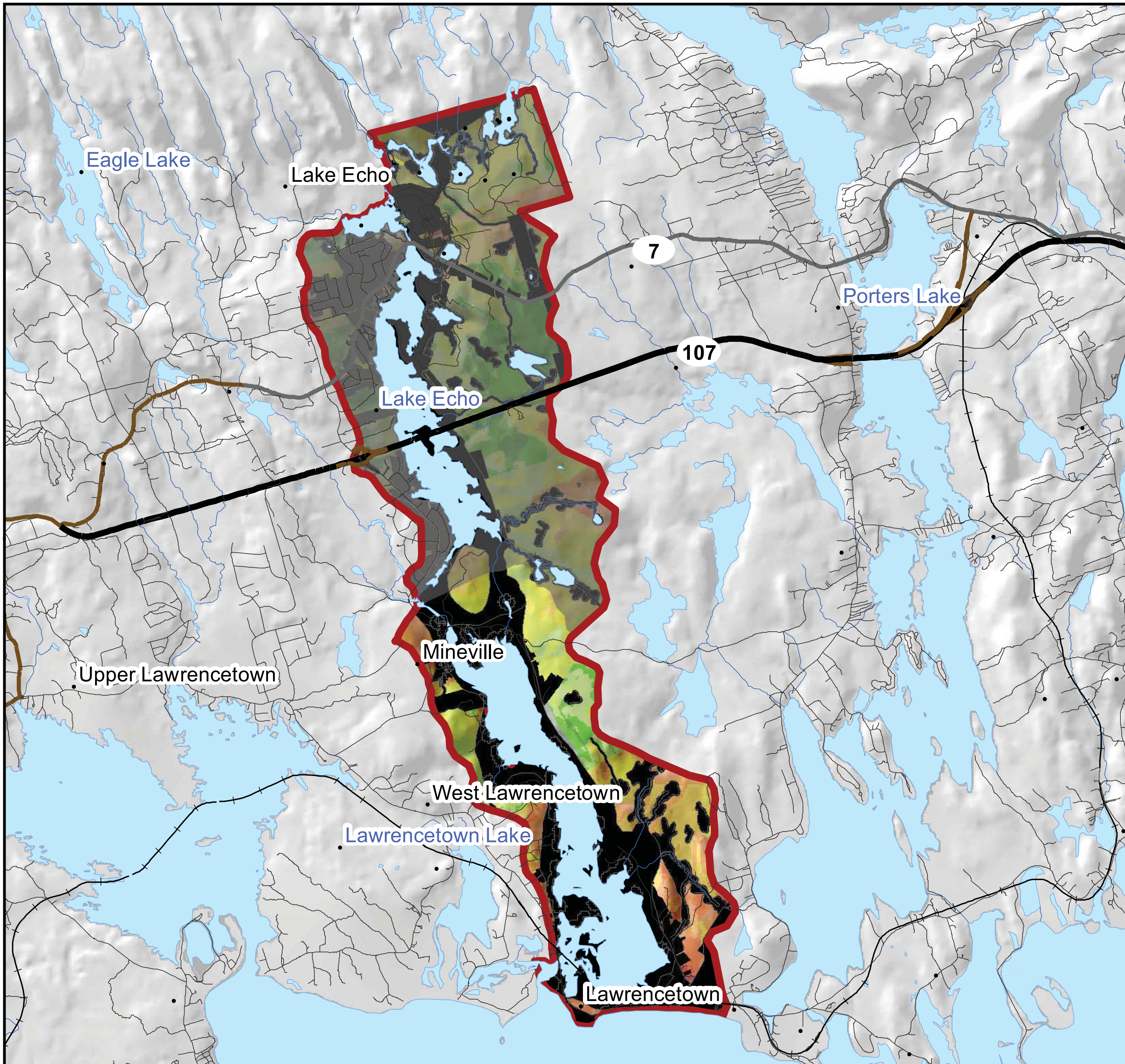
Lakes with no assimilative capacity and the areas directly tributary to them were shown on Figure 3.4. This information has been combined with the suitability for on-site services mapping from Figure 4.1 and the relative desirability information from Figure 5.2.1 to form Figure 5.2.4. This figure shows the suitability and desirability of lands for development in the study area, areas with assimilative capacity in their receiving water are full colour while areas tributary to lakes with no assimilative capacity are indicated by fading of the relative suitability and desirability shown in Figure 5.2.1.

If improvements to water quality in the systems with no assimilative capacity are not feasible, new development in the study area should be directed to other watersheds that are not directly tributary to these systems. Areas shown in Figure 5.2.4 with vibrant colours for relative suitability and desirability indicate where additional development could be located without affecting existing water quality in the systems with zero assimilative capacity.

5.3 Services for New Development

Services to facilitate the type of development described by the members of the community that participated in the Focus Group meetings are described in this section. Typical components located on individual properties serviced as clusters of up to 10 units are shown in Figure 5.3 and include:

- Cluster wastewater treatment (wastewater components are shown in red);
- A common water supply (components are shown in blue); and
- Onsite stormwater management (rain barrels and rain garden) and common roadside swales.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area Boundary
- No Go Areas

No Assimilative Capacity Available
- Best Desirability
- Worst Desirability

Assimilative Capacity Available
- Best Desirability
- Worst Desirability

- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Land Available for Development with Existing Assimilative Capacity

Drawn: YO	Date: March 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Figure 5.2.4

Notes:

Map Parameters
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False Northing: 0.00000000
Central Meridian: -63.00000000
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Linear Unit: Meter

0 550 1,100 2,200 Meters

File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\101015 Lake Echo - Lands Available for Development with Existing Assimilative Capacity 2.mxd   Last Saved: 20/11/2012 2:47:18 PM

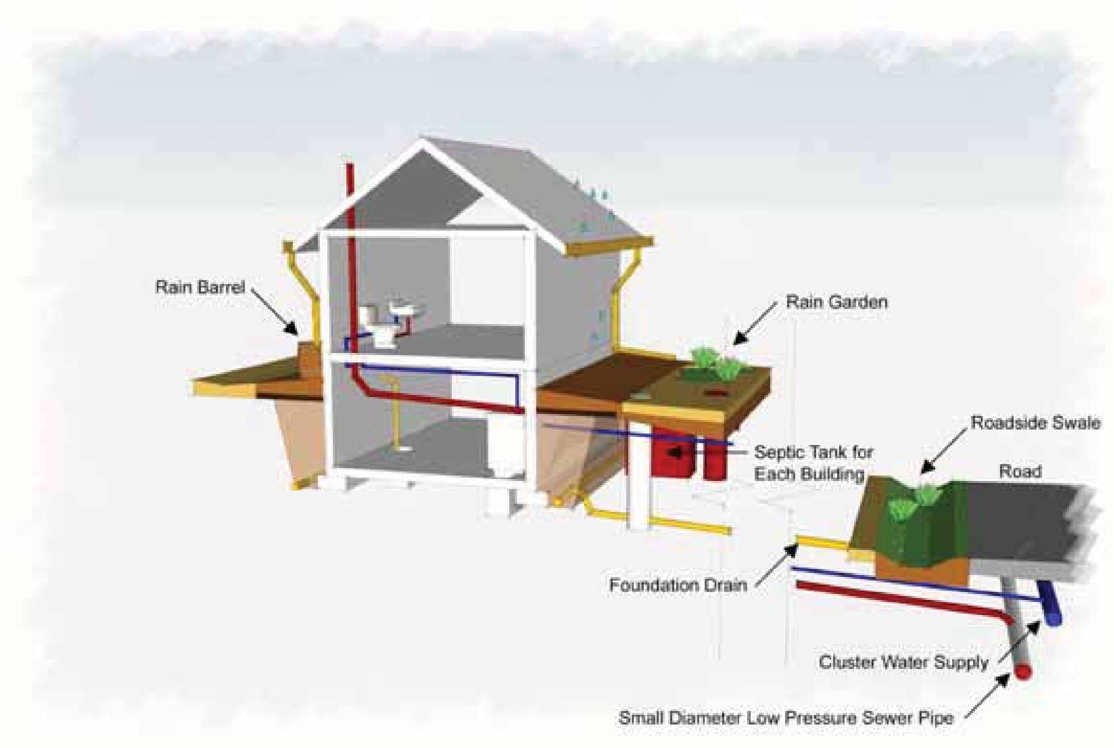

Figure 5.3: Illustration of Onsite/Cluster Services Required

5.3.1 Wastewater

Onsite wastewater treatment and dispersal systems are recommended for new single unit developments as well as for clusters of new development. Assessment of site specific conditions is required for selection of the most appropriate onsite systems and sizing of components for each application.

Failed onsite systems, identified by property owners and/ or through sanitary surveys must be upgraded or replaced. Replacement system options should also be assessed based on site specific conditions described in section 3.11. In locations where several failed systems are in close proximity or where space is limited, there may be opportunities for cluster systems to replace individual systems.

5.3.2 Stormwater

Onsite infiltration systems and storage systems should be used to limit runoff volume and peak flows from new development or redevelopment to predevelopment levels. Creation of additional storage/treatment/infiltration systems to address existing stormwater related issues related to water quality within the community should also be considered.

5.3.3 Water Supply

Wells may be used to service individual lots or clusters of development of up to10 units - The number of units each well is able to service depends on many factors. Overall costs of the wells depends on the depth the well is drilled which depends on the geology at any particular site. The overall cost per service for cluster services are in the order of 1.7 times the cost of single systems due to the costs of distribution piping. The cluster approach may be used to service the potential new development area adjacent Highway 107 as the bedrock potential for groundwater is good in this area.

A central water supply, treatment and distribution system should be considered to ensure an adequate supply of good quality water to the new development to the northeast of the existing community centre. Extension of the system to the Wonderland Mobile Home Park as well as the existing sub-divisions along Highway 7 should also be considered for inclusion in this system. There is a 5% difference in the estimated probable construction costs of the concepts considered for water supply with wells verses water supply from Lake Echo. Costs per service, based on all of the existing services in the water service area being included are in the order of 1.35 times the costs of water services for a single unit serviced with an individual well and point of use treatment system but offer a reliable and safe alternative to typical well water in this part of the community.

5.3.4 Minimum Lot Sizes

Minimum lots size must consider restraints imposed by current design requirements for onsite wastewater treatment and dispersal systems as well as limitations imposed by recharge requirements for well water supply and well locations for optimum siting of wells.

Based on the screening level assessment for water supply by wells, the minimum lot size for residential development should be set based on a requirement for a minimum of 5,854 square metres of permeable surface for each 1 cubic metre per day of demand. This should be added to the area taken by all impermeable surfaces on any property and the total compared to the minimum lot size required for the onsite wastewater treatment and dispersal system. The larger size should be used to establish a minimum property size on a site by site basis.

This minimum area of 5,854 square metres of permeable surface per lot is required to provide water for a single family residence under typical conditions in the Study Area. When added to the planned impermeable areas on each property, it forms the bases of the minimum lot size for areas with a soil depth exceeding 300 millimetres. In locations with soil depths of 150 to 299 millimetres, the minimum lot size should be 6,800 square metres and in locations with soil depths less than 149 millimetres, the minimum lot size should be 9,000 square metres to meet Nova Scotia Environment technical guidelines for onsite sewage disposal systems[13].

5.3.5 Costs of Services

Estimates of the range of construction costs expected for the services described in this section are summarized in Table 5.3.5(a). These are not the only costs expected for the provision of these services. Following is a list of additional costs:

- Operation and maintenance of the systems; and
- Costs for repair or replacement of components as their useful life is expended. Mechanical and electrical components typically have a shorter design life and need to be replaced after 20 years of service. Local installers indicate that failed soil dispersal systems in the area that need to be replaced are typically in the order of 25 years old. Other components such as piping and concrete structures typically last 50 to 100 years.

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[13] Nova Scotia Environment, April 2009. *On-Site Sewage Disposal Systems Technical Guideline: Minimum Lot Size requirements For Development Utilizing On-Site Sewage Disposal Systems.* Table 2.4.

Table 5.3.5(a): Cost Summary for Provission of Services in the Study Area

On-site Services	Wastewater Services	Stormwater	Water Supply	Overall Servicing Costs	Design Number of Units Serviced	($/ Unit Serviced)
	New or Reconstructed		Surficial or Bedrock			
Individual Systems	$4,000 - $12,000 **or** $15,000 - $25,000	$2,500 - $3,500	3,000 - $6,000 **or** $4,000 - $11,000	$9,500 - $21,500 **or** $21,500 - $39,500	1	$9,500 - $21,500 **or** $21,500 - $39,500
Cluster Systems	$50,000 - $115,000	$25,000 - $35,000	$13,000 - $40,000	$88,000 - $190,000	10	$8,800 - $19,000

Table 5.3.5 (b) Life Cycle Costs of Services in Lake Echo

Component		System Cost						Cost per Service
		Capital Cost (1)	Initial Cost (2)	Annual Operating and Maintenance Costs (3)	Replacement Costs (4)	Present Worth of 100 Year Life Cycle(5)	Number of Services	Present Worth of 100 Year Life Cycle(5)
On-site		$ 27,500	$ 27,500	$ 502	$ 32,250	$ 58,110	1	$ 58,110
	Wastewater (a)	$ 12,000	$ 12,000	$ 199	$ 17,550	$ 27,191	1	$ 27,191
	Stormwater (b)	$ 2,500	$ 2,500	$ 138	$ 2,500	$ 8,100	1	$ 8,100
	Water (c)	$ 13,000	$ 13,000	$ 165	$ 12,200	$ 22,819	1	$ 22,819
10 Unit Cluster		$ 563,237	$ 563,237	$ 20,947	$ 503,311	$ 1,322,828	10	$ 132,283
	Wastewater (a)	$ 315,057	$ 315,057	$ 16,127	$ 283,909	$ 858,655	10	$ 85,865
	Stormwater (b)	$ 25,000	$ 25,000	$ 1,375	$ 25,000	$ 81,004	10	$ 8,100
	Water (c)	$ 223,179	$ 223,179	$ 3,445	$ 194,402	$ 383,169	10	$ 38,317
Central Services Alternatives								
Community Septic Tank Systems		$ 65,494,246	$ 65,494,246	$ 149,993	$ 26,197,698	$ 91,190,121	989	$ 92,204
	Area 1 Martin Lake to Lake Echo	$ 13,220,622	$ 13,220,622	$ 81,428	$ 5,288,249	$ 19,876,516	297	$ 66,924
	Area 2 East Side of Lake Echo	$ 17,268,800	$ 17,268,800	$ 31,815	$ 6,907,520	$ 23,821,915	202	$ 117,930
	Area 3 Bell Park Area	$ 8,925,897	$ 8,925,897	$ 11,850	$ 3,570,359	$ 12,181,124	158	$ 77,096
	Area 4 Mineville Road	$ 10,214,168	$ 10,214,168	$ 15,900	$ 4,085,667	$ 14,006,413	212	$ 66,068
	Area 5 Dempster Crescent	$ 10,501,690	$ 10,501,690	$ 5,250	$ 4,200,676	$ 14,081,980	70	$ 201,171
	Area 6 Candy Mountain Road	$ 5,363,070	$ 5,363,070	$ 3,750	$ 2,145,228	$ 7,222,172	50	$ 144,443
Water Service Area		$ 27,253,459	$ 27,253,459	$ 235,184	$ 23,738,975	$ 36,246,004	956	$ 28,769
	Groundwater Supply and Treatment	$ 7,002,956	$ 7,002,956	$ 156,000	$ 4,201,774	$ 14,021,283	956	$ 7,591
	Reservoir	$ 3,791,416	$ 3,791,416	$ 22,000	$ 3,791,416	$ 4,101,485	956	$ 2,221
	Transmission Mains	$ 7,809,079	$ 7,809,079	$ 5,760	$ 7,809,079	$ 8,090,399	956	$ 8,463
	Water Distribution to Existing Development	$ 7,133,019	$ 7,133,019	$ 15,200	$ 6,419,717	$ 7,604,288	956	$ 7,954
	Existing Services	$ 1,516,988	$ 1,516,988	$ 36,224	$ 1,516,988	$ 2,428,549	566	$ 2,540

Notes

(1) Capital Costs are based on 2011 construction rates
(2) Assumes no higher level government funding
(3) Based on discussions with operators of existing similar sized systems in HRM
(4) Assumes contours are replaced with RTF systems after 25 years
(5) 100 year life cycle cost
Cost per service for central system components are based on full development, at design capacity
(a) Assumes on-site systems are C2 contour systems, community systems are recirculating filters
(b) Assumes rain gardens, one per unit
(c) Assumes wells are into bedrock and water treatment is at point of use for onsite, central treatment for Water Service Area

All of this information was used to assess the life cycle costs of the recommended services. These are summarized in Table 5.3.5(b). Onsite services for new development are the lowest costs. Cluster systems are most cost effective when the units serviced are located close together. The community based systems of new septic tanks on each property as well as collection and treatment systems are not cost effective due to the distances between services but may be required to replace groups of failed systems where smaller cluster systems cannot be located.

The water service district appears to be a cost effective means of providing potable water for new development as well as the existing systems that may be affected by pyritic slate bedrock or surface water of poor quality. This may be worth considering further.

5.3.6 Ownership, Operation, Maintenance and Monitoring

5.3.6.1 Individual Properties

Property owners traditionally own, operate, and maintain onsite wells and wastewater treatment systems. Nova Scotia Environment regulates the design and construction of wastewater treatment systems and water supply systems, including onsite services. There are no provincial requirements for monitoring of onsite systems for single properties or for reporting on their performance. NSE will investigate reports of suspected failing or malfunctioning treatment systems. In cases where a single onsite wastewater system is suspected of malfunctioning, NSE will contact the property owner directly and they will be responsible for designing and constructing solutions to the problem(s). Where multiple onsite systems are suspected of failing or malfunctioning, NSE typically goes to the municipality and the municipality is responsible to investigate the suspected problem(s) and recommend solutions. In some situations, the best solution is to ensure that the onsite systems meet current standards and are properly operated and maintained. Typically, the property owner is then responsible to have the recommended upgrades implemented. To ensure that the systems are upgraded in a consistent manner and are operated and maintained as required, some municipalities have established wastewater management districts to carry out these duties; these are discussed in section 5.3.6.3.

5.3.6.2 Condominium Associations

In HRM, condominium associations typically own cluster water and wastewater services where they service multiple units with multiple owners and in some cases on multiple properties. Each condominium association would:

- Own all of the components of the water system (distribution piping, wells, pumps, treatment and storage) as well as the wastewater system (septic tanks, pumps, collection piping, treatment and land application piping). Capital costs to construct the facilities would be shared by the members of the Association, the property owners sharing the common facilities;
- Be the entity responsible to operate and maintain the common facilities and to monitor them and report to NSE. NSE reviews the reports and requests system upgrades if required to meet effluent discharge quality objectives; and
- Pay the costs to operate, maintain, monitor and report. Typically these tasks are contracted out to a specialist contractor, familiar with the facilities and responsibilities of operating the systems and certified by NSE. A number of these contractors currently work on these systems throughout the HRM. Wastewater Management District

An alternative management approach is to form a wastewater management district in the Study Area. In other jurisdictions, the Wastewater Management District (District) owns all infrastructure associated with the collection and treatment of wastewater, including all infrastructure on private properties, one metre outside of the buildings serviced. The District is responsible for operation, maintenance, monitoring and reporting associated with the system for community collection and treatment as well as the systems that treat wastewater from single properties.

These districts are formed to ensure that all systems in a community are properly constructed, operated, maintained and monitored by a single responsible entity that then reports to the municipal unit that owns the District and to Nova Scotia Environment. The municipal unit is then able to make changes to its system or operational procedures to improve the system and reduce potential impacts on the receiving environments or improve conditions in the receiving environments as would be the case in the Study Area. These objectives can be achieved without the need for central services where the costs of these systems are prohibitive.

It is expected that the scope of responsibility could be expanded to include water supply systems and potentially to stormwater management systems although current regulatory framework, including the Halifax Charter, does not make provision for this. This would bring consistency to water supply and water quality in the community and allow an integrated approach to wastewater treatment, water supply and stormwater management with the overall objective of improving water quality in the lakes in this study area.

So that development can continue, the objective of the District would be improving water quality in the watershed lands tributary to the waterbodies with no assimilative capacity (Jack Weeks Lake, Lewis Lake, Lake Echo, and McCoy's Pond). If it is to be fashioned as in other Municipalities, the District would be responsible for operation, maintenance, monitoring and reporting for all wastewater, water and stormwater systems in the District; other arrangements are possible. HRM is a likely candidate for the role of manager of the Water – Wastewater Management District (District) as the entity responsible for development. Through the District, HRM can manage the performance of these services and can affect the impacts of development on receiving waters.

Each new subdivision, individual property development or redevelopment of an existing property would include specified infrastructure for all services. The District would take over these new facilities as well as all existing on-site services. All existing systems would need to be surveyed to determine their components, existing physical conditions and their ability to provide the required services. The District would then provide upgrades as necessary for proper operation.

Most of the required services could be contracted to qualified service providers. HRM would need to set up an administration group with responsibility for obtaining, overseeing and paying for the services as well as collecting fees from property owners to pay for the services. Estimates of the range of units serviced in the three growth scenarios are presented in Table 5.3.6.3. Also included in the table are estimates of the average annual costs for the District that includes the cost to:

- Operate and maintain the systems;
- Inspect and report on the systems; and
- Replace components when they reach the end of their useful life.

Table 5.3.6.3: Annual Costs for Operation, Maintenance and Replacement of Onsite and Clustered Services

Growth Scenario	Civic Units Participating		Total Average Annual Cost	Average Annual Cost per Unit
	2014	2030		
High	1720	2300	$ 2,452,957	$ 1,258
Medium	1355	1600	$ 1,823,718	$ 1,258
Low	1000	1000	$ 1,250,090	$ 1,250

5.4 Regulatory Controls and Management Strategies

Prior to any significant additional development in the Study Area, HRM should address the major constraints as outlined in the following plans. Input from various levels of government and all affected parties should be beneficial in the development and undertaking of these plans.

5.4.1 Management of Water Supply

5.4.1.1 LOCAL AQUIFERS

The largest available groundwater source for water supply is the local aquifers that supply existing wells. This source is limited in the quantity and quality of the water that it can supply. To facilitate the growing demand exerted by continuing development and minimize its impact, groundwater recharge is required. Drainage plans submitted as part of development plans for subdivisions should include recharge components. Review of the plans should consider:

- Maintenance of permeable areas and its ratio to paved (impermeable) areas;
- Proposed infiltration systems and their locations; and
- Water selected for infiltration systems. Only "clean" sources should be considered so that groundwater quality is not compromised.

5.4.1.2 WATER TREATMENT

Groundwater will likely require treatment prior to use to ensure that it is aesthetically acceptable and free from pollutants that can be health concerns. The most appropriate treatment and the extent required will need to be defined by sampling, analysis and comparison of results to CCME Drinking Water Guidelines as well as treatability testing. This testing should be completed as individual wells are being developed.

5.4.2 Management of Receiving Water Quality

Management of receiving water quality requires reduction of the impacts of future development on the environment as well as reducing the impacts of existing development.

5.4.2.1 MINIMIZING IMPACTS OF EFFLUENT DISCHARGES

The proposed treatment systems include contour systems that are designed to allow treatment of septic tank effluent as it passes through unsaturated soils enroute to the groundwater aquifer. Alternative systems utilize recirculating filter systems to treat the effluent prior to discharge to the environment. These treatment systems also include a land application component so that the effluent is further treated prior to entering the aquifer, similar to the contour systems. In the event that the infiltration component fails, some water remains on the surface and flows overland until it enters the surface water system.

CCME Guidelines for wastewater treatment plants require effluent discharges with maximum 25 mg/L for CBOD and suspended solids. Current design guidelines used by provincial regulators require 20 mg/L for rivers and estuaries, 5 mg/L for lakes and low flow streams or lower (depending on the ability of the potential receiving waters to provide dilution) for the same parameters. As a minimum, the proposed treatment systems will need to be able to achieve these Provincial objectives. Typically the recirculating filter systems should be able to achieve the limits for rivers and estuaries or better if designed and operated as required. Additional treatment is required for discharges to lakes. These systems are therefore recommended for cluster systems and replacement of failed systems.

In this study area, phosphorous loads are a concern. Although there are no specific limits imposed by NSE for phosphorous, the result of the receiving water assessment indicated that there should be for any treatment systems discharging effluent directly or indirectly into Lake Echo. Treatment systems must be able to retain most (90% or more) of the phosphorous generated in wastewater flows. Then, if the soils are unable to accept and further treat the effluent, the impact of the effluent on the receiving environment will be greatly reduced.

With respect to existing privately owned wastewater treatment plants in the community, design and construction of these facilities were regulated by NSE. Typically NSE would then issue a wastewater treatment plant a permit to operate that would include:

- Effluent water quality objectives for BOD, Suspended Solids and possibly Fecal coliform; and
- Sampling and reporting requirements.

By reviewing the reported information, NSE should be aware of the performance of all wastewater treatment plants in the community and their ability to meet their stipulated discharge objectives. It is understood that typically the discharge objectives or other requirements of the permit to operate only change if there are major changes in the treatment plant such as an expansion to accommodate an increase in flow.

5.4.2.2 Minimizing Other Impacts of Development

While sewage treatment can deal with issues such as E coli, Fecal coliforms, biological oxygen demand, phosphorus, nitrogen, etc. other pollutants can enter the watershed through inappropriate disposal of chemicals such as solvents and paints. An education and enforcement program related to chemical disposal for local residents and businesses should be established.

The application of road salt during winter can also have a significant impact on water quality. Road salting should be limited as much as possible, and methods of treatment for stormwater impacted by road salt and sediment should be examined and utilized where possible.

To limit impacts of vegetation clearing, subdivision style development in the Study Area should be limited to Open Space Design Developments as defined in the HRM Regional MPS. Clustered sewage treatment systems as opposed to individual septic fields are preferred so that their performance can be monitored.

Clear cutting in the watersheds tributary to Martins Lake, upstream of Lake Echo is significant. Nutrient discharges from clear cut areas have been estimated at more than two times the average loads from urban development. Control of clear-cutting and runoff from clear cut areas is important to minimize erosion and sedimentation as well as nutrient loads in streams, ponds and Lake Echo. Where possible, the most suitable locations in these areas should be considered for new development. Nutrient loads from these areas may be reduced by this development alternative, potentially resulting in water quality improvements in downstream receiving waters.

5.4.2.3 Mitigation for Additional Pollutant Discharges

Runoff from a large portion of the Study Area discharges to Lake Echo. The water quality in the Lake does not support objective water uses at times in the summer and fall because of algae resulting in part from the average annual phosphorous load. In the past two years it has been near the maximum load that can be assimilated without exceeding the water quality objective for phosphorous. Existing water quality appears to be the result of the activities in the tributary watershed including clear cutting and urban development (including wastewater systems that do not perform as required).

This does not mean that development in the watersheds tributary to these water bodies should be halted. If development carries on as it has in the past, further development may result in large phosphorous loads. A double approach to the problem is required:

- A reduction in current pollutant loads to these water bodies is required. The reduction must be at least equivalent to the additional phosphorous loads that are expected to be generated by future development to have no net effect. Potential sources of existing pollutant loads and measures to reduce them were discussed in Section 3.6; and
- Measures should be taken to reduce the impacts of future development. HRM has the ability to control impacts due to future development through the subdivision approval process.

HRM must work with existing property owners, starting with the owners of the largest and potentially greatest contributors to develop plans to reduce existing pollutant loads into McCoy's Pond, Martins Lake and Lake Echo as well as into Lewis Lake and its tributaries. An improvement in incoming water quality should result in an overall improvement to water quality in these receiving waters.

While working in conjunction with the Provincial and Federal governments is desirable and may allow for significant overall improvements, there is nothing to prevent HRM from working singly to achieve its desired goals.

5.4.2.4 Additional Improvements to Achieve Desired Water Uses

Watershed Management Plans involving all levels of government, private industry, special interest groups, individual citizens and other interested stewards have proven effective in the development and implementation of plans to improve conditions in watersheds and estuaries similar to these. A leader is required to initiate the planning process. In order to provide reduction in pollutants from upstream areas to offset pollutant loads from proposed development, it may be in HRM's best interest to step forward, take the lead and start the process. With such an organization, it may be feasible to achieve even greater reductions in pollutant loads than are required to offset the proposed development.

Generally, the rivers and streams in the area provide habitat for salmonid fish species such as brook and brown trout, and salmon. High nutrient levels such as phosphorus can impact cold water fish species and should not exceed 0.035mg/L. Water temperature and pH are additional issues. Watercourse and wetland buffers should be preserved to provide shade for the water and disturbance of pyritic slate bedrock should be avoided. Where it is absolutely necessary to disturb undisturbed pyritic slate bedrock or in areas where this type of bedrock is already exposed, it is recommended that a management plan for containing low pH runoff and neutralizing it prior to release to the environment be developed and implemented. Water and effluent releases to water bodies in the area should be within CCME guidelines for temperature and pH as well as the other water quality parameters listed in Table 3.3.3.

5.4.3 Buffers

Land considered undevelopable in this study should be confirmed and if agreed, changes made to the land use bylaw should be implemented for the following:

- Watercourse, wetland and lake buffers of 20 metres in line with HRM's Regional MPS should be supplemented in areas of shallow slopes which fall within the 20 metre buffer with an additional one metre of buffer for every two percent of slope under 10 percent, to a maximum of a 60 metre wide buffer or as defined by a detailed floodplain delineation study. Similar increases in the buffer width are reasonable for slopes over 20 percent;
- Lands that are less than 2 metres above the normal water level in the lakes in the study area and 3 metres above mean sea level; and
- Areas where pyritic slate bedrock is exposed or within 600 mm of the surface.

If these lands are removed from the areas available for future development, there is still plenty of land that is most suitable for development available to accommodate the high growth scenario in the Study Area.

5.5 Monitoring the Impacts of Development

Monitoring is required to establish baseline conditions in the Study Area and to follow development progress and its impacts. Assessment of the ongoing data may be used to modify development plans in response to unpredicted impacts. Typically this role is undertaken by regulators and managers of the development process, locally this would be NSE and HRM.

The assessments completed in this study are desktop studies based on limited field data for the most part. To be most reliable, field data should be collected to establish baseline or existing conditions with respect to groundwater levels and quality, surface water flood levels and quality, receiving water quality. Once established they can serve two purposes:

- To better estimate the impacts prior to development; and
- To compare with post development measurements to confirm that the actual impacts are as predicted prior to implementing mitigating measures if possible.

5.5.1 Surface Waters

Establishing reliable existing conditions in the lower end of the Salmon River system, including Lewis Lake, Martin Lake, Lake Echo, McCoy's Pond and Lawerencetown Lake, is important in the assessment of the impacts the proposed development may have on these systems. Long term monitoring of water quality in these waterbodies would build on the monitoring data that has already been collected and expand it into the areas most likely affected by future development to firmly establish baseline conditions in these waterbodies. The baseline data would be beneficial for comparison with monitoring results to determine if the management plans are producing the desired reductions in pollutant loads or if the plans need to be changed.

As a minimum, the program should consist of the following:

- **Locations of sample collection** – continue to sample locations used in this study (see Figure 3.2.3). Additional samples are suggested in Lewis Lake, Martin Lake and Lawerencetown Lake, just above the inlets to the lakes and at the lake outlets to be able to better determine locations where pollutants are entering the system;
- **Sampling frequency** – samples should be collected as often as financial limitations allow but it would be most beneficial to quantify seasonal variations in the system. As a minimum, samples should be collected in spring, summer and fall during wet weather as well as dry weather. This program should be conducted for as long as possible prior to further development and should continue during development and for long enough after full development is complete to establish its impact on the system;
- **Analysis parameters** – all of the parameters analysed in this study would be beneficial for a long term program, including:
  - E coli and Fecal coliforms;
  - Nitrogen in various forms, total phosphorous and Chlorophyll A;
  - BOD5 and Total Suspended Solids;
  - Salinity, Temperature, Dissolved Oxygen and pH;
  - If other pollutants are suspected, grab samples may be collected intermittently and analysed for other parameters of concern including:
    - Heavy metals;
    - Hydrocarbons;
    - Other potential pollutants;
- **Compilation and tracking requirements** – after analysis, results should be added to the existing results and plotted for each site against time as well as plotted against the other sampling sites for each sampling event. This provides an indication of areal and temporal changes in water quality through the drainage systems and this is useful in the determination of the location and sources of potential pollutants;
- **Analysis and reporting requirements** – depending on the changes noted or following completion of major developments, the data should be used to recalibrate the receiving water models and the results re-evaluated with respect to the impacts of development on water quality in the receiving waters; and
- **Action plans for findings that do not meet expectations** – where all possible measures are being implemented in the Study Area but the receiving waters are still being impacted more than is considered reasonable, alternate mitigation measures should be considered in the upstream

tributary areas of the watershed. First, major sources of pollutants would need to be identified and then plans developed for reduction or elimination. Given the location of the watershed, know upstream activities and the low pH observed in the limited testing completed by residents prior to this study, there appears to be opportunity to improve conditions in the receiving waters by addressing low pH in tributaries to the Salmon River. This would require a co-ordinated effort among many property owners and stakeholders. It requires a champion to make sure that something happens. This individual (or group) would have to gather the stakeholders and together develop a plan to identify the major sources of acid and assess their contributions as well as develop plans to reduce the most significant of the sources. All the while, the system would need to be monitored to ensure that the actions taken are producing increases in pH in Lake Echo.

Additional monitoring in the form of grab samples collected during wet and dry weather conditions may be warranted to identify some of the larger existing contributors of pollutants to these waters. This would be a first step in the process of reducing background concentrations of pollutant to offset additional loads added by planned additional development.

5.5.2 Groundwater

There is limited data available on ground water quality from the Study Area. The well sampling program associated with this study has provided some indication of well water treatment requirements. This program should be continued during the operation of the water supply systems as part of the normal operating requirements for each water supply.

As a minimum, a recommended monitoring program for groundwater should consist of the following:

- **Locations of sample collection** – samples should be collected from each water well servicing a cluster system as well as at representative domestic wells in the Study Area;
- **Sampling frequency** – as a minimum for all treatment systems servicing cluster developments, samples should be collected quarterly during wet seasons of spring and fall as well as lower flow seasons in the winter and late summer. These samples should be collected for a minimum of 1 year to quantify seasonal variations in these systems. A well-defined program of sample collection and analysis is required by provincial and federal regulations and is part of the Permit to Operate for all water treatment plants. Annual samples from the wells servicing single units, collected in the drier parts of summer should suffice;
- **Analysis parameters** – parameters required as part of a treatability program would include as a minimum:
  - Turbidity;
  - pH;
  - Salinity;
  - Colour;
  - Metals (dissolved and total);
  - TOC/DOC;
  - THM formation potential;
  - UV254 absorbance;
  - Bacteriological testing (E. coli + organisms of concern);
  - Hardness;

- Alkalinity;
- RCAP (ion balance, calcium, and inorganic minerals);

- **Compilation and tracking requirements** – after analysis, results should be added to the existing results and plotted for each site against time and sample location;
- **Analysis and reporting requirements** – the data should be re-evaluated with each set of new measurements with respect to the operation of any water treatment facilities. In addition, the data should be routinely compared to CCME Guideline values for drinking water; and
- **Action plans for findings that do not meet expectations** – Individual home and business owners should be informed of variations in their individual supplies. On clustered systems, adjustments to operation of treatment processes should be made to compensate for changes in well water quality and quantity as required. Where parameters not addressed by the treatment facilities are above guideline values it should be noted and reported and if this becomes routine, assessments must be made to address the issue, process modifications may be necessary if well water protection measures are not achievable.

Monitoring of well water levels around the community should be completed to quantify seasonal variations as well as long term changes in levels as development in the community proceeds.

5.5.3 Estimated Costs of Monitoring

The estimated annual cost to sample at the inlet and outlet of each lake listed previously as well as the sampling locations used in the sampling program completed for this study 3 times each year during dry weather and wet weather is in the order of $91,000.

The estimated cost to sample all existing wells once per year and all wells that will be constructed to service future development in clusters (high growth scenario) 4 times per year is estimated to cost in the order of $967,000.

Table 5.5.3 Annual Costs of Proposed Sampling Programs

Surface Water Program	*Sample Locations*	*Seasons Sampled*	*Wet*	*Dry*	*Annual Number of Samples*	*Sampling Costs*	*Analysis Costs*	*Reporting*	*Total Annual Cost*
Lake Echo	5	3	1	1	30	$ 11,625	$ 15,249	$ 4,500	$ 31,374
Lawrencetown Lake	3	3	1	1	18	$ 11,625	$ 9,150	$ 4,500	$ 25,275
Other Lakes	6	3	1	1	36	$ 11,625	$ 18,299	$ 4,500	$ 34,424
Total Surface Water Sampling Program									**$ 91,073**
Groundwater Program	*Sample Locations*	*Seasons Sampled*	*Wet*	*Dry*	*Annual Number of Samples*	*Sampling Costs*	*Analysis Costs*	*Reporting*	*Total Annual Cost*
Community Centre Wells	5	4	1	1	40	$ 15,500	$ 18,450	$ 6,000	$ 39,950
Assumed All existing plus new Clusters	1950	1	0	1	1950	$ 1,938	$ 899,644	$ 25,000	$ 926,582
Total Groundwater Sampling Program									**$ 966,532**

CHAPTER 6 IMPACT ASSESSMENT OF LAKE ECHO CASE 01278

6.1 Planned Development

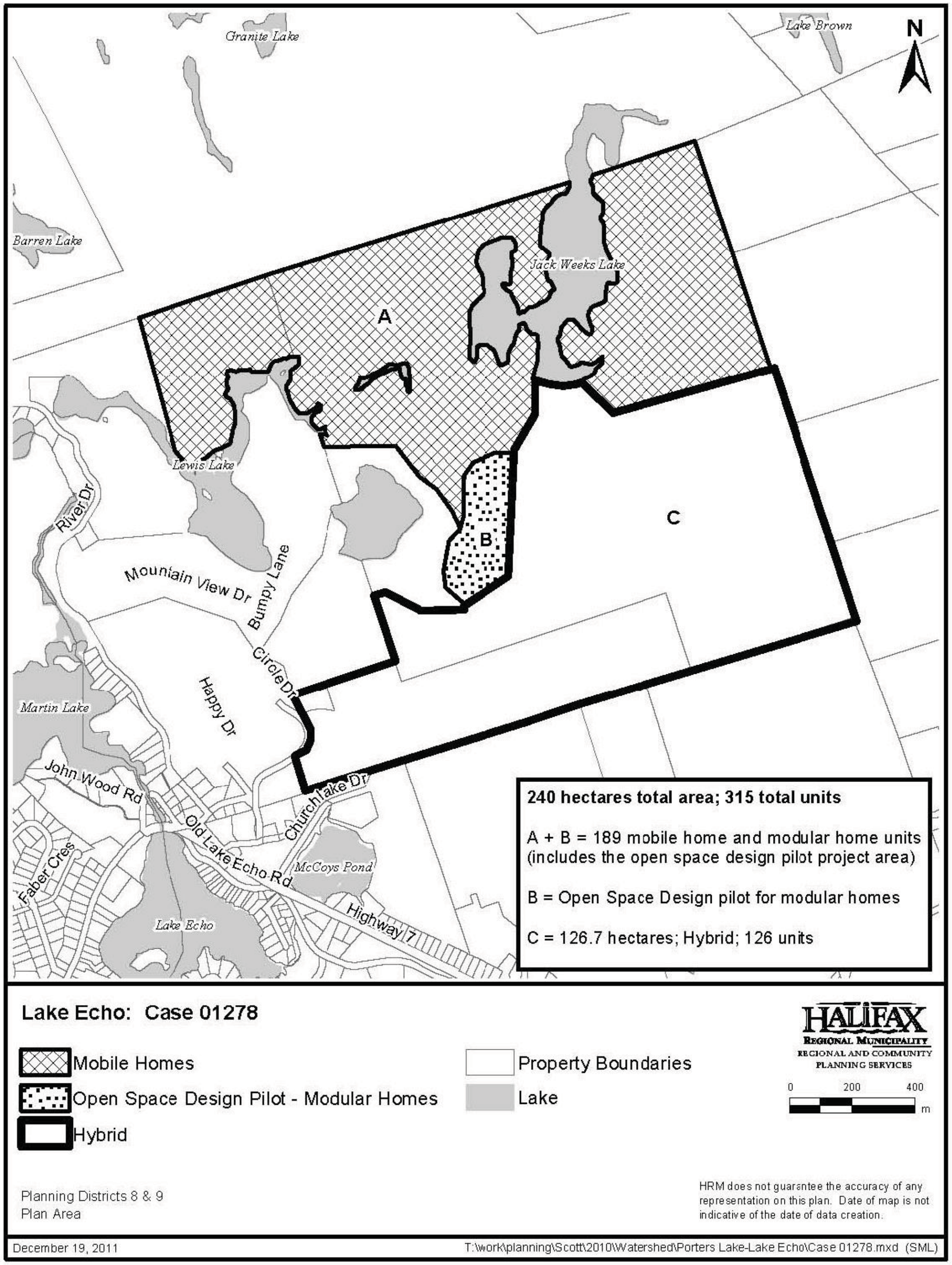
Discussions were held with the HRM planning staff responsible for this case. HRM staff directed the study team to the HRM website for a summary of progress on an application from PJC Land Developments Ltd (formerly Mountain View Mobile Home Park Limited). During the progress of the study there were several modifications to the plans available. On **December 19th 2011** the study team received a revised plan for the proposed development from HRM. It included only the lands in the Lake Echo watershed. This was the plan that was assessed for impacts on the receiving environment.

6.2 Owners Description of Planned Development

Figure 6.2 is a reproduction of the plan provided to the Study Team by HRM. The summary table indicates that 240 hectares will be developed with a total of 315 new units. Three types of development are considered:

- **Area A + B** is to be a mix of 189 mobile homes and modular home units designed as an open space sub-division;
- **Area B** is an open space sub-division pilot project with modular homes; and
- **Area C** is a 126.7 hectare Hybrid Open Space Sub-division. The plan indicates that there will be 126 units constructed.

Three hundred and fifteen (315) new units represents 105% of the number of units considered in the medium growth scenario and 45% of the number of units considered in the high growth scenario discussed in section 2.3.3 for expected growth in the Study Area. At an average of 2.37 persons per dwelling, this development could be home to 746 people, 20% of the2030 total population in the community for the medium growth scenario and 14% for the high growth scenario. The plan is not consistent with the low growth scenario that considers a decrease in population in the community.



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

CBCL LIMITED
Consulting Engineers

HRM Plan of Proposed Development Lake Echo Case 01278

Drawn:	Date: May 2012
Checked:	CBCL Project # 101015.00
Approved:	

Figure 6.2

Notes:

Map Parameters

File Path: L:\101015 Lake Echo\101015_Layout\101015 - Lake Echo\Figure 6.2 HRP Plan for Proposed Development.mxd Last Saved: 20/11/2012 10:53:38 AM

6.3 Land Available for Development

The study team completed an assessment of the developer's plan to determine if it was consistent with the recommendations for future development in this study area. A description of the assessments completed is provided in the following paragraphs.

In section 3.71 of this report, "No Go" areas were defined and it was recommended that the areas defined as "No Go" areas be conserved; not developed. To be compliant with this recommendation none of the "No Go" areas should be developed in this proposed development. Only lands outside of the "No Go" areas in the proposed development area should be considered available for development. Figure 6.3 was developed for the proposed development area from Figure 3.7.1. It shows lake areas and all "No Go" areas within the proposed development generated from the image provided by HRM, Figure 6.2.

Table 6.3 summarizes the assessment of land in Areas A, B, and C to determine the availability of developable land for the proposed development based on conserving the "No Go" areas. Results of the assessment are summarized as follows:

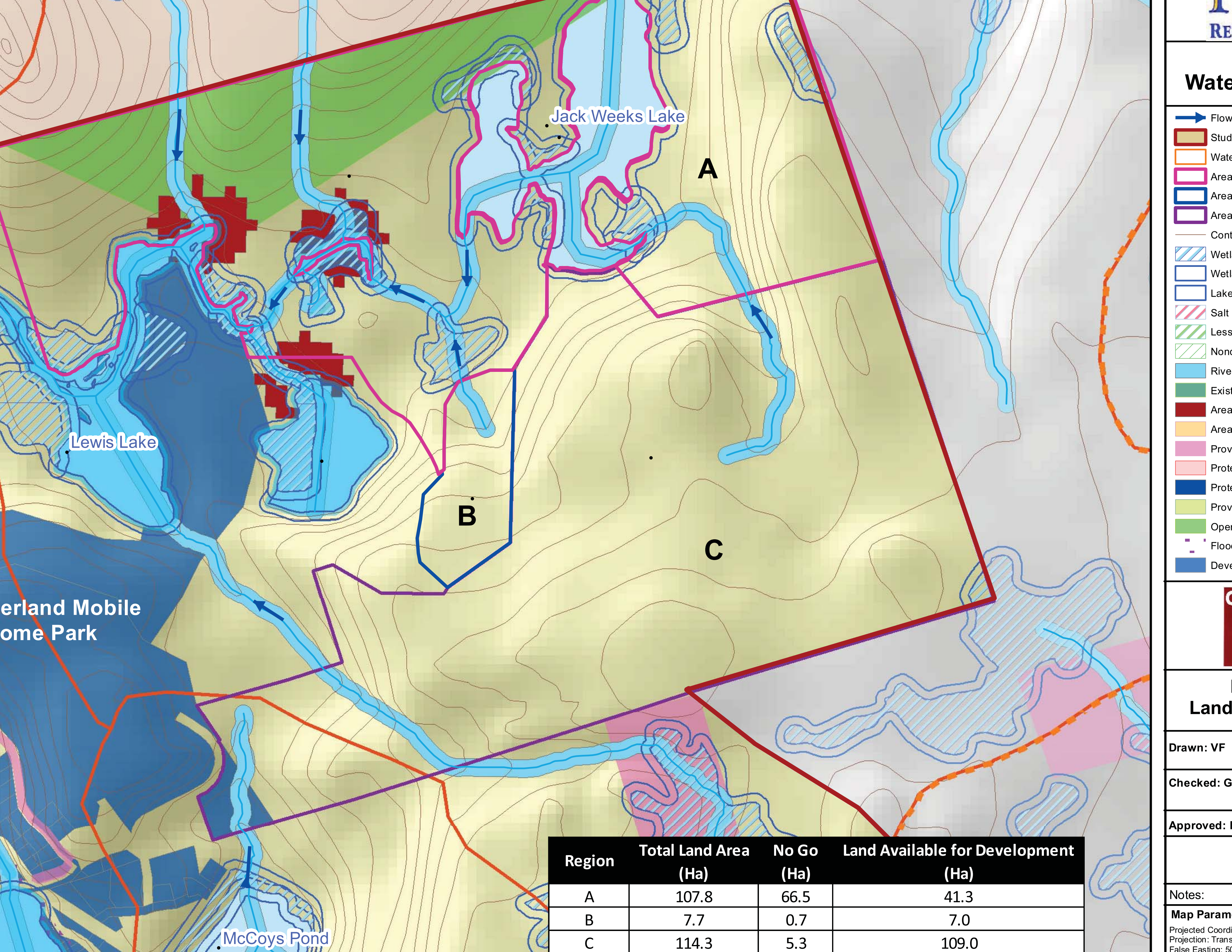
- There was a discrepancy with the total land area for the proposed development. The plan from HRM indicated that there was 249 hectares to be developed, the measured area was in the order of 229 hectares;
- 72.3 hectares (32% of the land area) are considered "No Go" areas and should not be developed with roads or buildings. This area should be retained in its existing state as part of the undeveloped portion of each residential lot;
- Of the land that is available for development, a portion will be required for roads. The estimated land required is 22.6 hectares (8% of the land area);
- The land available for residential lots is 206.3 hectares. This is made up of areas available for development (where building spaces, driveways etc. will be constructed) and "No Go" areas that will be preserved in their existing condition on the undeveloped portion of residential lots, where no construction will occur;
- Assuming that the minimum soil depth is greater than 300 mm, a minimum lot size of 5300 square metres is required for Classic Open Space Design sub-divisions (based on the area required for water recharge plus impermeable surface area). There is room for up to 198 lots in Areas A and B and 96 lots in Area C where the lots in the Hybrid Open Space Design sub-division will each be 1 hectare. There is potential for up to 299 lots in the entire development compared to the 315 units described in the planned development. A site specific hydrogeological assessment may indicate that more, or less area is required for each property to provide the necessary groundwater recharge and/or the design of the onsite wastewater system may require larger lots in the classic open space design portion of the sub-division. These factors may increase or reduce the total number of potential lots in the development; and
- Houses must be constructed outside of the "No Go" areas. The assessment indicates that theoretically 361 building lots of 1050 square metres as well as roads may be constructed in the areas outside of the "No Go" areas in the Classic Open Space portion of the sub-division. However, there is only enough space to develop 198 units in Area A + B based on the minimum lot size. Based on the assumptions shown in Table 6.3 the total number of units that can potentially be accommodated in the development is 294 and careful planning will require to achieve this, compared to 315 in the development plan.

Table 6.3 Land Available for Development in the Proposed Development Area – Case 01278

Development Region	Total Area	Land Area	No Go Areas	Portion of Land Area	Land Available for Development (Roads plus Building Areas) (1)	Land Required for Roads	Land Available for Residential Lots (2)	Potential Number of Residential Lots (3) and (4)	Most Suitable Areas for Development (see Figure 4.1)	Portion of Land Area	Potential Number of Units in Most Suitable Areas
	(Ha)	(Ha)	(Ha)		(Ha)	(Ha)	(Ha)		(Ha)		
A - Classic Open Space	123.0	107.8	66.5	62%	41.3	9.2	98.6	186	18.8	17.4%	179
B - Classic Open Space	7.7	7.7	0.65	8%	7.03	0.7	7.0	13	0.0	0.0%	0
C - Hybrid Open Space	114.3	114.3	5.28	5%	109.0	12.9	109.0	109	18.6	16.3%	18
Total	244.9	229.7	72.4	32%	157.3	22.7	214.7	308	37.4	16.3%	197

Assumptions:

Classic Open Space Design Sub-division				Comments
Average Lot Width - Classic Open Space Design	30	m/Lot		
Building Area Size	1050	m2		Building Area Size is the plot of land required for the main building plus garage, patio, driveway,and front, sides and back yards
Land for roads etc	450	m2/Lot	8%	of Lot Area for Classic Open Space Design sub-division
Required Water Supply Area	4900	m2/ Lot		Based on Groundwater Recharge, Lot Size May be Different Based on Onsite Wastewater System
Area for House, Garage, Driveway	400	m2/ Lot		
Classic Open Space Sub-division Lot Size	5300	m2		Includes Building Area as well as un-developed part of lot, may include No Go areas in the undeveloped portion
Hybrid Open Space Design Sub-divison				
Average Lot Width - Hybrid Open Space Design	75	m/Lot		
Land for roads etc	1125	m2/Lot	11%	of Lot Area for Hybrid Open Space Sub-division
Hybrid Open Space Design Sub-divison Lot Size	10000	m2		Includes roads



Region	Total Land Area (Ha)	No Go (Ha)	Land Available for Development (Ha)
A	107.8	66.5	41.3
B	7.7	0.7	7.0
C	114.3	5.3	109.0

The summary table on Figure 6.3 shows the estimated total “No Go” area as well as the area in each region of the proposed development that is available for development.

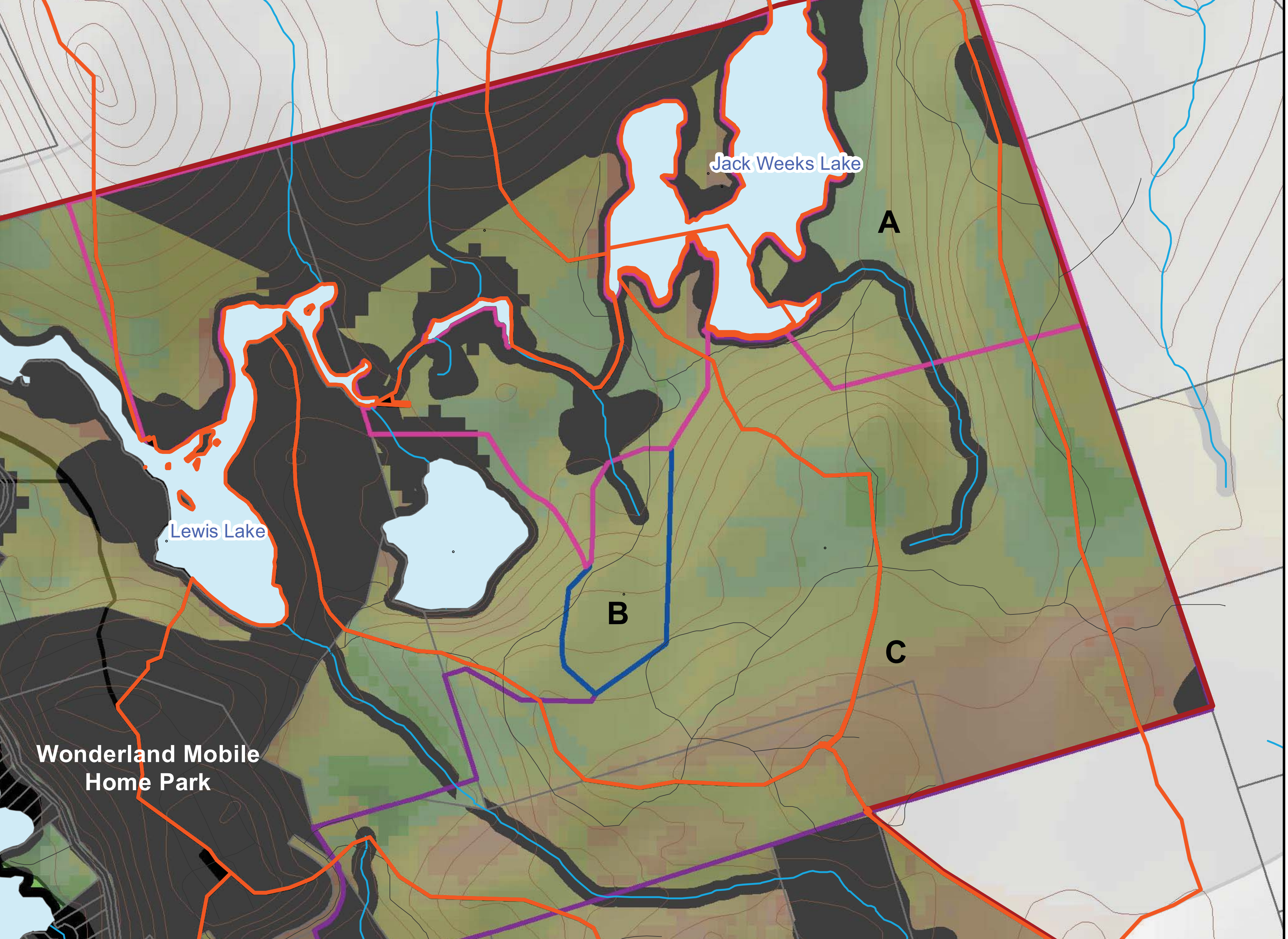
6.4 Suitability of the Area for Development

Figure 4.1 shows the lands in the study area that are most suitable for providing onsite water and wastewater service. On this basis, approximately 75% of the PJC Land Development Limited lands are highly suitable for development. The southern portion of their site is not as suitable for development due to the presence of pyritic slates that negatively impact water supply quality. This condition impacts approximately 50% of the land in Area C. Based solely on the assessment of capability of the land to support on-site wastewater treatment systems and water supplies, the PJC Land Development Limited’s property in Areas A and B and half of Area C is well suited to support servicing of the planned development and the other half of the land in Area C is less suitable.

The relative desirability of the land for development in comparison to the overall study area was also considered. Figure 6.4 was developed for the proposed development area from Figure 5.2.4. It shows lake areas and all “No Go” areas as well as the relative suitability and desirability of the land that is potentially developable. See section 5.2.1 for a description of the assessments completed to determine the relative desirability of the land outside of the “No Go” areas. Most of the land in the proposed development is tributary to Jack Weeks Lake, Lewis Lake and their immediate tributaries. Low pH measurements were made in all of these waterbodies. There is no assimilative capacity in them to accept additional acidic runoff.

If plans were provided showing how the proposed development could be completed without lowering the pH in these lakes or increasing their pH, then the proposed development could be considered. In this case, the assessment summarized in Table 6.3 indicates that approximately 16% of the land in the proposed development is considered most suitable and desirable for development as compared with other areas within the overall study area for the Lake Echo Watershed / Servicing Study. Depending on how the development is arranged, most of the units proposed for Area A may be located in the most desirable areas. This is not the case in Area B, there is no land meeting this classification. In Area C, the proposed hybrid open space design sub-division, it may only be feasible to locate 16% of the units proposed for the area within the most desirable lands.

On this basis, looking at the overall study area for this Lake Echo Watershed / Servicing Study, in Area A, it is possible to locate approximately 179 units on lands that are considered highly suitable and desirable for development. In Area B, it is not possible to locate any units on lands that are considered highly suitable and desirable for development. In Area C it is possible to locate 18 units on lands that are considered highly suitable and desirable for development. While most of the land in Area C should be technically able to support the proposed development, there is other land in the Study Area that is better able to support development (does not have underlying pyritic slates) and may be considered more desirable.



Region	Total Area (Ha)	Most Suitable and Desirable Land (Ha)
A	107.8	18.8
B	7.7	-

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Notes:

False Easting:

6.5 Impact Assessment of Proposed Development

The proposed development was assessed to determine its specific impacts on the surrounding environment. This assessment was commissioned in response to concerns raised by local residents affiliated with the Lake Echo Citizens for Responsible Development. Concerns raised by the group were summarized in a document received from the group. The document focused on existing water quality in Lake Echo, including the following points:

- High coliform counts, suspected source is failed on-site wastewater treatment systems;
- Low pH in the upper end of Lake Echo that can reduce its value as habitat for salmonoids;
- Concern that bedrock underlying the proposed development site is pyritic slate. Runoff that comes in contact with the bedrock has low pH and higher concentrations of iron and aluminum;
- Clear cutting and topsoil removal from large areas of the proposed development site. This has caused erosion and sediment has been transported to the lake. The site has been left this way so there is potential for this process to continue; and
- The ability of local lakes to assimilate additional pollutant loads.

These issues as well as others that developed during the assessments by the study team are addressed in the following paragraphs.

6.5.1 Onsite Wastewater Treatment

Properly functioning wastewater treatment systems are required to minimize potential impacts of wastewater treatment systems in the proposed development on downstream water bodies. Wastewater treatment for the proposed sub-division is expected to be separate from the existing treatment plant at the adjacent Wonderland Mobile Home Park. As a result the development is not expected to augment problems with that existing system.

By the recommendations set in Chapter 5, the treatment should be the most suitable onsite systems for individual properties as well as cluster s of up to 10 units. These systems should address water quality issues associated with wastewater treatment including the discharges of E coli and phosphorous in treatment system effluent.

6.5.1.1 Options for Onsite Wastewater Treatment in the Proposed Sub-division

Options for onsite treatment of wastewater are described in the Component Study report in Appendix I. To minimize the risk of impacts on all surface water systems including lakes, wetlands and streams within the proposed development, treatment to the highest level possible with the available technologies should be considered. This includes treatment with a recirculating filter system followed by UV disinfection prior to a land dispersal system.

6.5.1.2 Onsite Capability Mapping

Figure 3.11 presents the onsite capability mapping for the study area. Examination of the results for the proposed development site indicates that, at a conceptual level, the soils are suitable for onsite wastewater treatment and dispersal. This must be confirmed through onsite, insitu testing of soil depth and permeability in the locations of the proposed dispersal systems.

6.5.1.3 Lateral Movement of Effluent

If the soils underlying a soils dispersal system are not able to accept all of the flows delivered, a portion of the flows will travel horizontally rather than vertically as assumed in the design of these systems. This is a concern for properties located downhill (down gradient) from soil dispersal systems.

6.5.1.4 Ownership of Downstream Wetlands

Nova Scotia Environment has previously accepted plans where effluent flow from recirculating filters in excess of the infiltration capacity of the soils in the dispersal system is dispersed from shallow trenches and flows laterally in the root mat through undisturbed soils. Typically the dispersal trench is located a minimum of 30 metres from the wetland. This lateral flow provides additional treatment for the effluent prior to entering the wetland. This arrangement has typically only been considered where the receiving wetlands are within the property where the treatment and dispersal system is located.

6.5.2 Low pH in the Salmon River

Lake Echo receives inflows from the Salmon River including numerous side streams. pH measurements were taken in these streams by the residents group in 2010. They have also been taken by others in the upstream reaches of the Salmon River, in the vicinity of the airport in studies that were complete for several years following the construction of the airport. Construction of the airport exposed large quantities of pyritic slates; these generated acidic runoff which in conjunction with acid precipitation significantly lowered the pH of the Salmon River system. Numerous measures have been taken to mitigate the effects of the exposed slates but given the fact that these slates are prominent in the upper reaches of the Salmon River watershed, low pH inflows are to be expected in this system.

There is a band of pyritic slates that passes through the proposed development site. It is evident in Figure 3.10. To avoid creating additional exposed pyritic slates in the watershed, disturbance of slate bedrock must be minimized and preferably eliminated.

6.5.3 Approach to Land Development

Previous activities in the vicinity of the proposed development have reportedly involved clearing and topsoil removal exposing pyritic slate bedrock. It has been reported by the citizen's group that:

- There was silt laden runoff from the site and this was evident in the watercourses from the site to Lake Echo; and
- The exposed bedrock has leached acid resulting in lower pH of waters in tributaries to the Salmon River.

This approach to land development must be modified to minimize negative impacts on Lake Echo as well as the tributary systems during construction. Recommended approaches in sections 3.7 and 3.8 to maximize retention of existing environmental functions and minimize the amount of cut and fill and grading should be followed in the detailed design of the sub-divisions. Where cut and fill is necessary, proper erosion control measures and sediment control measures must be designed and implemented in accordance with Nova Scotia Environment guidelines to retain any soils that are accidentally eroded.

6.5.4 Approach to Stormwater Management

As demonstrated with the results of the water sampling program described in section 3.2, the existing water quality in McCoy's Pond and at the upper end of Lake Echo is a concern. There is no assimilative capacity in these water bodies for E. coli, phosphorous or acidic runoff based on desired water uses as discussed in section 3.4.

Measures are required to reduce existing pollutant loads to McCoy's Pond. Discharges from existing development in the watershed lands tributary to the pond should be addressed, including:

- Discharges from existing disturbed areas in the proposed development;
- Stormwater discharges from the existing mobile home park; and
- Effluent discharges from the wastewater treatment plant servicing the existing mobile home park.

For the proposed development to proceed, a stormwater management plan that limits pollutant discharges to the receiving environments is required. Section 3.6.2 describes recommended measures to reduce the risk of further degradation of water quality in these downstream receiving waters. This should include:

- Retention of all low areas and wetlands, including buffers within the proposed development site;
- Creation of additional constructed wetlands treatment areas, including detention capacity; and
- Provision of peak flow attenuation (e.g. rain barrels) and infiltration and treatment systems (e.g. rain gardens and filter strips) on individual properties.

6.6 Constraints on the Proposed Development

Typical constraints to development include:

- Assimilative capacity of downstream receiving water; and
- Water supply.

6.6.1 Assimilative Capacity

As described in Chapter 3, previous development and other activities in the Lake Echo watershed have generated significant nutrient (phosphorous and nitrogen) loads in the surface water system, including Lake Echo. When conditions (including water temperature) are suitable, this results in algae in the waters (indicated by chlorophyll A concentrations) above the levels considered suitable for the uses desired by residents of the community. Because algae concentrations exceed the upper levels recommended for fish and wildlife habitat Lake Echo has no assimilative capacity for additional loads of the components required for algae generation, including nutrients and heat. To maintain water quality in Lake Echo, no additional activities that result in increases in temperature or nutrient loads should be considered in the areas tributary to Lake Echo.

As shown in Figure 6.6.1, the proposed development is located on lands tributary to Lewis Lake and to Jack Weeks Lake that flows into Lewis Lake. The phosphorous loading model described in section 3.4.1 was used to assess the change in expected annual average total phosphorous concentrations in Jack Weeks Lake, Lewis Lake and Lake Echo of the proposed development. Results of the assessment are summarized in Table 6.6.1. The assessment assumes all of the proposed development on the PJC Land Development Limited's property will occur and there will be no additional development anywhere else in the watershed. The upper portion of the table shows some of the existing land-uses in the tributary areas and phosphorous concentrations in the main lakes in the Study Area. The lower portion of the table shows the results of development, changes in land use and increased number of residences in the watersheds tributary to Jack Weeks Lake and Lewis Lake. These changes result in changes in the average annual total phosphorous concentration in each lake in the system.

By this assessment, the development proposed on the PJC Land Development Limited's property has the potential to significantly increase the annual average phosphorous concentration in the Jack Weeks Lake and Lewis Lake. With this change there is potential for a change in trophic status in Lewis Lake from oligotrophic to mesotrophic due to the development. The annual average total phosphorous concentration in Lake Echo should decrease slightly. This is due to the projected decrease in the number of people that will occupy each unit as development proceeds which results in smaller phosphorous loads from existing onsite systems. New onsite systems are assumed to retain significantly more phosphorous in the groundwater regime, resulting in lower loads to the surface waters (including the lakes) for new development. The estimated phosphorous loads in each lake are based on typical phosphorous generation rates for the land-uses in the watershed, based on results of phosphorous export studies conducted in this region, but they are estimates. Baseline monitoring of these lakes should be started as soon as possible to confirm the assumptions used in the phosphorous loading model or to develop new assumptions if the measurements do not confirm the predicted existing conditions.

A second concern in the watershed is pH. Some of the pH measurements collected during this study, by HRM in the 2006 - 2011 sampling program and by the community residents program indicate pH at times at or below the minimum guideline for suitable salmon habitat (minimum pH 5.5). There is no assimilative capacity for additional acid loads in the local tributaries or in the lakes that will receive stormwater runoff from the proposed development, Jack Weeks Lake, Lewis Lake and Lake Echo.

6.6.2 Water Supply

Well water supplies were considered in section 3.1:

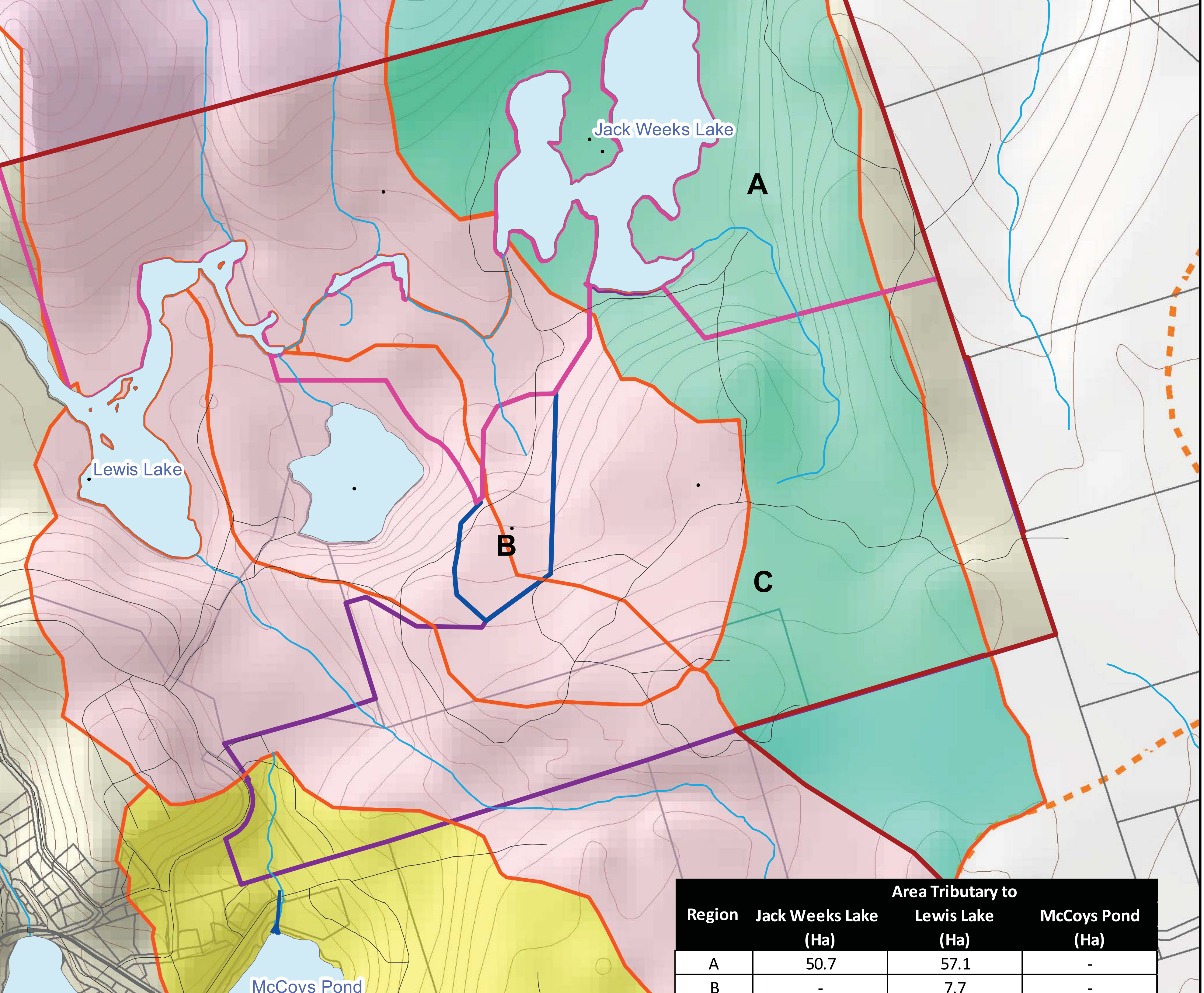
- Wells in surfical aquifers are typically able to provide more water than wells from bedrock aquifers and wells in pyritic slates appear to be the lowest producers. Bedrock wells are typically able to provide water for individual properties and clusters of up to 10 units; and
- Iron and manganese are aesthetic concerns. Surface contaminants may pose health risks for water from wells in the surficial aquifers. Iron, manganese and arsenic are present in most wells in bedrock that were tested.

Table 6.6.1 Predicted Annual Average Total Phosphorous Concentration in Study Area Lakes with Proposed Development – Case 01278

			Sub-watershed												
Development Scenario			**McKay Lake**	**Lake Williams**	**East Lake**	**Byron Lake**	**Tittle Lake**	**Loon Lake**	**Salmon River Long Lake**	**West , Granite Lakes**	**Brown, Jack Weeks Lakes**	**Lewis Lake**	**Martin Lake**	**Lake Echo**	**Lawerencetown Lake**
Existing Conditions															
Drainage Basin Area (Excl. of Lake Area)	Ha		4019.4	638.3	277.0	453.5	928.4	167.3	420.0	926.4	608.1	139.0	1145.8	1332.8	1021.2
Percent Clear Cut	%		15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	19.4%	17.0%	34.0%	16.9%	24.7%
Percent Developed	%		1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%	2.9%	22.0%	11.6%
Number of Residences Directly Draining to Lake	# Units		8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	400.0	100.0
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0120	0.0088	0.0124	0.0166	0.0145
Trophic Status Based on Total Phosphorous			Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic
With Proposed Case 01278 Development															
Assumed Portion of New Development in Each Sub-watershed			0%	0%	0%	0%	0%	0%	0%	0%	49%	51%	0%	0%	0%
Percent Clear Cut	%		15.9%	0.2%	1.0%	5.8%	6.0%	34.0%	24.7%	1.9%	10.3%	0.6%	34.0%	16.9%	24.7%
Percent Developed	%		86.8%	94.0%	97.0%	94.2%	92.5%	98.0%	95.9%	94.5%	76.8%	1.5%	92.3%	72.7%	82.2%
Number of Residences	# Units		8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	46.1	60.0	400.0	100.0
Average Annual Total Phosphorous Concentration	mg/L		0.0141	0.0117	0.0046	0.0072	0.0074	0.0086	0.0103	0.0059	0.0166	0.0138	0.0131	0.0165	0.0143
Predicted Increase	%		0%	0%	0%	0%	0%	0%	0%	0%	38%	57%	6%	-1%	-1%
Trophic Status Based on Total Phosphorous			Mesotrophic	Mesotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic

Assumptions:

All new development in the Study Area occurs on the PJC Land Development Limited lands. 50% of new development occurs in areas that are currently forests, and 50% occurs in areas that are currently clear cut in Jack Weeks Lake sub-watershed, the portions are 80% in forested areas, 20% in clear cut areas in the Lewis Lake sub-watershed
Shading indicates a change in trophic status
Estimated using the phosphorous loading model - should be validated with sampling
Average Annual concentration based on HRM's 2006-2011 Sampling Program



Region	Area Tributary to Jack Weeks Lake (Ha)	Area Tributary to Lewis Lake (Ha)	Area Tributary to McCoys Pond (Ha)
A	50.7	57.1	-
B	-	7.7	-

Drawn: VF

Checked: G

Approved:

Notes:

Map Param

Based on the samples taken from existing wells in the community and tested, well water quality is a constraint to development. As shown in Figure 3.10, pyritic slate bedrock underlies the southern portion of the proposed development, Area C. The constraint due to well water quality is greatest in this area. It would not be prudent to develop on-site wells with water quality issues similar to those in existing wells in the community, an alternate approach that uses a central water supply (as described in section 4.2) is recommended in areas underlain by pyritic slate bedrock as a minimum.

6.7 Actions Required to Accommodate the Proposed Development

For the proposed development to proceed, the developer would need to have plans that:

- Produce no net increase in the concentrations of water quality parameters that limit the assimilative capacity of Jack Weeks Lake, Lewis Lake or Lake Echo (nutrients, heat, and acid); and
- Consistently provide safe drinking water for all units in the development. Treatment to remove iron and manganese is expected to be required for most wells; arsenic removal will be required in some wells.

6.7.1 Required Plans for Development

Plans for the proposed development must include the following:

- Onsite wastewater collection, treatment and dispersal systems with adequate capacity for soil conditions in all areas of the proposed development (see the evaluations completed and recommendations in Appendix I). On-site and cluster treatment systems should include components for phosphorous removal to ensure that if the soil dispersal systems are unable to accommodate all effluent from the treatment system, phosphorous loads in overland flows will be minimal. A plan for monitoring individual onsite systems as well as systems for clusters of units should be required to ensure that the systems function as designed. A wastewater management district as described in section 5.3.6.3 would perform this function;
- Stormwater management plans for the proposed sub-division should include maintaining existing natural drainage systems with existing wetlands and their proposed buffers as “No Go” areas. Local collection systems, comprising swales adjacent each street should include integrated infiltration capacity, runoff detention and constructed wetland treatment prior to discharging into the natural drainage systems to maintain existing peak runoff flows and runoff quality. Similarly, infiltration, detention storage and treatment of runoff should be included on individual properties in the sub-division through the use of rain gardens, rain barrels and other applicable stormwater best management practices (see section 3.6);
- Grading plans with minimal cut and fill and minimal disturbance of pyritic slate bedrock (see section 3.8);
- Identification and management plans for acid generating pyritic slates on the development site that have already been exposed or disturbed and that may be exposed or disturbed during the construction process;
- Siting plans to ensure that “No Go” areas including riparian buffers are maintained in an undisturbed state (see Figure 6.3). Areas of elevated archeological significance should be investigated prior to development. The siting plans should make efforts to reduce the phosphorous loads from the proposed development areas by locating streets and building lots in areas that are currently clear cut and not clear cutting more areas than are absolutely necessary;

- Erosion and sediment control plans to minimize impacts on water quality in the water systems adjacent the development;
- Reduction of existing pollutant loads to adjacent water bodies to make assimilative capacity available to offset any additional loads that will be generated by the proposed development. Potential reduction projects are limited in the proposed development area but should be in areas immediately adjacent the development area or upstream of the proposed development. They could include:
  - Upgrades to the existing wastewater treatment plant at the Wonderland Mobile Home Park to reduce phosphorous and E coli counts in the effluent;
  - Identification of failed onsite systems in the areas tributary to the upper end of Lake Echo and upgrades to these systems or provision of alternate treatment systems such as a community treatment system as discussed in section 4.1.1;
  - Stormwater treatment systems for lands tributary to Jack Weeks Lake, Lewis Lake and Lake Echo with existing development and areas that have been recently clear cut; and
  - Any other projects that can be shown to reduce nutrient loads and increase the pH of inflows to the lakes adjacent the proposed development.

6.7.2 Safe Drinking Water

It would be undesirable to allow the creation of up to 315 new wells (or alternatively 20 cluster wells in Areas A + B and 96 individual wells in Area C) with water that does not meet current drinking water standards. Two alternatives for the provision of safe drinking water were considered in Chapter 4:

- Provide water to individual properties and clusters of up to 10 units. It was recommended in section 3.1 that the wells should be a mix of wells in the surficial aquifer (where a significant depth of surficial materials are available) and wells in the bedrock aquifer (where the bedrock is not pyritic slates). Each unit would likely have to be provided with a water treatment system designed to remove iron and manganese as a minimum, and in some cases arsenic. All drinking water consumed should be from the tap with the “point of use” treatment system. If multiple points of use are required, multiple treatment units would be required. A monitoring program would be required to ensure that the treatment systems perform as required. A water management district is recommended to ensure adequate water treatment is achieved to meet current drinking water quality guidelines for all water quality parameters; and
- Provide a central water supply system. The capital costs of a central water system were estimated to be comparable to the costs of cluster water supply if all of the residences in the potential water service area participate in the central system. The costs of operating a water management district to ensure adequate water quality will offset a portion of the additional capital cost for a central system.

A central water supply system for the new development should be considered a more sustainable approach than constructing onsite wells with potential water quality issues to be resolved by onsite treatment.

APPENDIX A

Focus Group Meeting Summaries

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Consulting Engineers

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LAKE ECHO WATERSHED / SERVICING STUDY

Community Focus Group Meeting
Lake Echo Community Centre, November 29 2011 from 7:00 to 9:30 pm.

Attendees included:

- Fourteen (14) residents of Lake Echo and two representatives of the proposed development near the northeast end of the Lake, invited by Councilor Hendsbee;
- Maureen Ryan HRM Regional & Community Planning, HRM Councilor David Hendsbee;
- Gordon Smith and Mike DeLay, CBCL Limited; and
- A copy of the sign-up sheet is attached.

A presentation was made by CBCL Limited that included:

- Some findings of investigations in the Study Area, including the results of the Water Quality Sampling Program in Lake Echo and the Survey of Water Quality Objectives and assessment of assimilative capacity;
- General discussions of possible sources of contaminants;
- The need to take measures to reduce existing pollutants to ensure that future development doesn't generate similar issues; and
- The availability of land for future development and it's suitability for provision of on-site wastewater treatment and water supply.

There were questions and extensive discussions on each subject. Some of the questions and issued that were raised during the discussions included the following:

- One participant suggested that septic systems fail when they reach around 35 years of age. People wanted to know average ages of houses around lake. Development in the community was described by the participants as starting off as cottages many years ago and as time passed the cottages were converted to full time residences, but the septic systems were not always upgraded. This may be a source of pollutants in the lake;
- Loss of forests due to harvesting, Hurricane Juan, recent development, and the large forest fire in 2008 have caused more runoff. This has lead to more erosion and flushing of sediment into the lake;
- The issue for some participants was not so much about where development should occur but how to control development over the longer term so that it does not impact the lake the way existing development has. The means to ensure this already exists in legislation. Regulations and guidelines for design, construction and ongoing up-keep need to be enforced. For instance, there is a need to figure out how to get people to clean and maintain their septic tanks and systems; and
- Fecal coliform counts near Ponderosa Drive indicate a potential source of pollutants. The on-site suitability mapping showed soils are not as good along Ponderosa Drive as they are in other areas in the watershed. It was suggested that there was a need to do something special on Ponderosa Drive.

The attendees were asked to consider future development in the community and to answer the following questions based on their options of the information presented:

- Is there a centre of the community of Lake Echo and if there is, where is it?
- Where will future development be located? The groups at each table were asked to draw the locations on the maps provided.

The attendees were advised that their opinions will be used to help the study team put together and assess impacts of development scenarios that would have the best chances of being accepted by the community. A public meeting would be held in the New Year to discuss the findings. All residents would have an opportunity to express their opinions at that time.

The discussions carried on as one large group. Summaries of the points covered are presented in the following bullets.

- It was generally agreed that:
  - Residential development will continue to occur in the area over the next 20 years;
  - It will likely be spread throughout the area; and
  - It should provide a mix of housing types.
- CBCL Limited suggested that the Community Centre might be the centre of the community. There were mixed opinions about this. One participant said the centre of the community was Lake Echo. Another described how the Community Centre had been build to try to develop a centre but that it had failed. Others argued that a community centre (core area) is important but that the development of a new one should be considered.
- There were a number of possible areas identified for future development. These were identified on a map of the study area at the meeting and a copy of the map is attached for reference:
  - Councillor Hendsbee indicated the locations of several on-going and planned sub-divisions in the study area;
  - There were two groups that suggested locations of future development centers in the community, both are shown on the map of the study area:
    - The first group pointed to the areas where the seniors development is proposed northeast of Lake Echo;
    - The second group suggested a new interchange be built on Highway 107, east side of Lake Echo, close to the lake, that would allow development on either side of the highway and improve access to existing development in Lake Echo. A community centre (core area) could be developed near the interchange; and
    - With the exception of areas within existing approved development plans, all areas should be developed as Open Space Subdivisions.
- It was agreed that the impacts on lake water quality of suggested development areas shown on the attached map would be assessed.

After the meeting, CBCL Limited reviewed the notes taken by the team members and summarized the discussions in this document.

Lake Echo Focus Group Mtg. Lake Echo Community Center
29 Nov 2011. 7:00-9:30 pm

Name	Organization	Phone/email
MALCOLM FIRTH	[redacted]	[redacted]
Michel Gaudreau	[redacted]	[redacted]
BILL JENKINSON	[redacted]	[redacted]
DAN Regan	[redacted]	[redacted]
JIM / MARCY LARDER	[redacted]	[redacted]
Don Mosher	[redacted]	[redacted]
Fran Bellefontaine	[redacted]	[redacted]
Chris Stredder	[redacted]	[redacted]
Clive Jones	[redacted]	[redacted]
GARY STRONACH	[redacted]	[redacted]
RALPH ORTON	[redacted]	[redacted]
Paul Norwood	[redacted]	[redacted]
DUNCAN CANN	[redacted]	[redacted]
John Rogers	[redacted]	[redacted]
Curtis Messervey	[redacted]	[redacted]
ALLAN CURRIE	[redacted]	[redacted]
M DELAY	CBCL LIMITED	[redacted]
Gordon Smith	CBCL "	[redacted]
Maureen Ryan	HRM Planning	[redacted]
Councilor David Hendsbee	HRM	

HALIFAX REGIONAL MUNICIPALITY

Tantallon and Porters Lake Watershed Servicing Study
Lake Echo Base Map

0 0.5 1 2 km

Roads: Arterial, Collector, TCH, Railroad, Ferry · Waterbodies · Lake Echo Study Area

CBCL Project # 101015
Data Sources: HRM, NSDNR
Coordinate System: NAD 1983 UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -63.0000
Latitude Of Origin: 0.0000
Units: Meter

CBCL LIMITED

APPENDIX B

Component Study – Groundwater Assessment

Contents

CHAPTER 1 AREA HYDROGEOLOGY

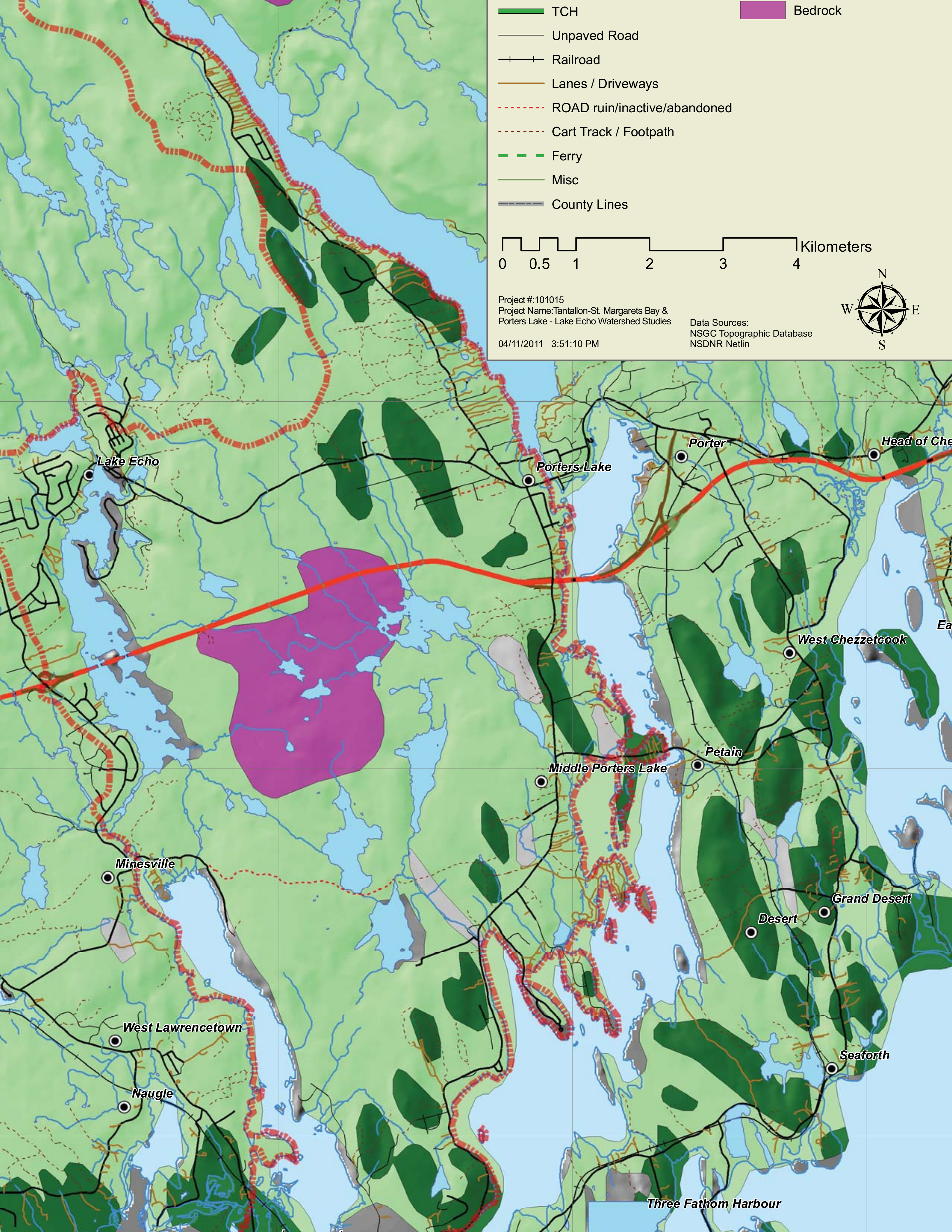
1.1 Surficial Unit

The composition of quaternary material varies in the Lake Echo study. Ice contact till plains predominate in the northern, western, and south-central parts of the study area, comprising locally sourced stoney, sandy till and frequent boulders appearing at the ground surface. The buffering capacity of the soil is poor as a result of the local slate and quartzite source rock. Quartzite tills predominate throughout most of the study area, typically reaching thicknesses of up to 20 m. An isolated zone of slate till is observed near Middle Porter's Lake, with a maximum thickness of 4 m. Granite tills occupy the northernmost part of the study area, near West Lake. Till cover is limited or absent in the centre of the study area, exposing Goldenville Formation bedrock. Drumlins are observed frequently beyond the eastern boundary of the study area. Drumlin till shows improved buffering capacity and better suitability for farmland. Although dominated by fine grained material, this terrain can provide good local deposits of sand and gravel suitable for individual water supplies.

Figure 1.1 shows provincial mapping of quaternary features within the Lake Echo area. There are 18 silty drumlins concentrated on the western shore of Porter's Lake. The composition of these features is similar to the surrounding plains, but may be of sufficient thickness to exhibit water bearing seams. Drumlins in the southern portion of the study area are composed of silt till and red clay derived from outside of the study area, with varying beds underlying the surface soils. Provincial mapping also indicates two or more esker ridges immediately east and south of Middle Porter's Lake. The granular material associated with eskers can provide excellent yields, although unconfined conditions can render the deposit susceptible to surface contaminants.

Well logs indicate that the thickness of surficial material is typically 2 to 6 m, reaching up to 69 m in the most extensive units. Groundwater flow in populated parts of the study area is expected to be dominated by systems local to drumlin features and steep slopes adjacent to Lake Echo, Martin Lake, and Porter's Lake. Upward gradients or springs at the toes of drumlins can create suitable areas for the development of shallow wells for individual groundwater supplies.

The corridor between Highway 7 and Highway 107 is expected to act as a groundwater recharge area, establishing local and intermediate flow paths that discharge to Lakes in the centre of the Lake Echo Study Area. Components of downward flow from these lakes could contribute to more regional discharge to coastal areas, or may form intermediate systems from lake to lake (e.g. Grand Lake – Caribou Lake – Snow


TCH
Bedrock
Unpaved Road
Railroad
Lanes / Driveways
ROAD ruin/inactive/abandoned
Cart Track / Footpath
Ferry
Misc
County Lines
0 0.5 1 2 3 4 Kilometers
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W
E
S
Project #:101015
Project Name:Tantallon-St. Margarets Bay & Porters Lake - Lake Echo Watershed Studies
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Data Sources:
NSGC Topographic Database
NSDNR Netlin
Lake Echo
Porters Lake
Porter
Head of Che
West Chezzetcook
Petain
Middle Porters Lake
Minesville
Grand Desert
Desert
West Lawrencetown
Seaforth
Naugle
Three Fathom Harbour

Lake). As homes in the study area are concentrated along coastal routes, wells drawing water from the quaternary unit will typically be associated with local shallow coastal flow systems.

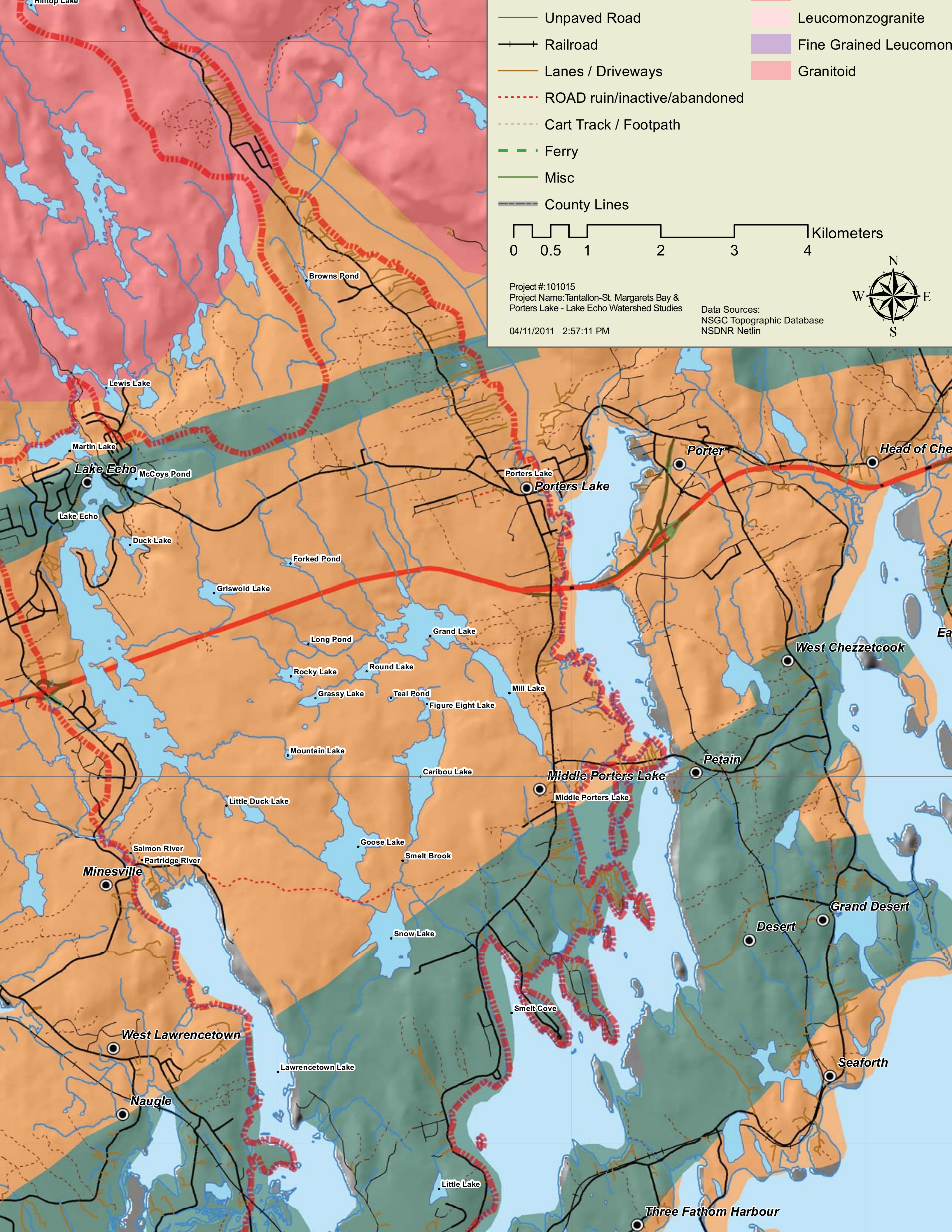
1.2 Bedrock Unit

Bedrock in the Lake Echo area is primarily metamorphic rock of the Meguma Group, contacting the Musquodoboit Batholith in the north (Figure 1.2). Rock types vary from sections of granodiorite in the extreme northeast part of the study area, to quartzite and slates over the remainder. Halifax Formation Slates occur primarily in the southern part of the study area, but also underlie the developed part of Lake Echo centre.

Groundwater flow in Halifax Formation slates occurs largely through a weathered zone occupying the upper 1 to 2 metres of the unit. Fracture partings bedding plains become less frequent, exhibit smaller openings, and decrease in connectivity with depth. Major water bearing features are nevertheless encountered at depth in selected locations. Quartzite and slate rock of the Goldenville Formation is similarly likely to exhibit greater hydraulic conductivity in the upper sequences, with water bearing features decreasing in frequency at depth. Fractures are frequently sub-vertical. Regional topographic patterns shown by provincial LiDAR mapping indicated that major structural features strike from north-northwest to south-southeast, and from east-northeast to west-southwest.

Flow in bedrock units is expected to include recharge to the shallower intervals of the bedrock by the system of lakes in the centre of the study area, with flow and discharge to Lake Echo and Porter's Lake. Upland areas are located primarily to the north of the study area, in association with granitic rocks of the Musquodoboit Batholith. Regional flow originating in this zone would generate flow paths passing under the study area and discharging to inlets or off-shore areas. Deeper groundwater flow paths are expected to be generally to the south and southeast.

Poor fracture connectivity can lead to low yields, but can also limit interference between adjacent locations. Poor fracture connectivity will also result in low hydraulic conductivities and associated low bulk fluxes through the bedrock. By contrast groundwater velocities through individual fractures may be high, which would have implications for contaminant transport. The gradient in the bedrock unit is expected to vary from downward to horizontal in the most northern parts of the study area, to upward closer to the inlets and coastlines. Flow patterns should reflect regional flow from inland areas, and local/intermediate flow within each of the peninsulas. Shallower intervals of the bedrock may transmit recharge from bog areas and larger lakes to coastal discharge zones.


Hilltop Lake
Unpaved Road
Railroad
Lanes / Driveways
ROAD ruin/inactive/abandoned
Cart Track / Footpath
Ferry
Misc
County Lines
Leucomonzogranite
Fine Grained Leucomon
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Project #:101015
Project Name:Tantallon-St. Margarets Bay & Porters Lake - Lake Echo Watershed Studies
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Data Sources:
NSGC Topographic Database
NSDNR Netlin
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Browns Pond
Lewis Lake
Martin Lake
Lake Echo
McCoys Pond
Lake Echo
Duck Lake
Forked Pond
Griswold Lake
Porters Lake
Porters Lake
Porter
Head of Che
Grand Lake
Long Pond
Rocky Lake
Round Lake
Grassy Lake
Teal Pond
Figure Eight Lake
Mill Lake
West Chezzetcook
Ea
Mountain Lake
Caribou Lake
Middle Porters Lake
Middle Porters Lake
Petain
Little Duck Lake
Salmon River
Partridge River
Minesville
Goose Lake
Smelt Brook
Grand Desert
Desert
Snow Lake
Smelt Cove
West Lawrencetown
Lawrencetown Lake
Seaforth
Naugle
Little Lake
Three Fathom Harbour

CHAPTER 2 GROUNDWATER SUPPLY

2.1 Required Yields

Drinking water needs in the Lake Echo area are supplied by individual water wells in the surficial and bedrock aquifers of the area. Many wells drilled into the surficial deposits reported yields adequate to supply light industry and small commercial developments. Options for additional groundwater supplies under scenarios for future development include the following:

- Individual wells (one well per household);
- Housing clusters (each well serving 10 households); and
- Central municipal supply (one well field serving the entire community).

Groundwater supply wells may be drilled or dug into surficial aquifers, or drilled into metamorphic bedrock units (or plutonic rocks in the northeast arm of the study area). Surficial deposits in ice contact till plains may function as unconfined aquifers, but the presence of finer material in thicker sequences of till should provide a degree of protection in most areas. Unconfined conditions will predominate in the centre of the study area where the bedrock is exposed (Figure 1.1).

Projected water demands for the Lake Echo area are shown in Table 2.1. Estimates are provided for three scenarios:

- The existing population / equivalent low-growth scenario;
- The estimated population under moderate development; and
- The anticipated population based on Statistics Canada estimated Unit Allocations (High Growth).

Table 2.1: Projected Water Demand for Lake Echo, NS

	Low Growth	Moderate Growth	High Growth
Population in 2030	2300	3700	5200
Housing Units in 2030	1000	1600	2300
Average Demand (m^3/day)	1224	1968	2766
Average Demand (L/min)	850	1367	1921
Peak Demand (L/min)	1912	2734	3842
% increase		61	126

The existing, or low growth demand (residential plus other uses) for the Lake Echo area, is estimated to be up to 1,224 m^3/day. A central municipal supply would be required to produce 850 L/min on average, and up to 1,912 L/min at peak times. With moderate growth, demand would increase by 61% to 1,968 m^3/day. At the maximum proposed population, demand is estimated at 2,766 m^3/day. Flows from a central supply would require an average pumping rate of 1,921 L/min, and a peak pumping capability of 3,842 L/min.

Conservation Subdivision Development (CSD) was considered as an alternative to single lot developments and central servicing. Clusters of households and other units would be serviced by single well or nest of wells and a single on-site sewage disposal system. For the purposes of example calculations a cluster of 10 units (domestic, commercial, or light industrial) was considered. A well serving 10 households would be required to supply 7.2 m^3/day, with an average pumping rate of 5 L/min, and peak flows of 10 L/min. A well serving a mixed cluster of residential, commercial, and light industrial users would be required to supply 12 m^3/day, requiring an average pumping rate of 8.5 L/min and peak flows of 17 L/min. These required pumping rates fall within observed ranges for existing wells (Sections 2.2 and 2.3).

2.2 Existing Drilled Wells in Surficial Units

2.2.1 Yield

Table 2.2 provides a summary of data from wells in the Lake Echo area (Nova Scotia Water Well Logs database, 2009).

Table 2.2: Surficial Unit Well Characteristics for the Lake Echo Area

	Well Depth (m) (n=138)	Static Water Level (m) n=(86)	Yield (L/min) (n=112)
95% Confidence Interval	26 to 36	3 to 4	69 to 201
First Quartile	5	2	9
Median	11	3	23
Third Quartile	51	4	84
Maximum	122	21	2270

Wells installed in surficial deposits are typically 11 metres deep or less, but can reach up to 51 metres in selected locations, with a maximum reported depth of 122 metres. The well yields are variable, ranging from 9 L/min in lower producing areas up to 84 L/min where yields are more favourable. Wells in the surficial unit are generally deeper and show a distribution of lower yields than the adjacent Porter's Lake study area, suggesting that surficial deposits are less productive in the Lake Echo study area. The maximum reported yield for a well installed in surficial material was 2,270 L/min.

The source of water to many surficial wells is described as sand, boulders, or gravel, referring either to localized gravel beds within till material, or to the quartzite tills that predominate in the study area. Many wells also reported finer grained materials, suggesting that many wells are equipped with extensive storage, or intercept fine sand seams not identified in the drilling logs. This could be consistent with wells drilled through drumlins on the eastern part of the study area. Dug wells are expected to provide the most favourable yields in this drumlin field, or on the eskers near Middle Porter's Lake. When situated on the margin of natural groundwater discharge areas (near the base of hill slopes), dugs wells can provide favourable yields and good water quality.

2.2.2 Water Quality

The chemistry of water drawn from surficial material in the study area will be influenced by quartzite and slate tills which are in turn related to the chemistry of the local host rock. Provincial mapping provides till chemistry data for the Lake Echo area (Stea and Dickie, 1979). Mean soil concentrations in area tills were: lead (60 mg/kg), arsenic (26 mg/kg), uranium (<0.4 mg/kg), iron (5.8 % by weight) and manganese (2614 mg/kg). The till geochemistry suggests that uranium poses a low concern in surficial wells, and that arsenic concentrations could be elevated in some surficial aquifers. Surficial wells intersecting slate tills are more likely to be affected by the underlying Halifax Formation, where arsenic concentrations are frequently elevated. Soil iron, manganese, and lead concentrations are elevated with respect to other regions and tills derived from different host rocks. This condition could be reflected in well water quality. Provincial water quality data were not available for wells drilled in the surficial unit.

Wells drawing water from surficial material can be at risk of contamination by surface sources. Older drilled wells with poor casings, areas where a confining unit is absent or discontinuous, and many dug wells are at highest risk. Influx of surface water can introduce bacteria, and shallow flow systems can transport nutrients, viruses, pharmaceuticals, and personal care products to nearby wells. Any emphasis on the use of screened wells in surficial material will require additional analysis of these factors, including an assessment of Groundwater Under the Direct Influence of surface water (GUDI).

2.2.3 Variability

The average depth of surficial materials is mapped as 4 metres over most of the study area, reaching up to 20 metres. Well records indicate that in other parts of the Lake Echo area the overburden thickness reaches a maximum of 69 m. Till types vary across the study area, from extensive thicknesses of siltier till in the drumlins to the east, to moderate thicknesses of quartzite tills in the central, west, and southern areas, to silty granite tills on the northeast arm. Thick deposits of surficial material described as gravel in well logs suggest that there could be buried fluvial features, potentially in association with depressions in the bedrock surface. The concentration of glaciofluvial features on the west shore of Porter's Lake also suggests the possibility of unmapped granular features.

Due to the variable nature of the aquifer material, water quality and quantity in these deposits can vary from good, where hardness is at a minimum, to poor where arsenic concentrations exceed drinking water standards. Conditions suggest that there is some potential for development of local surficial deposits, but that treatment and disinfection will be a requirement for many systems. The use of deep granular deposits would furthermore require better mapping and delineation.

2.2.4 Interference

The development of water supplies in surficial deposits is subject to several constraints. Due to the nature of construction of shallow wells, they are vulnerable to bacteria introduced through surface inputs and on-site sewage disposal system use. An increasing density of on-site sewage disposal systems and shallow wells has the potential to exacerbate nutrient and bacteria loadings to drinking water. Due to the local variability of surficial deposits, developers of individual properties will not be able to guarantee a viable shallow water supply prior to exploration and test pitting.

Increasing urbanization in Lake Echo Centre will decrease the available area for groundwater recharge, potentially lowering the local water table. The increased run-off resulting from land developments will affect shallow aquifers, increasing contaminant loading, and short-circuiting natural filtration processes. Drawdown influences could be limited by controlling the density of shallow wells in centres of development. A combination of high permeability gravel, storage in the well, and physical separation of adjacent deposits will tend to minimize interference effects under most conditions. A high density of wells in a given deposit, decreasing recharge areas (due to increasing urban area and run-off), or extended periods of drought could cause the water table to decline, increasing the danger of well interference and interruption of water supply.

2.3 Existing Wells in Bedrock Unit

2.3.1 Yield

Table 2.3 provides a summary of data from wells in the Lake Echo area (Nova Scotia Water Well Logs database, 2009).

Table 2.3: Bedrock Well Characteristics for the Lake Echo Area

Date	Well Depth (m) (n=1225)	Casing Length (m) (n=1141)	Depth to Bedrock (m) (n=1057)	Static Water Level (m) (n=798)	Yield (L/min) (n=1185)
95% Confidence Interval	51 to 54	8.7 to 9.5	5.4 to 6.2	4.4 to 4.9	31 to 45
First Quartile	33	6	2	3	7
Median	49	7	4	4	14
Third Quartile	69	9	6	5	32
Maximum	129	71	69	30	2270

Wells installed in the bedrock unit generally reach a depth of 33 metres, with over 75 wells in the study area exceeding a depth of 100 metres. The well yields are variable, depending directly on the number and size of fracture sets encountered. Deeper wells are generally required when shallow fracture sets do not intersect the borehole. Well yields are moderate to low, tending to fall between 7 and 32 L/min, with 73 wells reporting yields over 100 L/min and 5 wells over 500 L/min. This frequency of high yield wells (needed for central or shared supply), suggests that several test holes would be required to locate a major fracture zone.

Figure 2.1 shows a sample of the well distribution in the study area (records showing a georeferencing accuracy of 100 metres or better were plotted). In general the number of wells with yields exceeding 50 L/min in a given area appears to be proportional to the number of wells drilled in that area. A possible exception was noted in Lake Echo centre, where close to half of the wells in the sample showed yields exceeding 50 L/min. No single geologic feature was identified in this area; higher yields could be the result of localized granular deposits and/or steep grades in the area.

Pumping tests were available for Wonderland Mobile Homes (2 wells) and Bell Park School. Reported yields for the wells were moderate to good, ranging from 13.2 to 100 L/min, with long term safe yields from 1.4 to 27 L/min. These wells appear to be generally capable of meeting required demands, and two of the three wells could safely supply average (12 m^3/d) and peak (17 L/min) demands to cluster housing.

2.3.2 Water Quality

Bedrock in the study area, in particular Halifax Formation slates, can impart elevated concentrations of metals to groundwater. A survey of wells servicing the Lake Echo Community Centre and Lake Echo Fire Department showed good raw water quality. Arsenic and uranium concentrations were below the Canadian Drinking Water Quality Guideline (CDWQG) of 10 μg/L and 20 μg/L respectively. The manganese concentration at the community centre was 510 μg/L, exceeding the CDWQG of 50 μg/L. Iron concentrations were below the drinking water guidelines.

Seawater intrusion is a concern for residences on or near the coastline. Seawater intrusion could become a major concern for any single point large volume water takers, including a potential central supply well for the Lake Echo area.

Shallower boreholes can intersect the upper weathered zones of the quartzite and slate formations in the study area. Where this upper zone is not cased off, water cascading from the upper interval can contribute a significant proportion of the well yield. Although increased yields are favourable, water entering a well in this fashion commonly shares a connection with water sources at or near the ground surface. Such a connection renders wells vulnerable to bacterial contamination and road salt.

2.3.3 Variability

Bedrock yields can generally be expected to be at least 7 to 14 L/min, but yields exceeding 30 L/min were observed for just 25% of wells, and yields exceeding 100 L/min were observed for just 7% of wells. Fracture set connectivity and orientations are expected to vary across the study area. Metamorphic units are generally poorly transmissive (provincial median = 1.2 m^2/day), and contain few significant or highly producing fractures. Wells intersecting an upper sequence may benefit from a higher producing weathered zone, but are likely to be vulnerable to surface inputs. As wells are drilled deeper, the frequency of fracture partings tends to decrease, and deep wells will not always produce adequate yields in the Lake Echo area. Deep wells are more likely to depend one or two discrete fracture partings.

2.3.4 Interference

Pumping tests of local water supplies in the metamorphic bedrock provided apparent well transmissivities in the range 0.5 to 2.6 m^2/d. Low transmissivities are consistent with the nature of the

TCH
Unpaved Road
Railroad
Lanes / Driveways
ROAD ruin/inactive/abandoned
Cart Track / Footpath
Ferry
Misc
County Lines
0 0.5 1 2 3 4 Kilometers
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S
Project #:101015
Project Name:Tantallon-St. Margarets Bay & Porters Lake - Lake Echo Watershed Studies
11/11/2011 8:03:36 PM
Data Sources:
NSGC Topographic Database
NSDNR Netlin
Lake Echo
Porters Lake
Porter
Head of Chezze
West Chezzetcook
Petain
Middle Porters Lake
Minesville
Grand Desert
Desert
West Lawrencetown
Seaforth
Naugle
Three Fathom Harbour

deeper sequences of slate and quartzite aquifers, with few, poorly connected fracture partings, and occasional larger weathered partings along shear zones, bedding planes, and contacts with adjacent units. The storativity of metamorphic rocks in the study area is expected to be low. This type of environment is consistent with low yields, extensive drawdown within wells, and a moderate radius of influence. Contingent on fracture connectivity, there is a moderate potential for well interferences.

CHAPTER 3 ANALYSIS OF DEMAND AND WELL YIELD

Development of groundwater resources may be assessed according to the concepts of aquifer yield and basin yield (Freeze, 1971). A complete analysis and calculation of yields for aquifers in the Lake Echo area is beyond this scope of this study, however, preliminary calculations are shown in Table 3.1. Calculations are based on the following water balance equation (Freeze and Cherry, 1979):

$$Q(t) = R(t) - D(t) + dS/dt$$

Where:
Q(t) = total rate of groundwater withdrawal
R(t) = total rate of groundwater recharge to the basin
D(t) = total rate of groundwater discharge from the basin
dS/dt = rate of change of storage in the saturated zone of the basin

Table 3.1: Aquifer Yield Analysis

	Low Growth	Moderate Growth	High Growth
Infiltration (m/yr)	0.15	0.15	0.15
Area (m^2)	77 255 736	77 255 736	77 255 736
Recharge (m^3/yr) R(t)	11 588 360	11 588 360	11 588 360
Demand (m^3/yr) Q(t)	446 614	718 466	1 009 736
% of recharge pumped	4	6	9
Discharge (m^3/yr) D(t)	11 141 746	10 869 894[1]	10 578 624[1]

[1] Groundwater discharge estimate does not include water released from storage

Projected demands were compared to the available water budget for the Lake Echo area. Current demand is estimated at 4% of local groundwater recharge. The calculation assumes that all water is drawn from infiltrating precipitation falling within the study area, which implies a focus on withdrawals from surficial aquifers. Additional components of regional flow may be available in the bedrock aquifer. Calculations indicate that under a high growth scenario, groundwater use would increase only slightly to 9% of recharge to area aquifers. The remaining 91% of recharge local to the study area would remain available as base flow to streams, lakes, coastlines, and regional recharge.

Reliance on groundwater to service new developments in the Lake Echo area is likely to be focused on locating productive zones of the surficial and bedrock aquifers, and on treatment for arsenic, manganese, and iron. As subdivision developments progress, an increasing density of septic systems will become a factor. Further investigations should focus on the intensity of use of individual aquifers, and the water budgets for new subdivisions. With increasing development there will be a need for evaluation of sustainability on a case by case basis. Although the regional water budget suggests that projected development will be sustainable, local water budgets should be considered.

Table 3.2: Sourcing Options

Water Source	Number of Wells Needed to Meet Peak Demand	Formation	Comments
Central Municipal	2[1]	Surficial Unit	Exploration required
			Large tract of undeveloped land preferred
			Treatment for arsenic, iron and manganese may be required
			Moderate protection from surface influences
Cluster Supply (10 homes / well)	1670[2]	Surficial Aquifer	Yields are adequate
			Location of surficial deposits not well mapped
			Constraint on development - dwelling locations
			Constraint on development - potential contaminant sources
			Water supply vulnerable to surface contamination / septic influences
Cluster Supply (10 homes / well)	1670[2]	Bedrock and Surficial	Improved well spacing
			Better protection for bedrock wells
			Reduced well interference effects
			Reduced long-term drawdown in each aquifer
			Yields in bedrock wells commonly inadequate for peak demand
Individual Wells	2300	Bedrock and Surficial	Yields are adequate
			Well density could become a factor in Lake Echo centre
			Well interference effects may become a problem
			Some drawdown of water table, local water tables
			Dug wells affected by periods of drought
			Wells may draw groundwater affected by up gradient septic systems

1 Based on large diameter high-yield wells installed in quaternary deposits.

2 Total includes 1,600 existing units and 70 new cluster wells.

Supply options are presented in Table 3.2. Production characteristics of existing surficial wells suggest that a central municipal supply could be accomplished with as few as two large diameter wells, with the assumption that an extensive quaternary deposit can be located, and that several additional test wells would be a part of the exploration program. Ideally the well field would be located in an area apart from future residential, commercial, industrial, and coastal areas. Conditions in the western half of the undeveloped zone in the corridor between Highway 7 and Highway 107 appear to provide adequate separation and confinement of the aquifer. As geological data from the water well database are limited to populated areas along roadways, the presence and yield of quaternary deposits in this zone is unknown. Exploratory drilling programs in the valleys of tributaries to Grand Lake, could for example, reveal buried valley deposits. Further mapping and examination of available data sources would be required to select potential drilling locations.

Treatment prior to distribution could be a requirement to address arsenic, iron, and manganese concentrations. The data suggest that aquifer yields would be adequate to develop a central water supply provided that the yields in the water well database could be reproduced (i.e. if exploration succeeded in locating these high yield zones). Although potentially viable from a yield perspective, central services based on groundwater could be cost prohibitive pending the costs of treatment, exploration, and construction of a distribution network.

As groundwater resources in the Lake Echo area do not appear to be overexploited, additional development of groundwater resources should be sustainable. Although each of the scenarios presented in Table 3.2 is likely to be viable, widespread installation of individual water wells and on-site sewage disposal systems would not provide the most effective option for source water protection. With an increasing density of groundwater users, single wells supplying clusters of up to 10 homes would provide improved protection to area aquifers. This option has several advantages from a supply and aquifer vulnerability perspective including the following:

- Yields are generally adequate;
- Both surficial and bedrock wells can be incorporated, balancing well interference effects; and
- The use of bedrock wells reduces to potential for contamination by on-site sewage disposal systems in higher density subdivisions.

Cost sharing of a shared (cluster) system would require planning strategies consistent with Conservation Subdivision Design (e.g. open lot condominiums). A planning oriented investigation to assess the viability and promotion of shared wells and on-site sewage disposal systems in HRM is warranted.

CHAPTER 4 AQUIFER VULNERABILITY

4.1 Surficial Unit

Wells installed in the surficial unit are expected to be divided between water table wells, where overburden thicknesses are less than 5 m, and wells intersecting deeper deposits. Where the thickness of the overburden is limited, unconfined conditions are likely to prevail. Unconfined aquifers can receive inputs from the ground surface, and interruptions in supply caused by a low water table can occur. Potential contaminant sources include on-site sewage disposal systems, road salt, bacteria from storm water runoff, and localized spills of fuels or solvents. Careful planning is required to ensure that new and existing dug wells are not placed down gradient of septic systems and that separation distances are maximized.

As the distribution of on-site sewage disposal systems in a given area reaches a critical density, nutrient loading to the aquifer can overwhelm natural breakdown processes that attenuate effluent. As development proceeds, concentrations of NO_2^-, NO_3, NH_4^+, organic nitrogen, phosphates, pharmaceuticals, and other metabolites are expected to increase in the shallow groundwater and local water bodies. The mobility of pharmaceuticals and other metabolites (e.g. caffeine) in groundwater is not well characterized, but these compounds have been shown to be persistent and have been detected in drinking water.

Well logs indicate that extensive overburden thicknesses will allow for wells to be drilled deeper into the surficial unit. Where deeper sequences of overburden are present, drilled wells are preferred over dug wells. Shallow aquifers may be able to provide an adequate and moderately secure supply of drinking water provided that:

- Development pressures do not exceed the local aquifer yield;
- Widespread nutrient loading does not compromise the water quality;
- Well casings are properly constructed and/or upgraded; and
- Treatment needs are determined on a case by case basis.

4.2 Bedrock Unit

Conditions in the bedrock unit are expected to be semi-confined to confined where overlain by quartzite till, and confined where overlain by thicker silty deposits (e.g., drumlins). Quartzite and slate tills will provide adequate protection to the bedrock aquifers in areas where flow in the surficial sediments is primarily horizontal (limiting interaction with the bedrock unit). Incoming contaminants are likely to enter the shallow groundwater flow system and discharge to local water bodies. Where drumlins are present they generate secure conditions for the underlying sequences of bedrock, as the silty material and sloped ground surface will tend to discourage any large scale infiltration and downward flow of contaminants.

Proximity to the coastline is a disadvantage for deeper bedrock wells. Intrusion of brackish water is a concern in the southern part of the Lake Echo area, where development is focused along the coastlines of Lawrencetown Lake and Porter's Lake. Although projected developments are not expected to have widespread effects on the bedrock aquifer, any major water taking at a coastal site could draw the fresh water – seawater interface inland. Development of bedrock wells for large scale water takings in coastal areas should be avoided.

Some wells in the study area will be subject to GUDI classification. Factors such as proximity to surface water bodies and limited or absent confining layers indicate GUDI conditions. Any centralized water supplies, or supplies for public buildings would require GUDI investigations. Treatment would likely be required as mandated by the results of the GUDI study.

The bedrock aquifer may be able to provide a secure drinking water supply provided that:

- Development pressures do not exceed the aquifer yield;
- Excessive withdrawals do not occur close to coastal areas;
- Well casings are properly constructed and/or upgraded; and
- Treatment needs are met as required by GUDI studies and individual well water quality.

4.3 Well Head Protection Planning

If a centralized supply were to be developed to meet study area needs, the well field would require a Well Head Protection Plan (WHPP) under provincial legislation. A WHPP defines an area around the well field which is designated as protected land. Land uses within this area are restricted to ensure that activities do not compromise the aquifer which provides the water supply.

Ideally a well field and thus a Well Head Protection Area (WHPA) would be located in an undeveloped area, away from surface water bodies, with an adequate confining layer. Land which can be readily zoned and controlled by the municipality is preferable.

4.4 Potential Sources of Contamination

The following is a list of common land uses and their relative risk to source water, ranked from least risk to greatest risk (taken from Nova Scotia Environment and Labour's Developing a Municipal Source Water Protection Plan: A Guide for Water Utilities and Municipalities Step 3 – Identify Potential Contaminants and Assess Risk).

Low Risk Activities

- Land surrounding reservoir/well owned by water utility/municipality;
- Permanent open space dedicated to passive recreation; and
- Woodlands and managed forests.

Medium-Low Risk Activities

- Field crops: pasture, hay, grains, vegetables;
- Low-density residential: lots greater than 2 acres; and
- Churches, municipal buildings.

Medium Risk Activities

- Institutional uses: Hospitals, Universities;
- **Medium-density residential: 0.5 to 1.0 acre lot sizes; and**
- Commercial uses with limited hazardous material storage or underground chemical or fuel storage.

Medium-High Risk Activities

- Agricultural production: dairy, livestock, nurseries, orchards;
- Golf courses, quarries; and
- **High-density housing: lots smaller than 0.5 acre.**

High Risk Activities

- Retail commercial: gasoline, farm equipment, automotive, dry cleaners, photo labs, machine shops, furniture strippers;
- Industrial: all forms of manufacturing and processing;
- Underground chemical and fuel storage; and
- Waste disposal: pits, dumps, ponds, lagoons, landfills.

These categories provide an indication of the relative concern caused by potential sources of contamination to source water in the study area. More detailed studies would be required to assess the potential risk that each of the existing land uses poses to the source water, accounting for factors such as proximity to a well head, specific type and scale of activity, longevity of activity, management practices employed, etc.

The following section details the potential sources of water contamination within the Lake Echo Study Area. Locations of potential contaminant sources are shown on Figure 4.1. Development and potential sources of contamination are focused along main coastal roads. Low density housing and the absence of industrial activity leads to generally local potential sources of contamination. Two potential fuel storage and handling facilities, up to four private sewage treatment facilities, one potential chemical handling and storage facility, and three active or abandoned quarries in Lake Echo centre pose the most concentrated threats to water quality in the study area. Potential threats to groundwater quality in the Lake Echo study area appear to be generally minor and dispersed as compared to the Tantallon and Porter's Lake study areas.


TCH
Unpaved Road
Railroad
Lanes / Driveways
ROAD ruin/inactive/abandoned
Cart Track / Footpath
Ferry
Misc
Small Farm
Cemetery
Chemical Storage and Ha
Fuel Storage and Handlin
Private Wastewater Treatr
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Project #:101015
Project Name:Tantallon-St. Margarets Bay &
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Data Sources:
NSGC Topographic Database
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Middle Porters Lake
Minesville
Grand Desert
Desert
West Lawrencetown
Seaforth
Naugle
Three Fathom Harbour
Lawrencetown
Lloy

Agricultural Areas

There are five farms in the southeast corner of the study area and one farm to the west of Porter's Lake centre. Hobby farms and livestock are the most likely uses of farms in the area. The requirement for irrigation and/or spraying is unknown, but storage and handling of manure is likely. If water supply wells were to be located near farms, more detailed on-site reconnaissance would be required. Each of the farms could under specific conditions propose a threat to local shallow groundwater supplies under the direct influence of surface water (GUDI wells).

Pits and Quarries

Provincial mapping shows three small quarries near Lake Echo Centre, two small pits or quarries on the northeast arm of the study area, three small and one larger site along the west shore of Porter's Lake, and a larger pit/quarry to the west of Lawrencetown Beach. One of the quarries in Lake Echo Centre was active and operating above the water table. A second quarry was inactive and filled with water, indicating that the excavation was terminated below the water table. Contaminants released at the floor of pit/quarry excavations can short-circuit into adjacent aquifers. High risk land uses should be prohibited near pits and quarries.

Light Industrial Activity

Three sites in the study area were observed and classified as potential chemical storage and handling facilities. Individual site uses included a welding shop on the northeast arm (solvents, plating solutions, and degreasers), a plant nursery near Lake Echo Centre (fertilizers and pesticides), and a site storing refuse and abandoned or poorly maintained shacks adjacent to Highway 7.

Cemeteries

There are three known cemeteries in the study area, all located on main routes. Cemeteries were identified in Minesville, to the west of Porter's Lake, and on the northeast arm of the study area. Cemeteries in the study area have the potential to affect local shallow groundwater supplies.

Abandoned Mines

Minesville is host to a historically significant gold mining district of Nova Scotia. There are over 50 abandoned mine shafts, open cuts, and pits at and to the west of Minesville. Many of these shafts are located outside the western boundary of the study area. Gold deposits are commonly associated with elevated concentrations of arsenic.

Tailings deposited near the shafts and at gold ore processing sites can generate significant source zones of arsenic and other metals. Process streams are also associated with elevated concentrations of cyanide. Arsenic originating in flooded tailings ponds or flooded shafts may be present in its reduced form (AsIII), which is relatively mobile in aquifers. This mining district could present an obstacle to obtaining a reliable groundwater supply in the area.

Fueling and Service Stations

Three active service facilities were identified along Highway 7, including a service station, a used car dealership, and a heavy equipment contractor on Harmony Way. An abandoned garage was also noted on Highway 7. Three sites adjacent to the northern part of Porter's Lake included a smaller service station, a marina, and a truck servicing/tractor trailer storage lot. A heavy equipment refuelling station (three above-ground storage tanks) was identified near Lawrencetown.

Fuelling stations are equipped with one or more underground storage tanks (UST) for gasoline and diesel fuel. Older tanks can deteriorate and develop perforations, releasing fuel to the subsurface environment and generating significant source zones for groundwater contamination. Garages may use and store lube oil, degreasers, and paint. Older garages often have oil change pits and sumps excavated directly into the underlying soil, creating a direct conduit for flow of contaminants into the subsurface.

Private Sewage Disposal Systems

The Mountainview Wonderland Mobile Home Park operates a classified private sewage treatment system in Lake Echo Centre. Other likely locations for on-site sewage disposal systems serving larger facilities included two schools near Lake Echo Centre, and closer to Porter's Lake, the Lake Echo Community Centre. Facilities at or adjacent to Lawrencetown Beach included the teahouse and surf shop, a bed and breakfast, the beach canteen, and a group of outhouses on the beach parking lot.

Sewage treatment systems can impart elevated concentrations of bacteria, viruses, dissolved organic carbon, biological oxygen demand, chloride, nitrogen compounds, phosphates, pharmaceuticals, and personal care products (e.g., acetaminophen, caffeine, codeine, nicotine, antidepressants, antibiotics, and estrogenic steroids). High rates of extraction in areas where the density of sewage treatment systems is relatively high could impart contaminants to drinking water. Discharges of sewage effluent to salt water systems could help to alleviate this effect.

Seawater Intrusion

Development outside of Lake Echo Centre is focused largely along coastal routes including Mineville Road, Highway 207, and West Porter's Lake Road. Large scale use of groundwater in these coastal areas could lead to intrusion of brackish lake water or seawater. High pumping rates in coastal areas draw the freshwater-seawater interface inland. This effect could compromise existing wells closer to the coastline and eventually compromise the pumping well itself.

Location of Past Spill Events

In order to determine the location of past spill events within the study area, an Environmental Registry Search must be requested from Nova Scotia Environment and Labour. A Search must be requested for each property in question at a cost of $21.30 per civic address. This Search can also provide information on:

- Approvals issued under the *Environment Act;*
- Certificates of qualification issued under the *Environment Act;*
- Certificates of variance issued under the *Environment Act;*
- Orders, appeals, decisions and hearings made under the *Environment Act;*
- Notices of designation given pursuant to the *Environment Act;*
- Notices of a charge or lien given pursuant to the *Environment Act;* S.132;
- Policies, programs, standards, codes of practice, guidelines, objectives,
- Directives and approval processes established under the *Environment Act;*
- Convictions, penalties and other enforcement actions brought under the *Environment Act;*
- Information or documents required by the regulations to be included in the registry;

- Annual reports;
- Petroleum storage tank registration information; and
- Well log information

When potential areas for groundwater supply are confirmed it will be necessary to request a search for registered storage tanks and other point sources. The results of each Environmental Registry Search are available two to four weeks after the request is made.

CHAPTER 5 SUMMARY AND RECOMMENDATIONS

5.1 Summary

The groundwater resources evaluation of the Lake Echo area is summarized as follows:

- Incoming precipitation in the study area is assumed to recharge primarily the surficial aquifer; components of recharge to deeper groundwater regimes could occur in upland areas to the north of the study area, and in the central, uninhabited part of the site;
- Flow in the bedrock aquifer is assumed to be regional, with gradients primarily horizontal or upward;
- Surficial aquifers in lowland areas are composed primarily of granular deposits within quartzite and slate tills;
- Thicknesses of granular deposits commonly reach 6 metres, with a maximum reported overburden thickness of 69 m;
- Individual wells in the surficial aquifer are capable on average of providing 9 to 84 L/min;
- Wells installed in surficial aquifers are expected to be capable of supplying clusters of 10 homes or more;
- The bedrock unit is composed of metamorphic rock with an upper weathered zone and limited fracture partings at greater depths;
- Individual wells are on average drilled 33 to 69 m into the bedrock, and provide water at 7 to 32 L/min;
- Most wells installed in the bedrock should be capable of supplying clusters of up to 10 homes;
- Arsenic and uranium concentrations were below CDWQG in three samples from two bedrock wells;
- The manganese concentration exceeded the taste and odour guideline in a sample of raw water from the community centre;
- The depth and yield of drilled wells is variable. Many bedrock wells likely rely on single or discrete sets of fractures near the base of the well;
- A high density of shallow wells could cause a decline in the local water table, potentially interrupting the supply to the shallowest wells;
- The bedrock transmissivity and storativity are low, indicating that drawdown cones will be deep with a moderate radius of influence;
- Under current conditions approximately 4% of potential recharge is pumped for water use in the Lake Echo area;
- Under a high growth scenario up to 9% of potential recharge would be pumped as drinking water;

- A balanced approach would include wells drawing water from both the bedrock and surficial aquifers;
- An analysis of potential servicing scenarios indicates that all approaches could be sustained at the projected rate of growth;
- CSD style development would encourage the development of water supplies and on-site sewage disposal systems serving clusters of homes, providing improved groundwater resources management with respect to traditional open-lot designs;
- Under increasing population density, surficial aquifers will be vulnerable to bacterial inputs, nutrient loading (septic effluent), pharmaceuticals / metabolites (septic effluent), and water table depletion;
- The bedrock aquifer receives some protection from the overlying tills, particularly in upland areas and where drumlins are present;
- Well casings must be maintained in excellent condition to minimize surface inputs to all wells; and
- Arsenic, iron and manganese treatment could be required for some groundwater supplies in the study area.

5.2 Recommendations

Existing high-yield water supplies suggest that the yields of selected aquifers in the Lake Echo area are adequate to provide central servicing. Additional investigation would be required to locate an extensive deposit of granular material, preferably in a remote area where a WHPA could eventually be designated. If future development is to encourage growth of a centralized urban area, a detailed hydrogeological investigation is recommended.

Outlying parts of the Lake Echo area are expected to develop as traditional open space lots or according to the principles of CSD. The HRM Guidelines for Groundwater Assessment and Reporting (2006) provide instruction and requirements for new developments. As part of and in addition to this document, developers should be required to provide the following site specific information:

- Depth of till or surficial aquifer in the location to be developed;
- Presence or absence of silty material in location to be developed;
- Proximity to existing wells;
- Known problems with water quality or quantity in neighbouring wells;
- Projected density of residences; and
- Plan for best use of both bedrock and surficial wells.

If the population of the Lake Echo area is to approach 5,200, water supply planning measures should be implemented prior to further development. Measures to mitigate potential supply problems include:

- Drilling of test wells for central water supply;
- Evaluation of a central surface water supply;
- Nutrient loading calculations to evaluate the need for central sewage collection;
- Implementation of water conservation strategies (watering restrictions, low-flow appliances, rainwater cisterns);
- Promotion of well stewardship, casing maintenance, and regular water quality testing;
- Upgrades to existing wells;

- Incentives and requirements for developers to establish a binding lot plan showing well and on-site sewage disposal system locations;
- Incentives or requirements for developers to implement cluster supplies for groups of 10 (or more) single family homes;
- Establishment of guidelines for well maintenance and treatment for cluster supplies; and
- Monitor and reassess development of surficial aquifers.

Use of CSD concepts in the implementation of cluster well and on-site sewage disposal systems in HRM should be investigated in more detail. The study should seek to clarify the logistics of designing and promoting (or requiring) shared wells and on-site sewage disposal systems in the context of advantages and constraints specific to HRM.

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APPENDIX C

Component Study – Surface Water Quality Survey

Contents

Appendices

CHAPTER 1 INTRODUCTION

Receiving waters are distinct bodies of water (lakes, estuaries and embayments) that are of concern because they are in the flow path for receipt of potential pollutants and contaminants from their watershed. This study focuses on the water quality in Lake Echo as the primary receiving water for surface runoff from the associated watershed. Lake Echo is valued for its recreational and aesthetic potential, and population growth scenarios are being considered. Most development has occurred around the center of the lake in the community of Lake Echo. As there is no service by centralized freshwater supply or communal wastewater collection system in the area, the quality of surface water, as well as the mode of wastewater treatment and discharge, are of paramount importance for the current and future population of the area and for the ecosystem.

1.1 Objectives and Methodology

The objectives of this study are to describe the current state of surface water quality in relation to past and ongoing development pressures, and to present an informed discussion of the constraints and opportunities given by the surface water characteristics of the study region with respect to new developments. To address these objectives CBCL Limited carried out a sampling program to determine a number of water quality parameters under varying environmental conditions at strategic locations within the study area. This report also describes the findings of a phosphorus loading model based on land use and precipitation to predict phosphorus concentration in key lakes of the study region. As phosphorus concentration is a primary water quality parameter, its prediction and evaluation is a useful indicator for establishing the boundaries for sustainable development within the water shed. This applies particularly for decision-making on wastewater treatment systems and the management of surface water runoff patterns. In addition, a hydrodynamic model was developed to investigate effluent dilution patterns and likely bacterial pollution sources that would explain the observed pollutant concentrations during the sampling program.

1.2 Study Area

The watershed of Lake Echo is between 3 and 7 km wide, about 4.5 km long in the north-south direction and has a surface area of 13,612 ha (Figure 2.1). With a 243 ha surface area, Lake Echo is the second largest body of water in the watershed (after Lawrencetown Lake downstream). It is fed by Salmon

River, which itself fed by numerous small and mid-sized lakes. Lake Echo has a maximum depth of 10 m in the centre of the cove surrounded by the community of Lake Echo (Figure 3.2).

Table 1.1: Most Important Lakes in the Lake Echo Study Area

	Area, ha		
	Drainage Basin	Lake	Total
McKay Lake	4019	114	4134
Byron Lake	454	43	496
Tittle Lake	928	73	1002
Loon Lake	167	41	209
Williams Lake	638	91	729
East Lake	277	64	341
Salmon River Long Lake	420	96	516
Granite Lake	926	84	1010
Lewis Lake	747	60	807
Martin Lake	1146	49	1195
Lake Echo	1404	243	1647
Lawrencetown Lake	1021	463	1484

Area is given in hectares (ha, 1 ha = 10,000 m^2)

1.3 Definition of Assimilative Capacity

The so-called assimilative capacity refers to the ability of the environment or a portion of the environment (such as a stream, lake, or soil layer) to receive waste material without adverse effects on the environment or on users of its resources. The US EPA define assimilative capacity as "The ability of a body of water to cleanse itself; its capacity to receive waste waters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water"[1]. Determining assimilative capacity of aquatic ecosystems is not straightforward, since a substance may potentially affect many different organisms in a variety of ways. In general it is accepted that symptoms of water pollution (e.g., high nutrient levels, algal blooms, high *E. coli* counts, and deoxygenation) are observed when the assimilative capacity is exceeded. Two other terms are also relevant: 1) *critical load;* and 2) *self purification*. The term critical load is synonymous with assimilative capacity and is commonly used to refer to the mass of a substance which, if exceeded, will result in adverse effects, i.e., pollution. Self purification refers to the natural process by which the environment cleanses itself of waste materials discharged into it.

Because of the technical complexity in accurately determining critical loads, preliminary assessment of the assimilative capacity of receiving waters is generally done by examining whether there is exceedance in the ambient levels of water quality variables that are indicators of water pollution. For this study the focus has been on levels of nutrients (nitrogen and phosphorus), algal biomass (measured as chlorophyll *a*), oxygen status, organic pollution (BOD) and microbial populations (fecal coliform and *E. coli*). The

[1] U.S. Environmental Protection Agency (December 1997) Terms of Environment: Glossary, Abbreviations and Acronyms. [online] Washington, D.C. Available from: http://www.epa.gov/OCEPAterms/ [accessed 18th October 2010]

degree by which assimilative capacity has been exceeded or not can be assessed by relating concentrations at monitoring stations to water quality guideline levels published by the Canadian Council of Ministers of the Environment (CCME- http://ceqg-rcqe.ccme.ca/).

CHAPTER 2 FIELD INVESTIGATIONS

2.1 Methodology

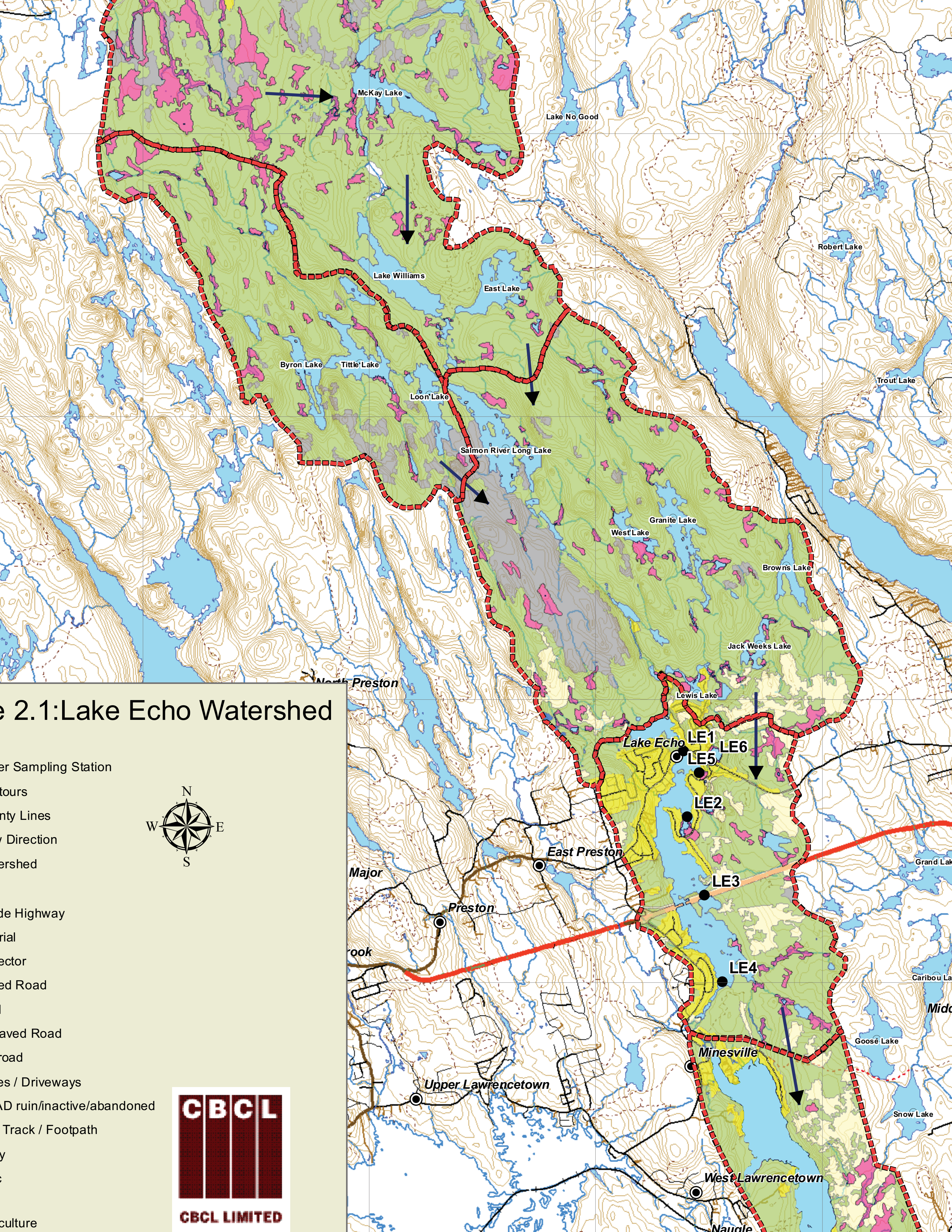
2.1.1 Sites and Parameters

The field sampling program was designed to cover a comprehensive suite of water-quality parameters (Table 2.1) in wet and dry weather conditions during spring, summer and fall season of 2010, and summer and fall of 2011. Sampling locations were strategically selected to provide baseline data for the most important locations within Lake Echo, as well as for the validation of the phosphorus model (Table 2.2). Details of the positioning of the sampling sites are shown in Figure 2.1 and Table 2.2.

In situ parameters of water temperature, pH and salinity were measured with a Horiba multi probe, Model W-21. The probe was lowered into the water column using a graduated cable for measurements at 1-m depth intervals where appropriate. Water samples for biological and chemical analyses were collected in sterilized sampling bottles and analysis was performed by laboratories according to recommended and accredited standard methods. All samples were stored on ice and delivered to the lab within six hours of taking the sample. Water samples for the determination of chlorophyll *a* were wrapped in metal foil to avoid degradation of pigment by sunlight.

Table 2.1: Water Quality Parameters Measured at Each Station

Parameter	Symbol	Units	Description
Water temperature		°C	Measured *in situ*
pH	pH		Measured *in situ*
Salinity		%	Measured *in situ*
Concentration of Escherichia coli	E. coli	CFU/100 ml	CFU (Colony Forming Units): the number of colonies on the incubation plate
Concentration of fecal coliform bacteria	FC	MPN/ml	MPN (Most Probable Number): an approximation of the number of bacteria from a count of the number of colonies.
Total Phosphorus	TP	mg/L	Laboratory measurement
Carbonaceous Biological Oxygen Demand	C.BOD	mg/L	Laboratory measurement
Chlorophyll *a*	Chl *a*	µg/l	Laboratory measurement



McKay Lake
Lake No Good
Robert Lake
Lake Williams
East Lake
Byron Lake
Tittle Lake
Loon Lake
Trout Lake
Salmon River Long Lake
Granite Lake
West Lake
Browns Lake
Jack Weeks Lake
North Preston
Lewis Lake
Lake Echo
LE1
LE6
LE5
LE2
LE3
LE4
East Preston
Major
Preston
Grand Lak
Caribou La
Goose Lake
Minesville
Upper Lawrencetown
Snow Lake
West Lawrencetown
Naugle
e 2.1:Lake Echo Watershed
er Sampling Station
tours
nty Lines
v Direction
ershed
de Highway
rial
ector
ed Road
aved Road
road
es / Driveways
AD ruin/inactive/abandoned
Track / Footpath
culture
N
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S
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Parameter	Symbol	Units	Description
Nitrate	Nitrate	mg/L	Laboratory measurement
Nitrite	Nitrite	mg/L	Laboratory measurement
Ammonia	Ammonia	mg/L	Laboratory measurement
Total Kjeldahl Nitrogen	TKN	mg/L	Laboratory measurement
Total suspended solids	TSS	mg/L	Laboratory measurement

Table 2.2: Station IDs and Locations for Water Sampling Sites in the Lake Echo Study Area

ID	Easting	Northing	Description
LE 1	469550	4954090	Northern area near beach and docks
LE 1 at dock	469495	4953964	
LE 2	469613	4952930	Northeast cove surrounded by Ponderosa drive
LE 2 from shoreline	469545	495258	
LE 3	469550	4951387	Middle of Lake Echo under HW7 bridge
LE 4	470237	4950020	Near outlet
LE 5	469823	4953717	Northeast cove near McCoys pond discharge
LE 6	470045	4953900	McCoys pond outlet
LE 7	469945	4954533	Trailer park Sewage Treatment Plant (STP) discharge ponds outlet
LE 8	470079	4954229	McCoys pond inlet
LE 9	469505	4954253	Martins Lake outlet

Geographic coordinates are UTM NAD83 Zone 20.

2.1.2 Technical Comments on Bacterial Counts

Fecal Coliform (FC) and E-Coli have been traditionally used in most jurisdictions as the primary bacterial indicators. Recently E-Coli (a subgroup of FC) was established as the preferred indicator (CCME 2004), because it is reported to correlate best with bather illnesses in sewage impacted recreational waters (Noble et al. 2003). For this study the samples were analysed for both E-Coli and FC. There is a vast spread in the measured FC range (and often questionably high values) reported by Maxxam Analytics for the 2010 samples using the MPN-Isogrid method. Results for E-Coli using the CFU method exhibit less variability and are within a range that is consistent with other local studies (HRM Lake sampling program at Lake Echo).

The units of measurement for bacteria reported in this study, CFU versus MPN, are based on different methods to estimate the number of bacteria in a sample. CFU, i.e. Colony Forming Units, is the number of colonies on an incubation plate determined by direct count. MPN, i.e. Most Probable Number, is the result of a calculation based on a statistical model using the number of colonies as an input and yields an estimate of the actual number of bacteria. At low concentrations, i.e. less than 100 cells, CFU and MPN methods yield very similar results. At high cell concentrations, the method resulting in MPN yields higher counts compared with CFU, because the MPN calculation takes into account the probability that there are more than one bacterium per colony. In addition, the results for FC bacteria reported in this study were determined by analysing the sample on large filters (ISOGRID) capable of detecting large numbers of FC, including those that grow poorly or ferment lactose slowly (source: Maxxam Analytics). This technique further contributes to the trend towards high values from the MPN method.

2.2 Water Quality Measurements

All results are listed on Table 2.3. Water quality samples were taken on 7 dates over the period between April and October 2010, with additional samples in July and November 2011. The weather conditions immediately prior to sampling days covered a range of dry and wet periods at different parts of the sampling season. Precipitation, which can exacerbate water quality problems by flushing contaminants into the receiving waters, ranged from 0 to 52 mm of cumulative rainfall over the 48 hours prior to each of the sampling days. The sections below report the findings for each measured parameter and present a discussion of them in the context of the Canadian Water Quality Guidelines for the Protection of Aquatic Life from the Canadian Council of Ministers of the Environment, hereafter referred to as the CCME Guidelines. This discussion follows the Update 7.1 (2007) of the CCME Guidelines Summary Table for water quality parameters (Appendix C.1).

		4	10.8	14.5	5.5											
		6	10.7	11.2	5.2											
		8	9.8	8.2	4.8											
	11:25	1	10.3	14.6	6.2	**<100**	<100	0.03	<5	2.3	<0.05				<0.05	
ug-10	**Dry, sunny**		Precipitation in last 48 hours = 0.9 mm													
	09:13	0.1	8.6	23.9	5.7	**4**	1000	<0.02	<5	9.8	<0.05	0.5	0.5	3	<0.05	0.18
		0.5	8.4	23.7	5.6											
		1.5	8.2	23.4	5.5											
		2.5	8.5	23.2	5.4											
		3.5	8.4	23.1	5.3											
	09:24	0.1	8.1	23.3	5.7	**9**	4400	<0.02	<5	5.8	<0.05	0.4	0.4	<2	<0.05	0.06
		1	7.9	23.3	5.7											
		2	7.6	23.0	5.8											
	09:56	0	8.2	23.2	5.8	**13**	1700	<0.02	<5	6.9	<0.05	0.3	0.3	3	<0.05	<0.05
		0.5	8.2	22.9	5.8											
		1.5	8.5	22.9	5.7											
	10:15	0.1	8.5	23.9	5.9	**<1**	900	<0.02	<5	6.4	<0.05	0.4	0.4	3	<0.05	0.12
		1	8.6	23.2	5.8											
		2	8.5	23.0	5.8											
		3	8.2	22.5	5.8											
ep-10	**Showers**		Precipitation in last 48 hours = 5.3 mm													
	09:35	0.1	9.8	18.0	5.6	**>250**	1100	0.02	<5	7.4	<0.05	0.2	0.2	2	<0.05	<0.05
		1	9.8	18.0	5.7											
		1.5	9.9	18.0	5.7											
		2	10.0	18.0	5.8											
		2.5	10.0	17.9	5.8											
		3	10.1	17.9	5.9											
	10:00	0.1	9.4	18.0	6.2	**7**	<100	0.03	<5	3.5	<0.05	0.4	0.4	3	<0.05	0.06
		1.25	9.4	18.0	6.4											
	10:20	0.1	9.8	17.5	6.4	**30**	<100	0.02	<5	6.1	<0.05	0.3	0.3	1	<0.5	0.06
		1	9.9	17.5	6.7											
	10:35	0.1	9.7	16.8	5.8	**7**	<100	0.02	<5	3.3	<0.05	0.2	0.2	1	<0.05	<0.05
		1	9.8	16.8	5.8											
		2	9.7	16.7	5.8											
		3	9.8	16.6	5.8											
		3.5	10.0	16.5	5.8											
	09:50	0.1	9.7	17.7	5.8	**28**	100	0.02	<5	6.2	<0.05	0.2	0.2	<2	<0.05	<0.05
		1	9.8	17.5	6.0											
		1.5	9.9	17.5	6.7											
	11:10	0.1	5.3	17.6	6.1	**12**	400	0.11	<5	27.8	<0.05	0.8	0.8	5	<0.05	0.1
ct-10	**Rain, windy**		Precipitation in last 48 hours = 10 mm													
	10:45	0.1	9.1	17.1	5.6	**240**	1100	0.02	<5	5.6	<0.05	0.3	0.3	2	<0.05	<0.05
		3	9.6	16.7	5.8											
		3.75	9.6	16.7	5.3											
	11:00	0.1	9.2	17.1	6.3	**10**	740	<0.02	<5	4.6	<0.05	0.3	0.3	2	<0.05	<0.05
	11:15	0.1	9.3	16.9	6.3	**40**	350	<0.02	<5	5.1	<0.05	0.3	0.3	2	<0.05	<0.05
	11:30	0.1	9.4	16.9	6.2	**1**	100	<0.02	<5	3.3	<0.05	0.2	0.2	3	<0.05	<0.05
	10:55	0.1	9.2	17.1	6.2	**55**	780	<0.02	<5	7.7	<0.05	0.3	0.3	2	<0.05	<0.05
		1.5	9.0	16.5	5.8											
	11:53	0.1	8.1	16.8	6.7	**32**	>10000	0.16	<5	20.7	<0.05	0.7	0.7	6	<0.05	<0.05
Oct-10	**Rain**		Precipitation in last 48 hours = 52.3 mm													
	10:20	0.1	9.2	12.0	5.8	**45**	48	<0.02	<5	2.3	0.1	0.5	0.6	8	0.1	<0.05
		3														
		3.75														
	10:40	0.1	9.5	13.0	5.5	**41**	100	0.02	<5	3.0	0.08	0.3	0.38	2	0.08	<0.05
	11:20	0.1	9.7	12.0	5.6	**12**	27	0.03	<5	5.6	0.06	0.3	0.36	<2	0.06	<0.05
	11:45	0.1	10.1	12.0	5.5	**15**	36	0.02	<5	6.7	0.11	0.4	0.51	3	0.11	<0.05
	10:45	0.1	9.7	12.0	5.2	**>250**	890	0.04	<5	19.4	0.07	0.5	0.57	2	0.07	<0.05
	10:35	0.1	10.3	12.0	5.1	**100**	1400	0.13	<5	66.8	0.11	0.7	0.81	7	0.11	<0.05
ul-11	**Dry, sunny**		No precipitation in last 48 hours													
t dock	09:45	0.1	7.3	22.1	6.1	6	4	0.177	<2	3.8	<0.1	<0.4	<0.4	<5		
	12:00							0.02								
	10:40	0.1	7.9	22.4	6.9	**5**	28	0.02	4	13.4	<0.1	0.9	0.9	10		
TP Pond outlet	11:20	0.1	0.7	22.0	7.2	**548**	568	2.4	5	6.9	**6.21**	**10.8**	17	8		
	11:45	0.1	6.4	16.6	6.2	**111**	190	1.61	5	1.5	**4.98**	**5.1**	10.1	6		
orth lake inlet	10:45	0.1	8.1	22.2		**3**	10	0.013								
ov-11	**Rain** (27 mm over the whole day, plus ongoing snowmelt)															
t dock	13:00	0.1	8.8	6.8	6.0	13	20	0.019	<2	2.2	0.16	1.4	1.6	<5		
	10:50	0.1	9.1	6.1	7.9	1	2	0.019								
	12:15	0.1	7.8	6.4	6.7	22	14	0.072	<2	21.8	<0.05	1.2	1.7	<5		
TP Pond outlet	12:50	0.1	4.8	8.0	6.4	<1	<2	1.32	<2	0.7	3.49	3.8	7.3	<5		
	12:30	0.1	8.4	7.5	6.6	5	30	0.172	<2	0.5	0.87	0.9	1.8	<5		
orth lake inlet	12:00	0.1	9.2	6.1	5.6	3	<2	0.014								

li thresholds CFU/100ml	
lfish harvest	14

2.2.1 Water Temperature

Temperatures in the water bodies tested ranged between 9 and 24°C over the sampling season. The warmest temperatures at all stations were measured on August 18, 2010 during a period of dry weather. Stations showed mostly uniform temperature through the water column. Temperature is a key physical parameter affecting life in marine and freshwater environments as it influences numerous other properties such as the solubility of gases in water, ionization constants, and the intrinsic growth rates of single celled organisms. Because temperature varies naturally in lakes both temporally and spatially CCME Guidelines, which are concerned about anthropogenic changes in ambient water temperature, are not relevant for this study's context.

2.2.2 pH

The pH in Lake Echo shows relatively little variability with values typically between 4.8 and 6.9. Variations of pH with depth are not systematic, and do not demonstrate conclusive increasing or decreasing patterns. The CCME Guidelines recommend a pH range of 6.5 to 9. Lake Echo waters generally do not meet this general criterion. However, slightly acid water is not unusual for Nova Scotia, where most watersheds have an environment with acidic soils, because of humic material. Values of pH less than 6.0 have been observed for similar studies in other watersheds with various levels of development, so it cannot be concluded with any certainty whether human activity is causing a drop in pH in Lake Echo.

2.2.3 Carbonaceous Biological Oxygen Demand (C.BOD)

C.BOD values were below the detection limit of 5 mg/L in all samples in Lake Echo. These low values indicate that there is little loading of lakes with dissolved organic matter. This has minimal effect on the oxygen levels, as confirmed by uniformly high values of dissolved oxygen concentrations in surface samples (see next section). However, high BOD values (between 4 and 5 mg/L) were detected the trailer park's STP receiving waters, at the STP Pond outlet and further downstream in MCCoys Pond which drains into Lake Echo.

2.2.4 Dissolved Oxygen

All vertical profiles of dissolved oxygen showed relatively uniform oxygen concentration with depth, including down to 8 m deep on 20 May 2010. The CCME Dissolved Oxygen Guidelines for freshwater aquatic life are 5.5 to 9.5 mg/L. The measured concentrations of dissolved oxygen in Lake Echo meet the guidelines. However, the pond receiving wastewater discharge from the trailer park's wastewater treatment plant was measured as hypereutrophic in July 2011, with a DO value of 0.7 mg/L. Downstream of the pond, McCoys Pond (which drains directly into Lake Echo) had a DO value below the recommended minimum on one occasion (5.3 mg/L on 29 September 2010).

2.2.5 Total Suspended Solids (TSS)

The concentration of total suspended solids in all water samples was low, typically less than 5 mg/L. TSS concentration has not been found to be of concern in the water bodies sampled.

2.2.6 Eutrophication Status (Phosphorus, Nitrogen, Chlorophyll)

The process of eutrophication is defined as the loading of inorganic and organic dissolved and particulate matter, including nutrients, to lakes at rates sufficient to increase the potential for high biological production, decrease basin volume and deplete dissolved oxygen (Cooke *et al*., 2005). For the purpose of this report the trophic status of each lake has been assessed by examining the concentrations of nutrients (P and N), the levels of algal biomass (as chlorophyll a present in the lake, and the state of oxygenation of the water column. The results allow for the classification of the lakes into oligotrophic, mesotrophic, eutrophic or hypereutrophic (see Table 2.4).

Table 2.4: Trophic State Indicators

	TP (mg/L)	Chl *a* (µg/l)	DO (mg/L)	TN (mg/L)
Oligotrophic	<0.01	<2.5	>7.2	<0.35
Mesotrophic	0.01 - 0.02	2.5 - 5	6.2 - 7.2	0.35 – 0.65
Meso-eutrophic	0.02 - 0.035	5 - 8		
Eutrophic	0.035 - 0.1	8 - 25	< 6.2	0.65 – 1.2
Hypereutrophic	> 0.1	> 25		> 1.2

Values in Table 2.4 are based on the following sources:

- Boundary values for TP and Chl A are from Vollenweider and Kerekes (1982) as recommended by Brylinski (2004) for NS Lake Phopshorus Loading Models;
- The boundary between mesotrophic and meso-eutrophic represents the threshold to avoid nuisance algae as defined by the Province of Ontario who use a TP limit of 0.020 mg/L. The equivalent Chl A is estimated at 5 µg/L, as supported by Figure 2.2;
- Boundary values for DO and TN from Cooke et al. (2005);
- TP and TN thresholds apply if the particular nutrient is limiting. Typically P is the limiting nutrient, and therefore a TN concentration in the eutrophic range has no impact if the TP concentration is limiting; and
- Total nitrogen can be calculated from the parameters measured in this study as the sum of TKN and Nitrate+Nitrite.

2.2.6.1 PHOSPHORUS

The findings indicate that total phosphorus concentrations in the lake are generally in the mesotrophic to meso-eutrophic range. On several occasions phosphorus levels in the summer and fall are close to the typical trigger range for eutrophication (0.035 mg/L). Measurements indicate that the watercourse and ponds receiving the trailer park's STP effluent and discharging into Lake Echo are hypereutrophic due to excessive nutrient loads.

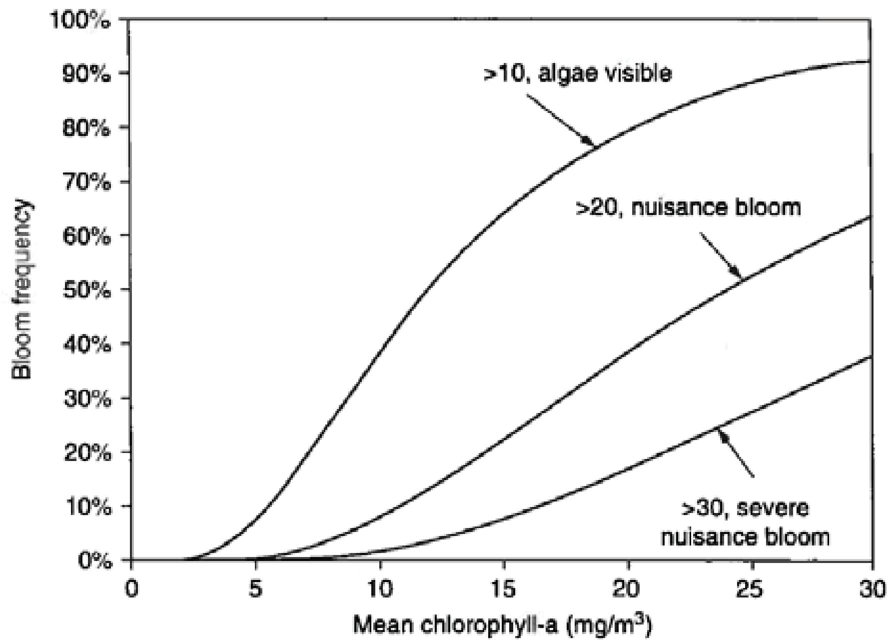

Figure 2.2 **Frequency of Algal Blooms (Defined as Chl A > 10, 20 or 30 mg/L) Related to Summer Mean Chl A** – Source: Walker 1985 (Reproduced from Cooke et al). The mean Chl A threshold for the onset of nuisance blooms is 5 µg/L.

In terms of water quality guideline, one cannot use the eutrophic trigger (0.035 mg/L) as an annual mean guideline because eutrophic conditions typically occur in the summer, when the annual mean value would be lower than the trigger range. There is no Federal or Nova Scotia guideline on recommended annual mean values. The Province of Ontario recommends an average value of 0.020 mg/L for the ice-free period to avoid nuisance algae, while a high level of protection against aesthetic deterioration provided by a TP less than 0.010 mg/L, which should apply to all lakes naturally below this value (Source: Ontario 1994). Based on these values, the lake has very little additional assimilative capacity. The nutrient loads from existing development and from the wastewater treatment plant need to be reduced first before considering additional inputs from future development.

2.2.6.2 Nitrogen

Nitrogen concentration in Lake Echo proper varied between 0.2 and 0.5 mg N/l (recorded at station LE5 on October 28 2010). Nitrate, nitrite and ammonia were almost always below 0.1 mg N/l, often even below 0.05 mg N/l (detection limit), however, TKN values range between 0.2 and 0.5 mg N/l. This indicates that most of the nitrogen in the water is in organic form. Ammonia levels were generally <0.05 mg N/l. However, on August 18 and September 28 2010, ammonia levels were detectable (between 0.006 and 0.12). This indicates that pollution from domestic waste does not exceed the uptake capacity of freshwater plants, except during dry seasons and intense usage of the watershed during the peak vacation season.

The ratio TN/TP can be used to assess which nutrient is controlling plant biomass growth due to its lower concentrations (Brylinski 2004). The ratio TN/TP is greater than 10 at all almost all sites, indicating that phosphorus is the limiting nutrient. On occasions where the ratio is less than 10, TP is in the hypereutrophic range and nitrate concentrations are also high, indicating no nutrient limitation in any case. Therefore TN concentrations in the mesotrophic range have no impact on plant growth because of TP limitations. This is typical of large watersheds where nutrient loadings are predominantly from non-point sources.

Outside Lake Echo proper, the tributary to McCoys Pond (LE7 and LE8) was found to have highly eutrophic levels of both nitrogen (TKN of 5.1-10.8 mg/L) and phosphorus (1.61-2.4 mg/L) on July 29 2011. Nitrate contributes about 60% to the TKN, suggesting products of bacterial decomposition and organic matter as the source of the nutrient. The nitrogen and phosphorus level at the outflow of McCoys Pond (site LE6), is not unusually elevated, suggesting that the nutrients are assimilated in the pond and that the high concentration in the tributary are not unusual.

2.2.6.3 CHLOROPHYLL

Chlorophyll levels in the waters of the lakes give a measure of the size of their resident phytoplankton populations, and provide one of the best indicators of eutrophication status. For 5 sampling days in seven, measured chloprophyll levels were in the meso-eutrophic range or higher. McCoys Pond had chlorophyll levels in the hyper-eutrophic range on three occasions.

2.2.7 Bacterial Indicators

The samples were analyzed for two bacterial indicators, fecal coliform (FC) and *Escherichia coli* (E. coli). The fecal coliform bacteria group is indicative of contamination from the intestinal tract of humans and other animals and includes other, more definite groups such E. coli. A commonly used standard based on E-Coli bacteria is 200 MPN/100 ml for primary recreational contact and 14 MPN/100 ml for shellfish harvesting.

Ecoli -

E-Coli concentrations were unsuitable for primary recreational contact in the lake on three occasions. Highest concentrations were observed during wet weather in the fall, including near the paddling club. The source of these high values could not be identified. Faulty sceptic systems from waterfront properties may be among the sources. While measured bacteria levels were very high in the pond receiving the trailer park's STP effluent (>500/100 ml on 29 July 2011 at LE7), further downstream the outlet of McCoys Pond into Lake Echo did not indicate excessive bacterial levels. This suggests the residence time in McCoys Pond may be large enough for sufficient bacteria die-off before its waters enter Lake Echo. The range of measured E. coli concentrations is consistent with data collected by HRM at Upper Lake Echo.

2.3 Evolution of Trophic Status Indicators at Lake Echo Since 2007

The Halifax Regional Municipality (HRM) has reported on three sampling events per year, spring, summer and winter, in Lake Echo since 2007. The HRM sampling site is located in the northern section of the lake between LE1 and LE2 (south of the island at the north end of the lake). Several water quality parameters were measured by HRM, including those determined in this study. The data are presented in Table 2.5.

Table 2.5: HRM Water Quality Sampling Data at Lake Echo

	Units	RDL	CCME Guideline Level	LAKE ECHO														
Sampling Date & Time	DD/MM/YYYY 24hr time			22/11/11	08/08/11	08/04/11	28/10/10	12/08/10	17/05/10	22/10/09	29/07/09	03/06/09	20/11/08	03/09/08	30/05/08	31/10/07	13/08/07	06/06/07
FIELD DATA																		
Secchi Depth	Meters	N/A		1.1	1.2		2.2	2.1	1.6	1.3	1.5	1.7	1.3	1.1	1.9	1.25	2.0	2.0
Temp	Celsius	N/A		7.35	20.72		10.77	22.55	13.42	9.19	23.07	16.66	6.76	18.95	14.93	11.14	21.11	16.03
Dissolved Oxygen	mg/L	0.2	6-9.5	11.74	8.51		12.16	8.35	11.08	11.02	8.43	10.01	13.15	9.40	10.54	9.29	7.84	8.92
pH	pH	N/A	6.5-9.0	5.02	5.39		6.85	5.99	6.81	5.55	5.58	6.57	5.82	4.99	4.60	5.03	4.82	5.12
Specific Conductance	mS/cm	0.001		0.034	0.035		0.045	0.040	0.039	0.037	0.036	0.037	0.040	0.038	0.041	0.037	0.086	0.050
TDS	g/L	0.01		0.022	0.023		0.029	0.026	0.025	0.024	0.023	0.024	0.024	0.025	0.027	0.024	0.056	0.033
Salinity	ppt	0.01		0.01	0.01		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02
INORGANICS																		
Total Alkalinity (Total as CaCO3)	mg/L	5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
Dissolved Chloride (Cl)	mg/L	1		5	6	11	8	7	8	6	5	7	6	5	7	5		7
Colour	TCU	5		130	114	59	46	66	64	128	84	54	120	130	73	62	40	30
Total Kjeldahl Nitrogen (TKN)	mg/L	0.4		0.8	0.5	ND	0.5	ND	ND	0.9	ND	ND	0.5	0.5	0.3	1		0.3
Nitrate + Nitrite	mg/L	0.05		0.06	ND	0.06	0.06	ND	0.1	0.08	ND	ND	0.09	ND	0.11	0.05		0.11
Nitrate (N)	mg/L	0.05	13	0.06	ND	0.06	0.06	ND	0.1	0.08	ND	ND	0.09	ND	0.11			
Nitrite (N)	mg/L	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	19	0.12	ND	0.06	ND	0.05	0.06	0.06	ND	0.06	ND	ND	ND	ND		ND
Total Organic Carbon (C)	mg/L	0.5		15.9	11.6	7.7	8.0	9.3	9	13.4	9.6	6.2	11	10	4.9	11		5.6
Orthophosphate (P)	mg/L	0.01		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND
pH (Lab)	pH	N/A	6.5-9.0	5.3	6.1	5.6	6.0	6.3	5.8	5.2	6.0	5.8	5.10	5.22	5.33	5.32		5.63
Total Phosphorus (1M depth)	mg/L	0.002		0.012	0.018	0.011	0.013	0.020	0.048	0.020	0.012	0.013	0.017	0.015	0.004	0.009	0.01	0.009
Reactive Silica (SiO2)	mg/L	0.5		3.3	2.1	2.5	1.8	1.4	1.5	3.1	1.8	0.5	3.5	2.5	1.4	3.1		1.1
Total Suspended Solids	mg/L	5		ND	ND	ND	ND	ND	ND	ND	ND	ND	1	2	ND	2	3	ND
Dissolved Sulphate (SO4)	mg/L	2		3.00	4	4	5	4	4	4	4	4	ND	4	4	2		5
Turbidity	NTU	0.1		1.2	1.4	0.9	1.1	1.7	1.2	0.9	1.1	1.2	0.7	0.7	0.6	0.9	1.2	0.8
Conductivity	µS/cm	1		32	33	42	44	41	41	41	36	40	40	38	42	37		47
MICROBIOLOGICAL																		
Fecal coliform Lake	CFU/100mL	2	200						169	14	38	14	18	32	1	5	82	43
Fecal coliform Outlet	CFU/100mL	2	200						977	4	22	2	24	35	6	1	170	23
Chl A - Acidification method	µg/L	0.05		0.80	4.75	5.89	3.80	10.82	2.42	4.06	2.08	5.11	2.21	3.01	1.92	2.20	21.04	--
Chll A - Welschmeyer method	µg/L	0.05		0.78	4.50	5.95	3.55	10.16	2.40	4.55	2.06	5.49	2.67	2.92	2.04	2.41	18.55	3.38
E. Coli Lake	MPN/100mL			3	22	ND	55	2	2									
E. Coli Outlet	MPN/100mL			1	38	ND	70	6	40									
Total coliform (Lake)	MPN/100mL					93	866	>4838										
Total coliform (Outlet)	MPN/100mL					378	1010	>4838										

The values of water quality parameters measured by HRM are generally consistent with the present CBCL sampling results. Phosphorus concentration was determined to a lower detection limit in the HRM samples (0.002 mg/L). The evolution of trophic status indicators (TP and Chl A) is shown on Figure 2.3, showing a common meso-eutrophic threshold level to visually examine exceedences. The mean concentration of total phosphorus between 2007 and 2011 was 0.016 mg/L, and 0.022 mg/L (which exceeds the 0.02 mg/L threshold) if calculated from 2010 to 2011. This is consistent with measured levels oscillating between 0.02 and <0.02 mg/L during this study (except for an unexplained peak on 29 July 2011 at 0.177 mg/L for which measurement or analysis error cannot be ruled out). There was one eutrophic event measured on 17 May 2010 (TP = 0.048 mg/L). The nearby CBCL sample 3 days later on 20 May 2010 indicated 0.02 mg/L at LE1, but 0.03 mg/L further downstream at LE3. Finally, it is noted that the average Chl A level exceed the meso-eutrophic threshold.

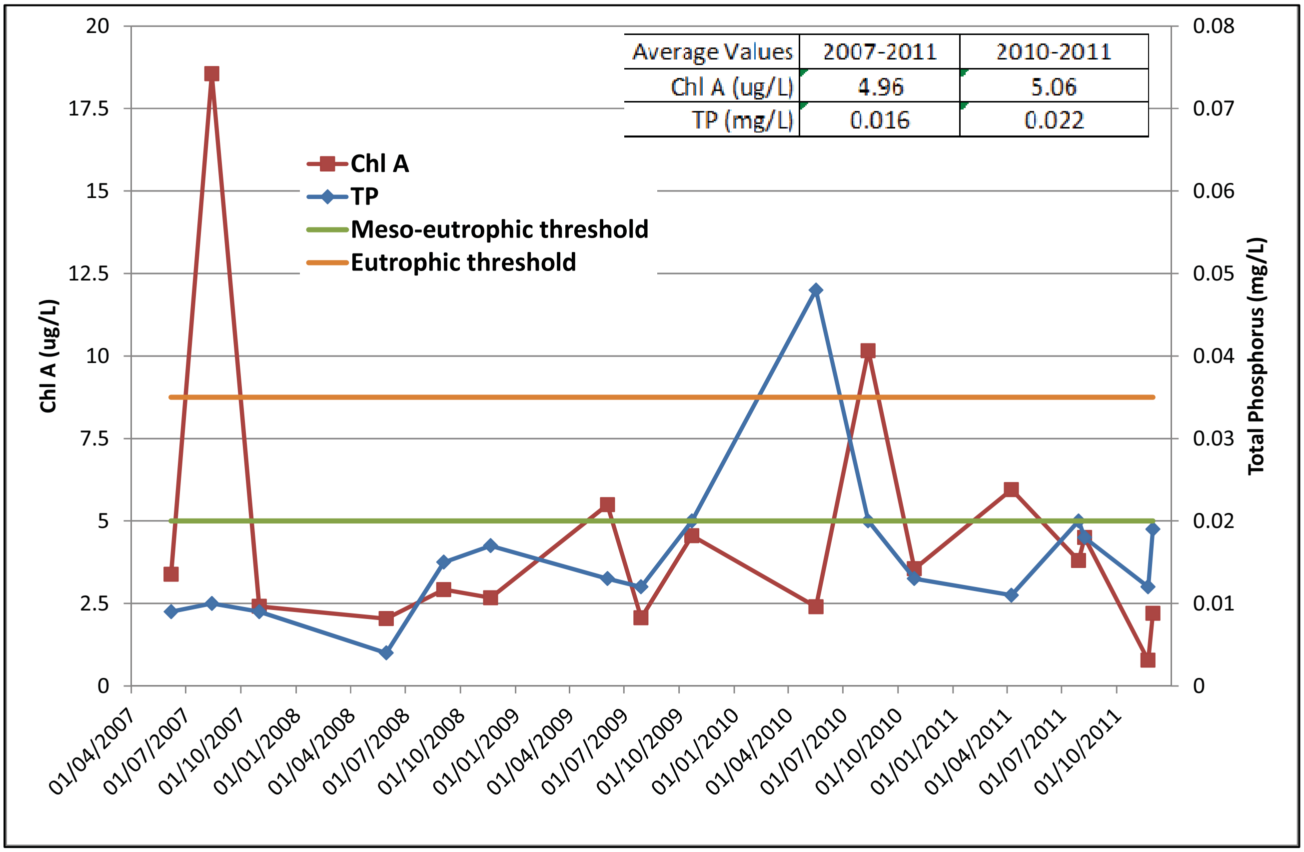

Figure 2.3 Lake Echo Trophic Status Indicators from 2007 to 2011

Data sources: HRM sampling program (2007 to 2011), CBCL samples (summer and fall 2011)

CHAPTER 3 WATER QUALITY MODELLING

3.1 Lake Phosphorus Loading Model

3.1.1 Model Description

The Brylinski model is a simple eutrophication modelling tool that is widely used in Nova Scotia to predict the annual average phosphorus (P) concentration in a lake (receiving water body) based on its hydrological, morphological and watershed characteristics (Brylinski, 2004). It is a black box model that inputs estimated export loads of phosphorus from various land use activities in a watershed and calculates the average annual P concentration in the receiving lake. The P concentration can then be related to an expected trophic status (water quality) and allows for an assessment as to whether the system has any additional assimilative capacity to receive loading of P from developments in the watershed.

The model has to be used with caution as it is based on several assumptions:

- Loss of P to lake sediments is proportional to its concentration in the lake, and internal loading of P from sediments is ignored;
- There is complete mixing of the P throughout the lake - This assumption would likely apply to most of Lake Echo except its relatively limited deep areas where stratification may occur;
- Export coefficients from various land uses in the watershed are based on theoretical estimates that are not always verifiable, but relevant nonetheless because used as calibration parameters; and
- There is a steady state situation which implies that P and hydrological loading are constant and there is no fluctuation in inputs. This is the most problematic assumption because loadings are typically greatest during runoff events.

Despite the limitations inherent to the above assumptions, the model usefully provides a tool for:

- Preliminary screening of receiving waters in order to predict whether there might be any possible eutrophication problems;
- Providing a conceptual and theoretical check on the results of water quality analyses;
- Planning of the survey for water quality monitoring;
- Assessing the potential impacts of any development in a watershed that might release additional loading of P into a receiving water;
- Assisting in making recommendations on watershed planning and management;
- Assessing the potential of lakes to receive additional loads of P before exceedance of assimilative capacity is observed; and

- Linking with other models (e.g. phosphorus-chlorophyll-water transparency models) in order to predict the level of phytoplankton populations that can be expected in a lake. This then gives an idea of the water quality for recreational and drinking water purposes.

3.1.2 Model Inputs

For this study, the land use patterns for each watershed were obtained from provincial data sources. Specifically, the watershed boundary layer was provided by the NS Geomatics Centre, the vegetation cover is derived from a province-wide inventory of air-photo digitized forest stand polygons, and associated descriptors from the NS Department of Natural Resources, and the number of dwellings comes from the NS Geomatics Centre 1:10,000 topographic database. Land use areas and associated phosphorus export coefficients and loads are presented in Table 3.1, and summarized graphically in Figure 3.1 for the entire watershed.

After integrating and totalling the estimated P loading from each land use area, an expected P concentration for each lake was calculated using the model, thereby allowing for an assessment of its theoretical expected eutrophication status. Detailed input and output parameters for each individual lake model are given in Appendix C.2.

Table 3.1 Phosphorus Loading Model Land Uses and Export Coefficients

Note: The coefficients are based on values recommended by model author Brylinski (2004), which were estimated for Nova Scotia and Maine which has similar climate, geological and soil characteristics.

Land-Use	TP Generation by Land-use	Area by Land-use	Total Load by Land-use	Portion of Total Load
	g/year/ha	ha	g/year	%
Forest	69	7,478	516,009	22%
Clear Cut	625	1,269	792,849	35%
Wetland	31	930	28,631	1%
Residential Lots	350	351	122,718	5%
Roads & pavement	3,500	32	112,350	5%
Total Non- point Source Loads			**1,572,557**	**68%**
Point source - STP load 480 pop x 624.2 g P/cap/year			299,616	13%
Point sources - onsite septic systems 400 dwellings x 2.7 people/dwelling x 800 g P/cap/year x 0.5 retention coef.			432,000	19%
Total Point Source Loads			**731,616**	**32%**
Total Runoff Phosphorous Load			**2,304,173**	100%

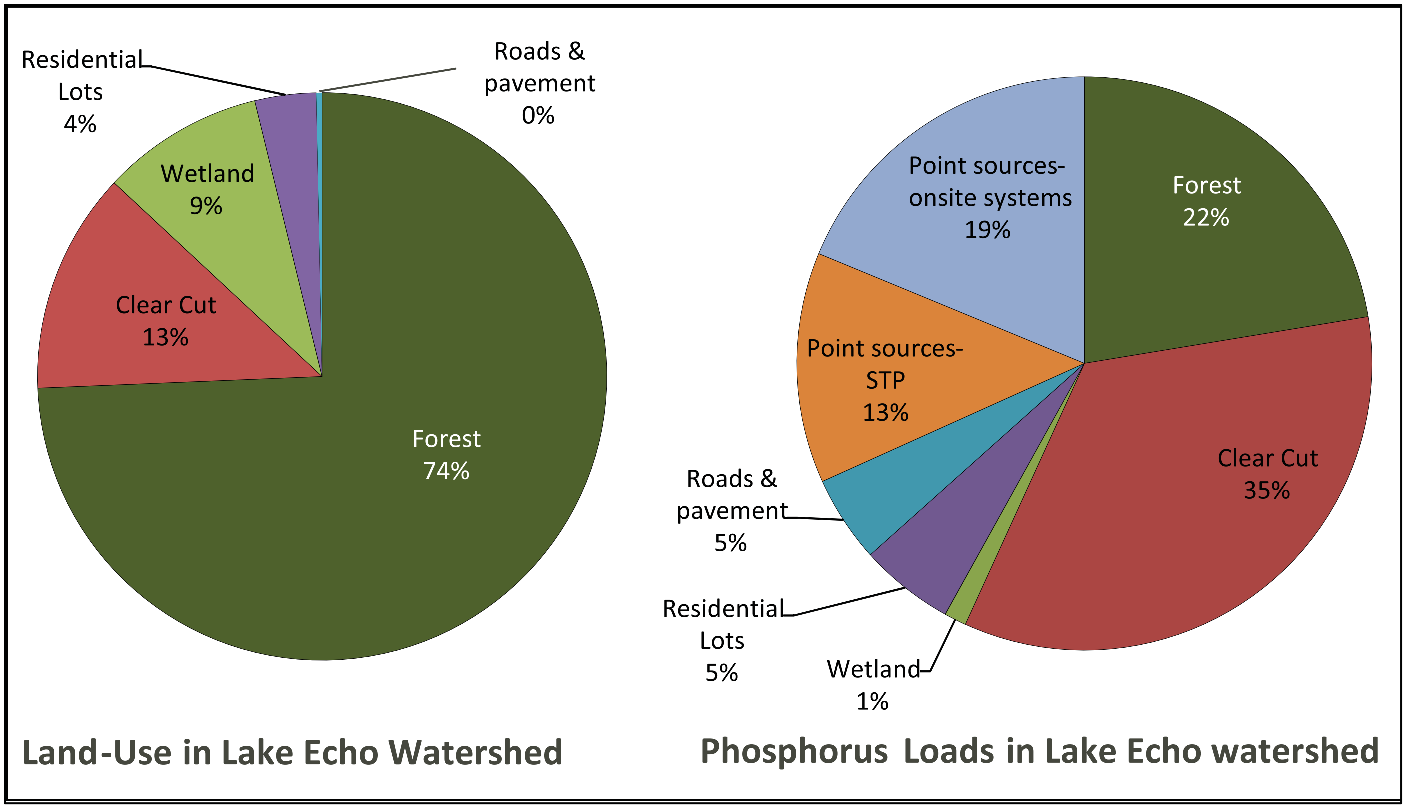

Figure 3.1: Phosphorus Loading Model Land Uses and Associated Loads

3.1.3 Results

Based on the above inputs and assumptions, **the predicted annual mean P level in Lake Echo is 0.0188 mg/L**, which is consistent with sampling results. Based on an estimated trailer park population of 480 and a plant P load of 624 g P/cap/year (primary treatment without phosphorus removal), it is estimated that P loads from the trailer park STP are responsible for 0.0023 mg/L of P in the lake, i.e. 13 % of the total.

The Province of Ontario recommends a maximum average value of 0.020 mg/L for the ice-free period to avoid nuisance algae, while a high level of protection against aesthetic deterioration provided by a TP less than 0.010 mg/L, which should apply to all lakes naturally below this value (Source: Ontario 1994). Therefore, there is very little room for additional phosphorus loads, and none for Chlorophyll A.

3.2 Hydrodynamic Model

A numerical hydrodynamic model was developed to investigate dilution patterns and likely pollution sources that would explain the observed pollutant concentrations during the sampling program. Currents calculated by a hydrodynamic model were used to drive time-dependent far-field effluent dispersion simulations for a number of pollutant discharge scenarios. The model system is MIKE21 (Danish Hydraulic Institute), which has a wide base of users worldwide and extensive recognition from the coastal science and engineering community. MIKE21 solves the momentum and continuity equations over a finite-element mesh to simulate 2-dimensional hydrodynamic circulation. The model mesh consists of triangular cells of variable size based on bathymetric data from the Province (Figure 3.2).

3.2.1 Impact of Existing Trailer Park Sewage Treatment Plant (STP)

Model inputs

Model inflows, bacteria and phosphorus concentrations from the STP in the inlet to Lake Echo were estimated first using simple dilution and decay equations for various hydrologic conditions (Table 3.2). Bacteria will die-off between the STP outfall and the lake inlet through the STP natural settling ponds, and through McCoys Pond. The results show a wide variability in FC concentrations in the inlet to Lake Echo (8/100 ml for dry conditions, when residence time (and therefore die-off) is maximum in the ponds to >10,000 /100ml for wet conditions where residence time is much reduced. This wide range is supported by observations at site LE6.

Results – STP Effluent concentrations

The modeled percentage of STP effluent into the lake (on a 0-100 scale) is shown on Figure 3.3.
Based on yearly-average flows (3.6 m3/s through the Lake), the STP effluent concentration throughout most of the lake is 0.16% (i.e. diluted 600 times). It can be used to scale for other parameters. For example, using a typical STP effluent TP concentration of 1.7 mg/L, then 0.2% contour represents 0.003 mg/L, based simply on dilution (nutrient uptake from various processes between the STP outfall and the lake is not accounted for).

Results – FC concentrations

Modeled bacteria concentrations due to the STP in Lake Echo are shown on figure 3.4. Part of the bacterial contamination observed in Lake Echo can be attributed to the STP in wet weather. However it cannot be the only source, based on the water quality observations showing FC concentrations at times much higher than modeled, including far away from MCCoys Pond inlet into the Lake. This prompted further investigation of the potential contribution of malfunctioning sceptic systems.

Table: 3.2: Calculation of Bacteria and Phosphorus Concentrations between the STP and McCoys Pond Outlet into Lake Echo

	Step 1	Step 2
	STP Lagoon	McCoys Pond
Lake area, m2	1770	43,622
Assumed mean depth, m	0.5	0.8
Volume, m3	885	34897.6
Watershed area, ha	3.7	60
Yearly-average watershed flow (Q, m3/s)	0.001	0.022
Assumed FC decay rate, /day	0.5	
STP flow, m3/s (320 trailers x 1.5m3/d)	0.006	
STP Phosphorus conc, mg/l	1.700	

	Dry conditions (Q/2)		Yearly-average flow (Q)		Wet conditions (Qx2)	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
	STP Lagoon	McCoys Pond	STP Lagoon	McCoys Pond	STP Lagoon	McCoys Pond
Total flow (watershed+STP) ,m/s	0.006	0.017	0.007	0.028	0.008	0.050
Residence time, days	2	24	1	15	1	8
FC inlet (CFU/100 ml)	10,000,000	1,467,398	10,000,000	954,924	10,000,000	599,443
FC oultet after dilution and decay in pond (CFU/100 ml)	3,918,193	**8**	3,829,199	**663**	3,612,089	**10,547**
Percent STP effluent into outflow	89%	33%	80%	20%	67%	11%
P outlet concentration (mg/l)	1.51	**0.57**	1.36	**0.34**	1.14	**0.19**
Pollutant concentrations in Lake Echo that are due to STP effluent (based on hydrodynamic model)						
	Dry conditions (Q/2)		Yearly-average flow (Q)		Wet conditions (Qx2)	
Percent STP effluent	0.31%		0.15%		0.08%	
FC in Lake Echo (CFU/100 ml)	<1		<100		1 to 500	
TP in Lake Echo (mg/l)	0.005		0.002		0.001	

Note - Concentrations observed at McCoys Pond outlet (LE6) were as follows:

Sep-Oct 2010 in wet conditions: FC bacteria 400 to >10000 /100 ml and TP = 0.11 to 0.16 mg/L

Summer 2011 (dry) – FC bacteria 28 FC/100 ml, and TP 0.020 mg/L.

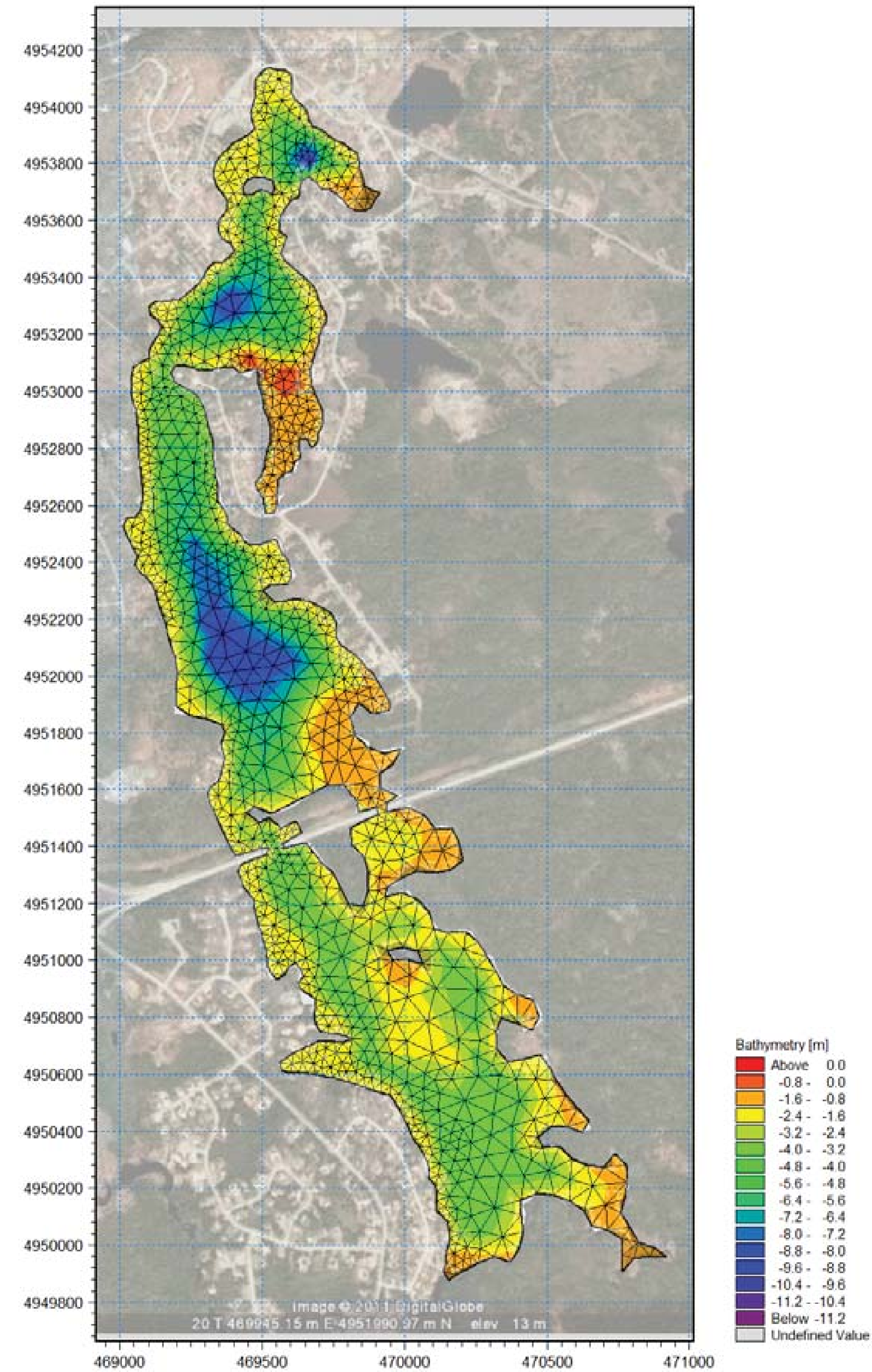

Figure 3.2: Hydrodynamic model domain

Source of bathymetric information: Nova Scotia Department of Agriculture & Fisheries

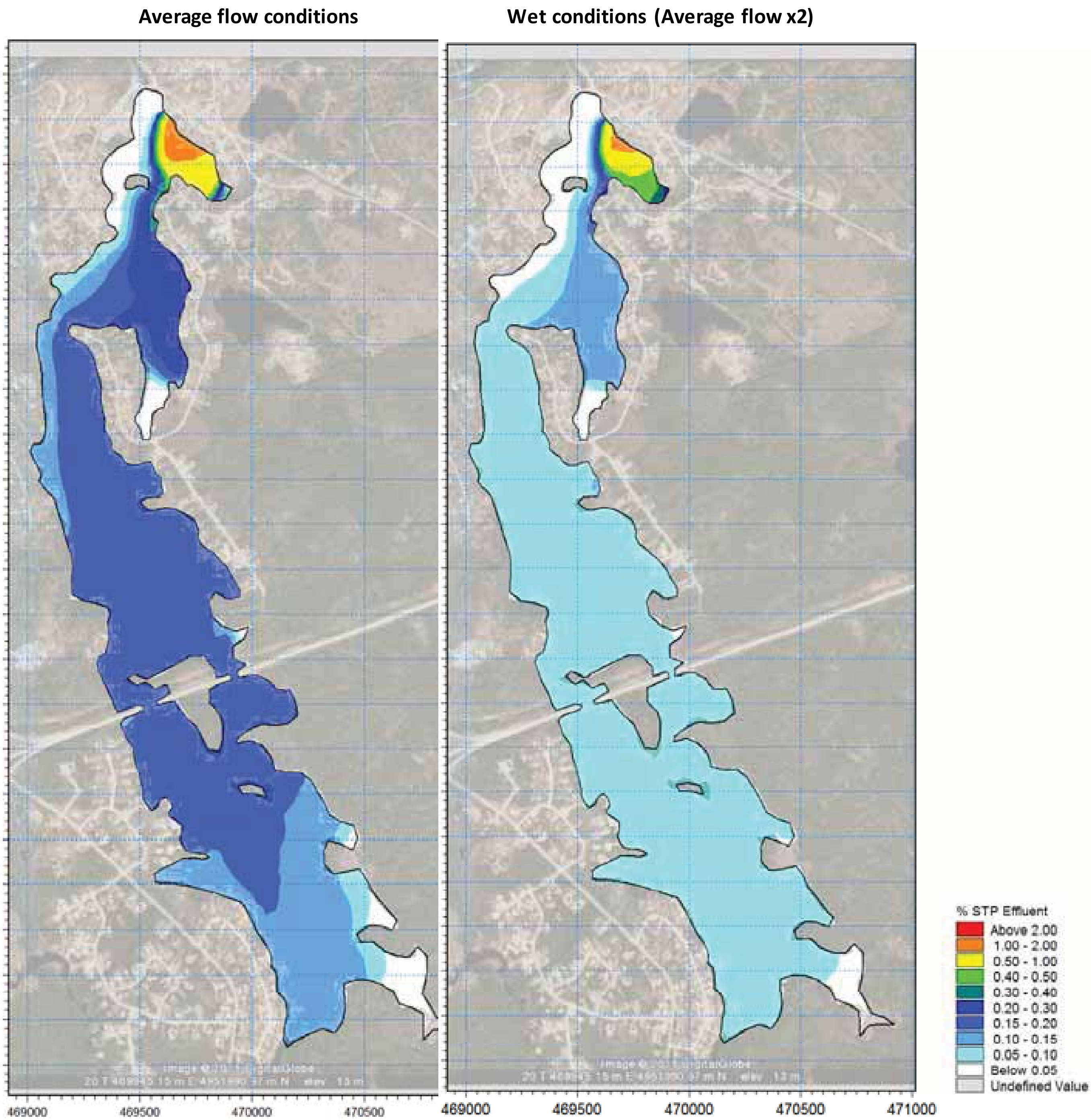

Figure 3.3: Modeled Percentage of Effluent from Trailer Park STP in Lake Echo

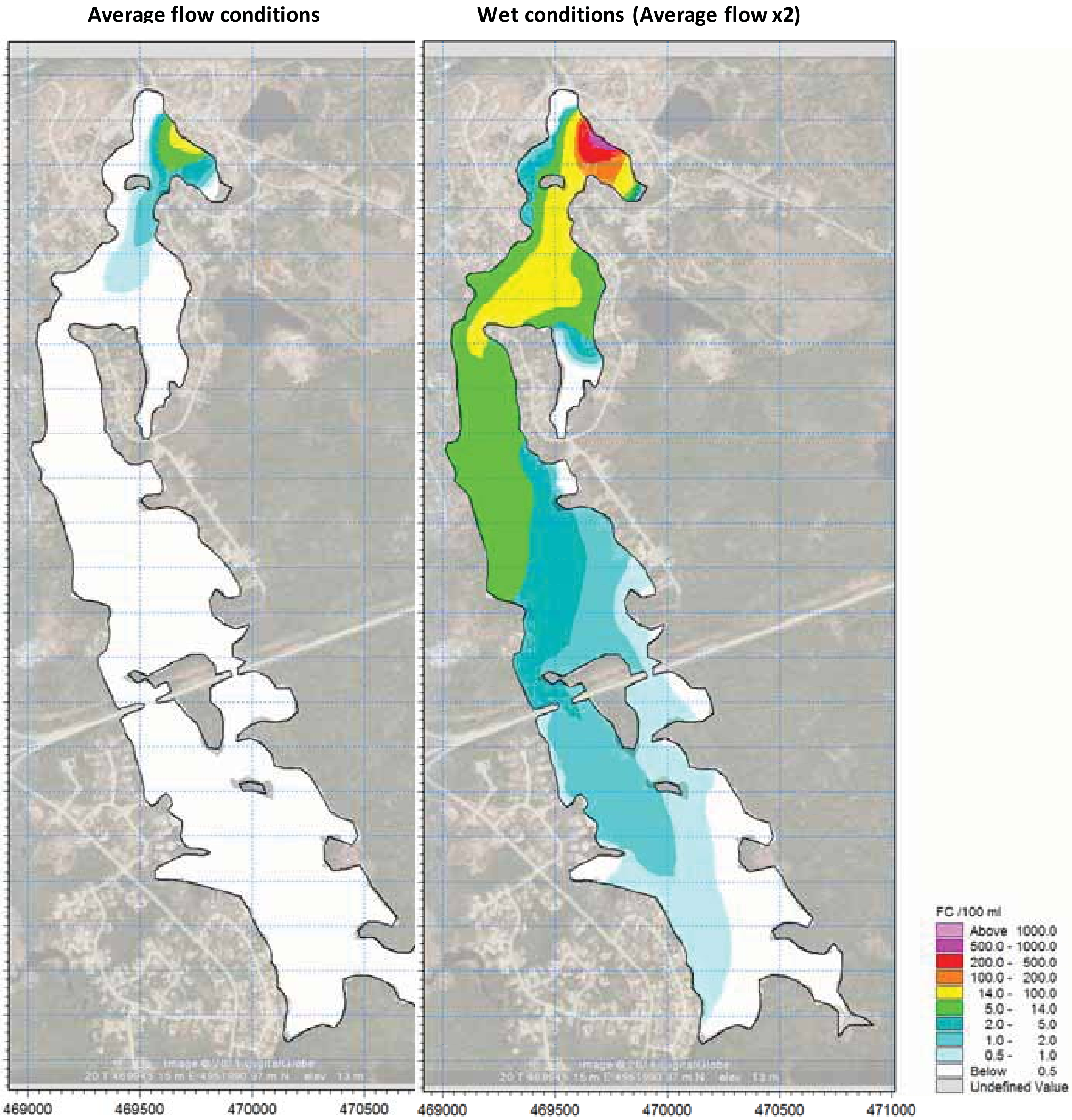

Figure 3.4: Modeled FC Concentrations Due to Trailer Park STP Assumptions Listed in Table 3.2

3.2.2 Impact of Malfunctioning Sceptic Systems

It is estimated that there are approximately 300 to 400 houses on sceptic systems located either on the lake shore, or close to a lake tributary. It is reasonable to assume that a proportion of these sceptic systems may be aging and malfunctioning particularly during wet periods when the ground is saturated, causing an increase in sceptic field runoff. The present modeling exercise seeks to answer the following question: can malfunctioning sceptic fields be a contributing factor to the high FC concentrations observed at times in the lake?

Modeling was based on the following assumptions, which are unverified at this point:

- Residential wastewater loading =10^8 FC/ 100 ml (the range of values given by EPA is 10^7 to 10^9 FC/100 ml);
- Sceptic system design flow rate = 1000 L/day; and
- 50 malfunctioning fields (out of 300 to 400 properties) with a leak rate of 10% of the design flow rate, i.e. 100 L/day.

The density of malfunctioning sceptic fields was assumed to correspond approximately to the distribution of waterfront properties. Results are shown on Figure 3.5. The conclusion is that malfunctioning sceptic fields may indeed cause bacteria levels in the lake to reach several 100 FC/100 ml.

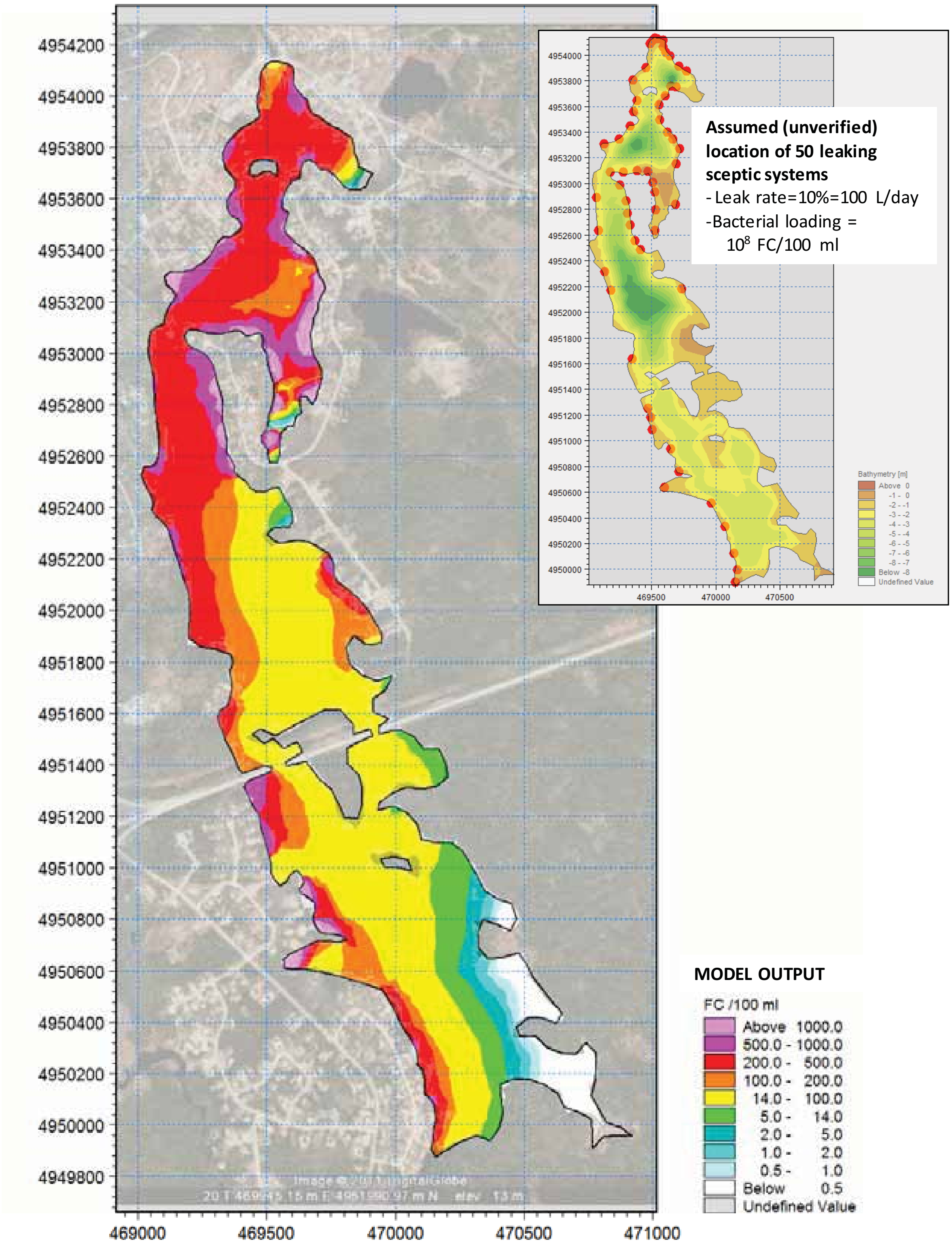

Figure 3.5: **Modeled FC Concentrations Due to 50 Sceptic Systems Leaking 10% of their Effluent into the Lake**

CHAPTER 4 SUMMARY AND CONCLUSIONS

The Lake Echo watershed was studied to contribute to an informed discussion of the opportunities and constraints for future development in the area based on water quality. The study's main components were:

- A field sampling program to measure water quality parameters;
- A model-based phosphorus loading analysis of lakes in the greater Lake Echo watershed; and
- A hydrodynamic and effluent dispersion model of Lake Echo.

A suite of physical, chemical and biological water quality parameters was measured at nine sites within the study region on eight days between April and October 2010, and in the summer-fall of 2011 under a variety of meteorological conditions. Overall, the measured water quality parameters are within the range of recommendations by the Canadian Water Quality Guidelines for the Protection of Aquatic Life from the Canadian Council of Ministers of the Environment. However, Lake Echo has two main issues with water quality:

- Bacteria concentrations after a rainfall event are typically high, and at times exceed the guideline for direct recreational contact; and
- Nutrient (phosphorus) and algae levels in the summer and fall are close to the typical trigger range for eutrophication.

As a result, the lake has little additional assimilative capacity. Excess bacteria and nutrient levels observed at times are most likely due to a combination of the following factors:

- Wastewater discharge from the trailer park's wastewater treatment plant into McCoys Pond that drains into the lake. The pond is hypereutrophic, and the receiving lake cove was found to be eutrophic on one occasion; and
- Malfunctioning sceptic fields which may cause bacteria levels in the lake to reach several 100 FC/100 ml.

Measures for reducing bacterial and nutrient inputs into the lake need to be implemented in all future development schemes (e.g. reduction of storm water runoff, nutrient removal for the existing STP servicing the trailer park).

CHAPTER 5 REFERENCES

Brylinsky M (2004) "User's Manual for Prediction of Phosphorus Concentration In Nova Scotia Lakes: A Tool for Decision Making" Version 1.0. Prepared For The Nova Scotia Water Quality Objectives and Model Development Steering Committee, Nova Scotia Department of Environment and Labour. Jan 2004. (http://www.gov.ns.ca/nse/surface.water/surfacewater.research.asp)

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Thomann and Mueller, 1987. "Principles of Surface Water Quality Modeling and Control". Harper & Row Publishers Inc, 1987. ISBN 0-06-066677-4.

APPENDIX C.1

Summary of Canadian Water Quality Guidelines for the Protection of Aquatic Life

Sources:
http://ceqg-rcqe.ccme.ca/ [accessed 20 Nov 2012]

Canadian Environmental Quality Guidelines Summary Table

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	**Chemical groups**	**Short Term**	**Long Term**		**Short Term**	**Long Term**	
1,1,1-Trichloroethane **CASRN** 71556	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2,2-Tetrachloroethene PCE (Tetrachloroethylene) **CASRN** 127184	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	**110**	1993	*No data*	**Insufficient data**	1993
1,1,2,2-Tetrachlorethane **CASRN** 79345	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2-Trichloroethene TCE (Trichloroethylene) **CASRN** 79-01-6	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	**21**	1991	*No data*	Insufficient data	1991
1,2,3,4-Tetrachlorobenzene **CASRN** 634662	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	**1.8**	**1997**	*No data*	**Insufficient data**	1997
1,2,3,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	**Insufficient data**	1997	*No data*	**Insufficient data**	1997

Comments or questions? Contact us at info@ccme.ca

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3-Trichlorobenzene **CASRN** 87616	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**8**	1997	No data	**Insufficient data**	1997
1,2,4,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
1,2,4-Trichlorobenzene **CASRN** 120801	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**24**	**1997**	No data	5.4	1997
1,2-Dichlorobenzene **CASRN** 95501	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**0.7**	1997	No data	**42**	1997
1,2-Dichloroethane **CASRN** 1070602	Organic Halogenated aliphatic compounds Chlorinated ethanes	No data	**100**	1991	No data	**Insufficient data**	1991
1,3,5-Trichlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
1,3-Dichlorobenzene **CASRN** 541731	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**150**	1997	No data	**Insufficient data**	1997
1,4-Dichlorobenzene **CASRN** 106467	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**26**	1997	No data	**Insufficient data**	1997
1,4-Dioxane		NRG	NRG	2008	NRG	NRG	2008
3-Iodo-2-propynyl butyl carbamate IPBC **CASRN** 55406-53-6	Organic Pesticides Carbamate pesticides	No data	**1.9**	1999	No data	No data	No data
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**5.8**	1999	No data	Insufficient data	1999

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Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	*No data*	1999	*No data*	*No data*	1999
Acridine PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**4.4**	1999	*No data*	Insufficient data	1999
Aldicarb **CASRN** 116063	Organic Pesticides Carbamate pesticides	*No data*	**1**	1993	*No data*	**0.15**	1993
Aldrin	Organic Pesticides Organochlorine compounds	*No data*	~~**0.004**~~	1987	*No data*	*No data*	*No data*
Aluminium	Inorganic	*No data*	**Variable**	1987	*No data*	*No data*	*No data*
Ammonia (total)	Inorganic Inorganic nitrogen compounds	*No data*	**Table**	2001	*No data*	*No data*	*No data*
Ammonia (un-ionized) **CASRN** 7664417	Inorganic Inorganic nitrogen compounds	*No data*	**19**	2001	*No data*	*No data*	*No data*
Aniline **CASRN** 62533	Organic	*No data*	**2.2**	1993	*No data*	Insufficient data	1993
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.012**	1999	*No data*	Insufficient data	1999
Arsenic **CASRN** none	Inorganic	*No data*	**5**	1997	*No data*	**12.5**	1997
Atrazine **CASRN** 1912249	Organic Pesticides Triazine compounds	*No data*	**1.8**	1989	*No data*	*No data*	*No data*
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	*No data*	**370**	1999	*No data*	**110**	1999
Benzo(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.018**	1999	*No data*	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.015**	1999	No data	Insufficient data	1999
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009
Bromacil **CASRN** 314409	Organic Pesticides	No data	**5**	1997	No data	Insufficient data	1997
Bromoxynil	Organic Pesticides Benzonitrile compounds	No data	**5**	1993	No data	Insufficient data	1993
Cadmium **CASRN** 7440439	Inorganic	No data	**Equation**	1996	No data	**0.12**	1996
Captan **CASRN** 133062	Organic Pesticides	No data	**1.3**	1991	No data	No data	No data
Carbaryl **CASRN** 63252	Organic Pesticides Carbamate pesticides	3.3	0.2	2009	5.7	0.29	2009
Carbofuran **CASRN** 1564662	Organic Pesticides Carbamate pesticides	No data	**1.8**	1989	No data	No data	No data
Chlordane	Organic Pesticides Organochlorine compounds	No data	~~**0.006**~~	1987	No data	No data	No data
Chloride	Inorganic	**640,000 µg/L or 640 mg/L**	**120,000 µg/L or 120 mg/L**	2011	**NRG**	**NRG**	2011
Chlorothalonil **CASRN** 1897456	Organic Pesticides	No data	**0.18**	1994	No data	**0.36**	1994
Chlorpyrifos **CASRN** 2921882	Organic Pesticides Organophosphorus compounds	0.02	0.002	2008	NRG	0.002	2008
Chromium, hexavalent (Cr(VI)) **CASRN** 7440473	Inorganic	No data	**1**	1997	No data	**1.5**	1997
Chromium, trivalent (Cr(III)) **CASRN** 7440473	Inorganic	No data	**8.9**	1997	No data	**56**	1997
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	Insufficient data	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Colour **CASRN** N/A	Physical	No data	**Narrative**	1999	No data	**Narrative**	1999
Copper	Inorganic	No data	**Equation**	1987	No data	No data	No data
Cyanazine **CASRN** 2175462	Organic Pesticides Triazine compounds	No data	**2**	**1990**	No data	No data	No data
Cyanide	Inorganic	No data	**5 (as free CN)**	1987	No data	No data	No data
Debris **CASRN** N/A	Physical	No data	No data	No data	No data	**Narrative**	1996
Deltamethrin **CASRN** 52918635	Organic Pesticides	No data	0.0004	1997	No data	Insufficient data	1997
Deposited bedload sediment	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	Insufficient data	1999	No data	Insufficient data	1999
Di(2-ethylhexyl) phthalate **CASRN** 117817	Organic Phthalate esters	No data	**16**	1993	No data	Insufficient data	1993
Di-n-butyl phthalate **CASRN** 84742	Organic Phthalate esters	No data	**19**	1993	No data	Insufficient data	1993
Di-n-octyl phthalate **CASRN** 117840	Organic Phthalate esters	No data	Insufficient data	1993	No data	Insufficient data	1993
Dibromochloromethane	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Dicamba **CASRN** 1918009	Organic Pesticides Aromatic Carboxylic Acid	No data	**10**	1993	No data	No data	No data
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	No data	~~**0.001**~~	1987	No data	No data	No data
Dichlorobromomethane	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Dichloromethane Methylene chloride **CASRN** 75092	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**98.1**	1992	No data	Insufficient data	1992

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**0.2**	1987	No data	No data	No data
Diclofop-methyl **CASRN** 51338273	Organic Pesticides	No data	6.1	1993	No data	No data	No data
Didecyl dimethyl ammonium chloride DDAC **CASRN** 7173515	Organic Pesticides	No data	**1.5**	1999	No data	Insufficient data	1999
Diethylene glycol **CASRN** 111466	Organic Glycols	No data	**Insufficient data**	1997	No data	Insufficient data	1997
Diisopropanolamine DIPA **CASRN** 110974	Organic	No data	**1600**	**2005**	No data	**Insufficient data**	2005
Dimethoate **CASRN** 60515	Organic Pesticides Organophosphorus compounds	No data	**6.2**	1993	No data	Insufficient data	1993
Dinoseb **CASRN** 88857	Organic Pesticides	No data	0.05	1992	No data	No data	No data
Dissolved gas supersaturation **CASRN** N/A	Physical	No data	Narrative	1999	No data	Narrative	1999
Dissolved oxygen DO **CASRN** N/A	Inorganic	No data	**Variable**	1999	No data	**>8000 & Narrative**	1996
Endosulfan	Organic Pesticides Organochlorine compounds	0.06	0.003	2010	0.09	0.002	2010
Endrin	Organic Pesticides Organochlorine compounds	No data	~~**0.0023**~~	1987	No data	**No data**	No data
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	No data	**90**	1996	No data	**25**	1996
Ethylene glycol **CASRN** 107211	Organic Glycols	No data	**192 000**	1997	No data	Insufficient data	1997
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.04**	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**3**	1999	No data	Insufficient data	1999
Fluoride	Inorganic	No data	**120**	2002	No data	**NRG**	2002
Glyphosate **CASRN** 1071836	Organic Pesticides Organophosphorus compounds	**27,000**	**800**	**2012**	**NRG**	**NRG**	**2012**
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	No data	~~**0.01**~~	1987	No data	No data	No data
Hexachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
Hexachlorobutadiene HCBD **CASRN** 87683	Organic Halogenated aliphatic compounds	No data	**1.3**	1999	No data	No data	No data
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	No data	**0.01**	1987	No data	No data	No data
Imidacloprid **CASRN** 13826413		No data	**0.23**	2007	No data	**0.65**	2007
Iron	Inorganic	No data	**300**	1987	No data	No data	No data
Lead	Inorganic	No data	**Equation**	1987	No data	No data	No data
Linuron **CASRN** 41205214	Organic Pesticides	No data	**7**	1995	No data	No data	1995
Mercury **CASRN** 7439976	Inorganic	No data	**0.026**	2003	No data	**0.016**	2003
Methoprene **CASRN** 40596698		No data	**0.09 (Target Organism Management value: 0.53)**	2007	No data	Insufficient data	2007
Methyl tertiary-butyl ether MTBE **CASRN** 1634044	Organic Non-halogenated aliphatic compounds Aliphatic ether	No data	**10 000**	2003	No data	**5 000**	2003

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) MCPA **CASRN** 94746	Organic Pesticides	No data	2.6	1995	No data	4.2	1995
Methylmercury	Organic	No data	0.004	2003	No data	NRG	2003
Metolachlor **CASRN** 51218452	Organic Pesticides Organochlorine compounds	No data	7.8	1991	No data	No data	No data
Metribuzin **CASRN** 21087649	Organic Pesticides Triazine compounds	No data	1	1990	No data	No data	No data
Molybdenum	Inorganic	No data	73	1999	No data	No data	No data
Monobromomethane Methyl bromide	Organic Halogenated aliphatic compounds Halogenated methanes	No data	Insufficient data	1992	No data	Insufficient data	1992
Monochlorobenzene **CASRN** 108907	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	1.3	1997	No data	25	1997
Monochloromethane Methyl chloride	Organic Halogenated aliphatic compounds Halogenated methanes	No data	Insufficient data	1992	No data	Insufficient data	1992
Monochlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	7	1987	No data	No data	No data
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	1.1	1999	No data	1.4	1999
Nickel	Inorganic	No data	Equation	1987	No data	No data	No data
Nitrate **CASRN** 14797-55-8	Inorganic Inorganic nitrogen compounds	550,000 µg/L or 550 mg/L	13,000 µg/L or 13 mg/L	2012	1,500,000 µg/L or 1500 mg/L	200,000 µg/L or 200 mg/L	2012

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nitrite	Inorganic Inorganic nitrogen compounds	No data	**60 NO_2-N**	1987	No data	No data	No data
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	No data	**1**	2002	No data	**0.7**	2002
Nutrients		No data	**Guidance Framework**	2004	No data	**Guidance framework**	2007
Pentachlorobenzene **CASRN** 608935	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**6**	1997	No data	**Insufficient data**	1997
Pentachlorophenol PCP	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**0.5**	1987	No data	No data	No data
Permethrin **CASRN** 52645531	Organic Pesticides Organochlorine compounds	No data	**0.004**	2006	No data	**0.001**	2006
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.4**	1999	No data	Insufficient data	1999
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	No data	**4**	1999	No data	No data	No data
Phenoxy herbicides 2,4 D; 2,4-Dichlorophenoxyacetic acid	Organic Pesticides	No data	**4**	1987	No data	No data	No data
Phosphorus	Inorganic	No data	**Guidance Framework**	2004	No data	**Guidance Framework**	2007
Picloram **CASRN** 1918021	Organic Pesticides	No data	**29**	1990	No data	No data	No data
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	No data	~~**0.001**~~	1987	No data	~~**0.01**~~	1991
Propylene glycol **CASRN** 57556	Organic Glycols	No data	**500 000**	1997	No data	Insufficient data	1997
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.025**	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	**Chemical groups**	**Short Term**	**Long Term**		**Short Term**	**Long Term**	
pH	Inorganic Acidity, alkalinity and pH	No data	**6.5 to 9.0**	**1987**	No data	**7.0 to 8.7 & Narrative**	1996
Quinoline PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**3.4**	1999	No data	Insufficient data	1999
Reactive Chlorine Species total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants	Inorganic Reactive chlorine compounds	No data	**0.5**	1999	No data	**0.5**	1999
Salinity	Physical	No data	No data	No data	No data	**Narrative**	1996
Selenium	Inorganic	No data	**1**	1987	No data	No data	No data
Silver	Inorganic	No data	**0.1**	1987	No data	No data	No data
Simazine **CASRN** 122349	Organic Pesticides Triazine compounds	No data	**10**	1991	No data	**No data**	No data
Streambed substrate	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	**Narrative**	1999	No data	**Narrative**	1999
Styrene **CASRN** 100425	Organic Monocyclic aromatic compounds	No data	**72**	1999	No data	No data	No data
Sulfolane Bondelane **CASRN** 126330	Organic Organic sulphur compound	No data	**50 000**	2005	No data	Insufficient data	2005
Suspended sediments TSS	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	**Narrative**	1999	No data	**Narrative**	1999
Tebuthiuron **CASRN** 34014181	Organic Pesticides	No data	**1.6**	1995	No data	Insufficient data	1995
Temperature	Physical Temperature	No data	**Narrative**	1987	No data	**Narrative**	1996

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Tetrachloromethane Carbon tetrachloride **CASRN** 56235	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**13.3**	1992	No data	Insufficient data	1992
Tetrachlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**1**	1987	No data	No data	No data
Thallium	Inorganic	No data	**0.8**	1999	No data	No data	No data
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	No data	**2**	1996	No data	**215**	1996
Toxaphene	Organic Pesticides Organochlorine compounds	No data	**~~0.008~~**	1987	No data	No data	No data
Triallate **CASRN** 2303175	Organic Pesticides Carbamate pesticides	No data	**0.24**	1992	No data	No data	No data
Tribromomethane Bromoform	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Tributyltin	Organic Organotin compounds	No data	**0.008**	1992	No data	**0.001**	1992
Trichloromethane Chloroform **CASRN** 67663	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**1.8**	1992	No data	Insufficient data	1992
Trichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**18**	1987	No data	No data	No data
Tricyclohexyltin	Organic Organotin compounds	No data	Insufficient data	1992	No data	Insufficient data	1992
Trifluralin **CASRN** 1582098	Organic Pesticides Dinitroaniline pesticides	No data	**0.2**	1993	No data	No data	No data

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Triphenyltin	Organic Organotin compounds	No data	**0.022**	1992	No data	No data	1992
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	**Narrative**	1999	No data	**Narrative**	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	**NRG**	**NRG**	2011
Zinc	Inorganic	No data	**30**	1987	No data	No data	No data

Chemical name	Chemical groups
No Chemicals with Data	

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Recreational Water Quality Guidelines and Aesthetics

Recreational water refers to surface waters that are used primarily for activities in which the user comes into frequent direct contact with the water, either as part of the activity or incidental to the activity. Examples include swimming, windsurfing, waterskiing, white water sports, scuba diving, and dinghy sailing. Secondary recreational uses include boating, canoeing, and fishing, which generally have less frequent body contact with water.

General Requirements

Health and Safety

Water used primarily for recreational purposes should be sufficiently free from microbiological, chemical, and physical hazards, e.g. poor visibility, to ensure that there is negligible risk to the health and safety of the user. Recreational water quality guidelines, summarized in Table 1, were prepared by the Federal–Provincial Advisory Committee on Environmental and Occupational Health and published by Health and Welfare Canada (1992).

These guidelines deal mainly with potential health hazards related primarily to recreational water use, but also relate to aesthetics and nuisance conditions. Health hazards associated with direct recreational contact with water include infections transmitted by pathogenic microorganisms and injuries resulting from impaired visibility in turbid waters. The determination of the risk of infection is based on a number of factors, including results of environmental health assessments, results of epidemiological studies, levels of indicator organisms, and the presence of pathogens. Sampling and enumeration of microbiological indicators and pathogens in recreational waters are also discussed. New guidelines for safe recreational water environments are currently being prepared by the World Health Organization with the assistance of Health Canada.

Aesthetics

The local setting of recreational water bodies is also important, as the surrounding countryside has a strong visual effect on the enjoyment of lakes and rivers, whether the activity is physically active or passive, such as gazing on the scenery.

In northern waters, swimming is not a major recreational activity, and factors other than microbiological are major components when determining the suitability of lakes and rivers and their environments as recreational areas. Visual impact of the whole area is as important as the quality of the water.

Impacts on a water source come from many activities. These include logging, mining, drainage of wetlands, dredging, dam construction, agricultural runoff, industrial and municipal wastes, land erosion, road construction, and land development. These factors all have to be considered in areas of natural beauty that are used for the many recreational activities engaged in by Canadians and visitors to Canada.

References

Health and Welfare Canada. 1992. Guidelines for Canadian recreational water quality. Cat. No. H49-70/1991E. Minister of Supply and Services Canada, Ottawa.

Moody, R.P., and I. Chu. 1995. Dermal exposure to environmental contaminants in the Great Lakes. Environ. Health Perspect. 103(Suppl. 9):103–114.

Summary — Guidelines for Canadian recreational water quality.

Parameter	Guideline
Microbiological	
Escherichia coli (fecal coliforms)	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 2000 *E. coli* per litre. Resampling should be performed when any sample exceeds 4000 *E. coli* per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Enterococci	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 350 enterococci per litre. Resampling should be performed when any sample exceeds 700 enterococci per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Coliphages	Limits on coliphages can not be specified at this time. See Health and Welfare Canada (1992) for additional information.
Waterborne pathogens	The pathogens most frequently responsible for diseases associated with recreational water use are described in Health and Welfare Canada (1992), i.e., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella*, *Shigella*, *Aeromonas*, *Campylobacter jejuni*, *Legionella*, human enteric viruses, *Giardia lamblia,* and *Cryptosporidium*.
Cyanobacteria (blue-green algae)	Limits have not been specified. Health Canada is in the process of developing a numerical guideline for microcystin, a cyanobacterial toxin. Water with blue-green surface scum should be avoided because of reduced clarity and possible presence of toxins.
Chemical characteristics	Limits for chemicals have not been specified because of lack of data. Decisions for use should be based on an environmental health assessment and the aesthetic quality. Dermal exposures to environmental contaminants has recently been reviewed by Moody and Chu (1995).
Temperature	The thermal characteristics of water should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.
Clarity	The water should be sufficiently clear that a Secchi disc is visible at a minimum of 1.2 m.
pH	When the buffering capacity of the water is very low,6.5 to 8.5; range of 5.0 to 9.0 is acceptable.
Turbidity	A limit of 50 Nephelometric Turbidity Units (NTU) is suggested.
Oil and grease	Oil or petrochemicals should not be present in concentrations that • can be detected as a visible film, sheen, or discoloration on the surface; • can be detected by odour; or • can form deposits on shorelines and bottom deposits that are detectable by sight and odour.
Aquatic plants	Bathers should avoid areas with rooted or floating plants; very dense growths could affect other activities such as boating and fishing.
Aesthetics	All water should be free from • materials that will settle to form objectionable deposits; • floating debris, oil, scum, and other matter; • substances producing objectionable colour, odour, taste, or turbidity; and • substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.
Nuisance organisms	Bathing areas should be as free as possible from nuisance organisms that • endanger the health and physical comfort of users or • render the area unusable. Common examples include biting and nonbiting insects and poisonous organisms, for example jelly-fish.

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Reference listing:

Canadian Council of Ministers of the Environment. 1999. Recreational water quality guidelines and aesthetics. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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APPENDIX C.2

Phosphorus Loading Models

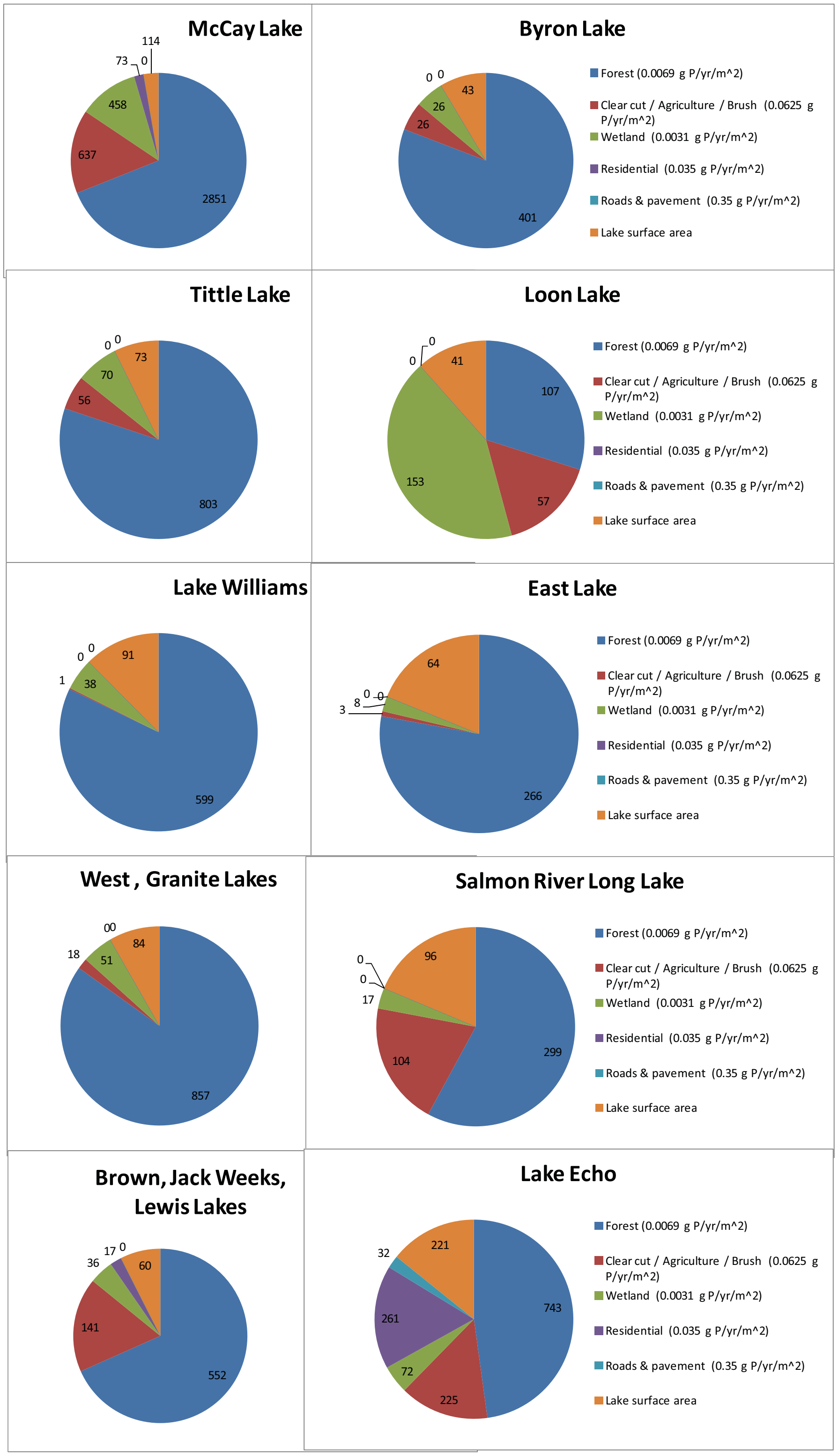


Figure C.1: Model Inputs – Areas (in ha) for Each Watershed and Associated P Export Coefficients

Note: Lake surface areas include main lake plus smaller lakes and ponds in the watershed.

McKay Lake model (headwater lake)

Input Parameters	Symbol	Value	Units	Budgets		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	4019.4	ha			
Area Land Use Category 1 (Forest)	Ad1	2851.4	ha			% Total
Area Land Use Category 2 (Clear Cut)	Ad2	637.3	ha	Upstream Inflow	0	0
Area Land Use Category 3 (Wetland)	Ad3	458.2	ha	Precipitation	1561492.6	4.01
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	37380775	95.99
Area Land Use Category 5 (Residential Lots)	Ad5	72.5	ha	Evaporation	-206092.3	0.53
Area Land Use Category 6 (Camp)	Ad6	0.0	ha	Total Outflow	38736175	99.47
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	114.5	ha			% Total
Lake Volume	V	3.29	$10^6 m^3$	Upstream Inflow	0	0
Hydrology				Atmosphere	28624	4.29
Upstream Hydraulic Inputs	Qi	0	$m^3 yr^{-1}$	Land Run Off	634733	95.18
Annual Unit Precipitation	Pr	1.36	$m\ yr^{-1}$	Development	3520	0.53
Annual Unit Lake Evaporation	Ev	0.18	$m\ yr^{-1}$	Sedimentation	-120038	18.00
Annual Unit Hydraulic Runoff	Ru	0.93	$m\ yr^{-1}$	Total Outflow	546839	82.00
P Loading				Total Check		100.00
Upstream P Input	Pi	0	gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P $m^{-2} yr^{-1}$			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P $m^{-2} yr^{-1}$			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P $m^{-2} yr^{-1}$			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P $m^{-2} yr^{-1}$	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P $m^{-2} yr^{-1}$			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P $m^{-2} yr^{-1}$			
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P $m^{-2} yr^{-1}$			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P $m^{-2} yr^{-1}$			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P $m^{-2} yr^{-1}$			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P $m^{-2} yr^{-1}$			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P $m^{-2} yr^{-1}$			
Number of Dwellings	N_d	8	#			
Average number of Persons per Dwelling	N_u	2.20	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	0.5	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	gm P $cap^{-1} yr^{-1}$			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	gm P $m^{-2} yr^{-1}$			
Point Source Input 2	PS2	0	gm P $m^{-2} yr^{-1}$			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Pp_{ti}	1561492.634	$m^3 yr^{-1}$			
Total Evaporation Hydraulic Loss	Eo	206092.2966	$m^3 yr^{-1}$			
Total Hydraulic Surface Run Off	Ql	37380774.85	$m^3 yr^{-1}$			
Total Hydraulic Input	Qt	38942267	$m^3 yr^{-1}$			
Areal Hydraulic Load	q_s	33.83	$m\ yr^{-1}$			
Total Hydraulic Outflow	Qo	38736175.18	$m^3 yr^{-1}$			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	28624	gm yr^{-1}			
Total Overland Run Off P Input	Je	634733	gm yr^{-1}			
Total Development P Input	Jd	3520	gm yr^{-1}			
Total P Input	Jt	666877	gm yr^{-1}			
Lake P Retention Factor	Rp	0.18	n/a			
Lake Phosphorus Retention	Ps	120038	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.0141**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	546839	gm yr^{-1}			
Lake Mean Depth	z	2.9	m			
Lake Flushing Rate	FR	11.77	times yr^{-1}			
Lake Turnover Time	TT	0.08	yr			
Lake Response Time	RT(1/2)	0.05	yr			

Byron Lake model (headwater lake)

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl. of Lake Area)	Ad	453.5	ha
Area Land Use Category 1 (Forest)	Ad1	401.0	ha
Area Land Use Category 2 (Clear Cut)	Ad2	26.3	ha
Area Land Use Category 3 (Wetland)	Ad3	26.2	ha
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha
Area Land Use Category 6 (Camp)	Ad6	0.0	ha
Area Land Use Category 7	Ad7	0.0	ha
Area Land Use Category 8	Ad8	0.0	ha
Area Land Use Category 9	Ad9	0.0	ha
Area Land Use Category 10	Ad10	0.0	ha
Lake Surface Area	Ao	42.6	ha
Lake Volume	V	1.22	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs	Qi	0	$m^3 yr^{-1}$
Annual Unit Precipitation	Pr	1.36	$m\ yr^{-1}$
Annual Unit Lake Evaporation	Ev	0.18	$m\ yr^{-1}$
Annual Unit Hydraulic Runoff	Ru	0.93	$m\ yr^{-1}$
P Loading			
Upstream P Input	Pi	0	$gm\ P\ yr^{-1}$
Annual Unit Atmospheric P Deposition	Da	0.0250	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 1 P Export Coefficient	E1	0.0069	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 2 P Export Coefficient	E2	0.0625	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 3 P Export Coefficient*	E3	0.0031	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 4 P Export Coefficient	E4	0.0081	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 5 P Export Coefficient	E5	0.0350	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 6 P Export Coefficient	E6	0.0000	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 7 P Export Coefficient	E7	0.0000	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 8 P Export Coefficient	E8	0.0000	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 9 P Export Coefficient	E9	0.0000	$gm\ P\ m^{-2} yr^{-1}$
Land Use Category 10 P Export Coefficient	E10	0.0000	$gm\ P\ m^{-2} yr^{-1}$
Number of Dwellings	N_d	0	#
Average number of Persons per Dwelling	N_u	2.20	n/a
Average Fraction of Year Dwellings Occupied	N_{pc}	0.5	yr^{-1}
Phosphorus Load per Capita per Year	Si	800	$gm\ P\ cap^{-1} yr^{-1}$
Septic System Retention Coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	$gm\ P\ m^{-2} yr^{-1}$
Point Source Input 2	PS2	0	$gm\ P\ m^{-2} yr^{-1}$
Point Source Input 3	PS3	0	
Point Source Input 4	PS4	0	
Point Source Input 5	PS5	0	
Phosphorus Retention Coefficient	v	7.2	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	581290.5392	$m^3 yr^{-1}$
Total Evaporation Hydraulic Loss	Eo	76721.14464	$m^3 yr^{-1}$
Total Hydraulic Surface Run Off	Ql	4217819.176	$m^3 yr^{-1}$
Total Hydraulic Input	Qt	4799110	$m^3 yr^{-1}$
Areal Hydraulic Load	q_s	11.08	$m\ yr^{-1}$
Total Hydraulic Outflow	Qo	4722388.57	$m^3 yr^{-1}$
Upstream P Input	Ju	0	$gm\ yr^{-1}$
Total Atmospheric P Input	Jd	10656	$gm\ yr^{-1}$
Total Overland Run Off P Input	Je	44899	$gm\ yr^{-1}$
Total Development P Input	Jd	0	$gm\ yr^{-1}$
Total P Input	Jt	55555	$gm\ yr^{-1}$
Lake P Retention Factor	Rp	0.39	n/a
Lake Phosphorus Retention	Ps	21666	$gm\ yr^{-1}$
Predicted Lake Phosphorus Concentration	[P]	**0.0072**	$mg\ L^{-1}$
Lake Phosphorus Outflow	Jo	33889	$gm\ yr^{-1}$
Lake Mean Depth	z	2.9	m
Lake Flushing Rate	FR	3.87	$times\ yr^{-1}$
Lake Turnover Time	TT	0.26	yr
Lake Response Time	RT(1/2)	0.09	yr

Budgets

Hydraulic Budget (m^{-3})

		%Total
Upstream Inflow	0	0
Precipitation	581290.54	12.11
Surface Run Off	4217819.2	87.89
Evaporation	-76721.145	1.6
Total Outflow	4722388.6	98.4
Total Check		100.00

Phosphorus Budget ($gm\ yr^{-1}$)

		%Total
Upstream Inflow	0	0
Atmosphere	10656	19.18
Land Run Off	44899	80.82
Development	0	0.00
Sedimentation	-21666	39.00
Total Outflow	33889	61.00
Total Check		100.00

*based on Dillon & Molot (1997)

Tittle Lake model

Input Parameters	Symbol	Value	Units	Budgets		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	928.4	ha			
Area Land Use Category 1 (Forest)	Ad1	802.6	ha			**%Total**
Area Land Use Category 2 (Clear Cut)	Ad2	56.0	ha	Upstream Inflow	4722389	32.89
Area Land Use Category 3 (Wetland)	Ad3	69.8	ha	Precipitation	999945.31	6.97
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	8634057.3	60.14
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha	Evaporation	-131976.94	0.92
Area Land Use Category 6 (Camp)	Ad6	0.0	ha	Total Outflow	14224414	99.08
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	73.3	ha			**%Total**
Lake Volume	V	2.10	10^6 m^3	Upstream Inflow	4722389	23.4
Hydrology				Atmosphere	18330	12.66
Upstream Hydraulic Inputs (Byron Lake)	Qi	4722389	m^3 yr^{-1}	Land Run Off	92556	63.93
Annual Unit Precipitation	Pr	1.36	m yr^{-1}	Development	0	0.00
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}	Sedimentation	-39089	27.00
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}	Total Outflow	105686	73.00
P Loading				Total Check		99.99
Upstream P Input (Byron Lake)	Pi	33889	gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^{-2} yr^{-1}	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}			
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}			
Number of Dwellings	N_d	0	#			
Average number of Persons per Dwelling	N_u	2.20	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}			
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppti	999945.3089	m^3 yr^{-1}			
Total Evaporation Hydraulic Loss	Eo	131976.9435	m^3 yr^{-1}			
Total Hydraulic Surface Run Off	Ql	8634057.302	m^3 yr^{-1}			
Total Hydraulic Input	Qt	14356391	m^3 yr^{-1}			
Areal Hydraulic Load	q_s	19.4	m yr^{-1}			
Total Hydraulic Outflow	Qo	14224414.24	m^3 yr^{-1}			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	18330	gm yr^{-1}			
Total Overland Run Off P Input	Je	92556	gm yr^{-1}			
Total Development P Input	Jd	0	gm yr^{-1}			
Total P Input	Jt	144775	gm yr^{-1}			
Lake P Retention Factor	Rp	0.27	n/a			
Lake Phosphorus Retention	Ps	39089	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.0074**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	105686	gm yr^{-1}			
Lake Mean Depth	z	2.9	m			
Lake Flushing Rate	FR	6.77	times yr^{-1}			
Lake Turnover Time	TT	0.15	yr			
Lake Response Time	RT(1/2)	0.07	yr			

Loon Lake model

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl. of Lake Area)	Ad	167.3	ha
Area Land Use Category 1 (Forest)	Ad1	107.0	ha
Area Land Use Category 2 (Clear Cut)	Ad2	56.9	ha
Area Land Use Category 3 (Wetland)	Ad3	152.7	ha
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha
Area Land Use Category 6 (Camp)	Ad6	0.0	ha
Area Land Use Category 7	Ad7	0.0	ha
Area Land Use Category 8	Ad8	0.0	ha
Area Land Use Category 9	Ad9	0.0	ha
Area Land Use Category 10	Ad10	0.0	ha
Lake Surface Area	Ao	41.4	ha
Lake Volume	V	1.19	10^6 m^3
Hydrology			
Upstream Hydraulic Inputs (Tittle Lake)	Qi	14224414	m^3 yr^{-1}
Annual Unit Precipitation	Pr	1.36	m yr^{-1}
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}
P Loading			
Upstream P Input (Tittle Lake)	Pi	105686	gm P yr^{-1}
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}
Land Use Category 3 P Export Coefficient*	E3	0.0035	gm P m^{-2} yr^{-1}
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}
Number of Dwellings	N_d	0	#
Average number of Persons per Dwelling	N_u	2.20	n/a
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}
Septic System Retention Coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}
Point Source Input 3	PS3	0	
Point Source Input 4	PS4	0	
Point Source Input 5	PS5	0	
Phosphorus Retention Coefficient	v	7.2	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppt_i	565102.3701	m^3 yr^{-1}
Total Evaporation Hydraulic Loss	Eo	74584.56271	m^3 yr^{-1}
Total Hydraulic Surface Run Off	Ql	1555828.524	m^3 yr^{-1}
Total Hydraulic Input	Qt	16345345	m^3 yr^{-1}
Areal Hydraulic Load	q_s	39.27	m yr^{-1}
Total Hydraulic Outflow	Qo	16270760.57	m^3 yr^{-1}
Upstream P Input	Ju	0	gm yr^{-1}
Total Atmospheric P Input	Jd	10359	gm yr^{-1}
Total Overland Run Off P Input	Je	48381	gm yr^{-1}
Total Development P Input	Jd	0	gm yr^{-1}
Total P Input	Jt	164426	gm yr^{-1}
Lake P Retention Factor	Rp	0.15	n/a
Lake Phosphorus Retention	Ps	24664	gm yr^{-1}
Predicted Lake Phosphorus Concentration	[P]	**0.0086**	mg L^{-1}
Lake Phosphorus Outflow	Jo	139762	gm yr^{-1}
Lake Mean Depth	z	2.9	m
Lake Flushing Rate	FR	13.67	times yr^{-1}
Lake Turnover Time	TT	0.07	yr
Lake Response Time	RT(1/2)	0.04	yr

Budgets

Hydraulic Budget (m^{-3})		%Total
Upstream Inflow	14224414	87.02
Precipitation	565102.37	3.46
Surface Run Off	1555828.5	9.52
Evaporation	-74584.563	0.46
Total Outflow	16270761	99.54
Total Check		100.00

Phosphorus Budget (gm yr^{-1})		%Total
Upstream Inflow	14224414	64.3
Atmosphere	10359	6.30
Land Run Off	48381	29.42
Development	0	0.00
Sedimentation	-24664	15.00
Total Outflow	139762	85.00
Total Check		100.02

*based on Dillon & Molot (1997)

Lake Williams model

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl. of Lake Area)	Ad	638.3	ha
Area Land Use Category 1 (Forest)	Ad1	598.9	ha
Area Land Use Category 2 (Clear Cut)	Ad2	1.3	ha
Area Land Use Category 3 (Wetland)	Ad3	38.1	ha
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha
Area Land Use Category 6 (Camp)	Ad6	0.0	ha
Area Land Use Category 7	Ad7	0.0	ha
Area Land Use Category 8	Ad8	0.0	ha
Area Land Use Category 9	Ad9	0.0	ha
Area Land Use Category 10	Ad10	0.0	ha
Lake Surface Area	Ao	90.8	ha
Lake Volume	V	2.61	10^6 m^3
Hydrology			
Upstream Hydraulic Inputs (McKay Lake)	Qi	38736175	m^3 yr^{-1}
Annual Unit Precipitation	Pr	1.36	m yr^{-1}
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}
P Loading			
Upstream P Input (McKay Lake)	Pi	546839	gm P yr^{-1}
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^{-2} yr^{-1}
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}
Number of Dwellings	N_d	0	#
Average number of Persons per Dwelling	N_u	2.20	n/a
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}
Septic System Retention Coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}
Point Source Input 3	PS3	0	
Point Source Input 4	PS4	0	
Point Source Input 5	PS5	0	
Phosphorus Retention Coefficient	v	7.2	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppt_i	1237908.851	m^3 yr^{-1}
Total Evaporation Hydraulic Loss	Eo	163384.3622	m^3 yr^{-1}
Total Hydraulic Surface Run Off	Ql	5936352.43	m^3 yr^{-1}
Total Hydraulic Input	Qt	45910436	m^3 yr^{-1}
Areal Hydraulic Load	q_s	50.4	m yr^{-1}
Total Hydraulic Outflow	Qo	45747052.1	m^3 yr^{-1}
Upstream P Input	Ju	0	gm yr^{-1}
Total Atmospheric P Input	Jd	22692	gm yr^{-1}
Total Overland Run Off P Input	Je	43338	gm yr^{-1}
Total Development P Input	Jd	0	gm yr^{-1}
Total P Input	Jt	612869	gm yr^{-1}
Lake P Retention Factor	Rp	0.13	n/a
Lake Phosphorus Retention	Ps	79673	gm yr^{-1}
Predicted Lake Phosphorus Concentration	[P]	**0.0117**	mg L^{-1}
Lake Phosphorus Outflow	Jo	533196	gm yr^{-1}
Lake Mean Depth	z	2.9	m
Lake Flushing Rate	FR	17.53	times yr^{-1}
Lake Turnover Time	TT	0.06	yr
Lake Response Time	RT(1/2)	0.03	yr

Budgets

Hydraulic Budget (m^{-3})		%Total
Upstream Inflow	38736175	84.37
Precipitation	1237908.9	2.7
Surface Run Off	5936352.4	12.93
Evaporation	-163384.36	0.36
Total Outflow	45747052	99.64
Total Check		100.00

Phosphorus Budget (gm yr^{-1})		%Total
Upstream Inflow	38736175	89.2
Atmosphere	22692	3.70
Land Run Off	43338	7.07
Development	0	0.00
Sedimentation	-79673	13.00
Total Outflow	533196	87.00
Total Check		99.97

*based on Dillon & Molot (1997)

East Lake model (headwater lake)

Input Parameters	Symbol	Value	Units	Budgets		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	277.0	ha			
Area Land Use Category 1 (Forest)	Ad1	265.9	ha			**%Total**
Area Land Use Category 2 (Clear Cut)	Ad2	2.8	ha	Upstream Inflow	0	0
Area Land Use Category 3 (Wetland)	Ad3	8.3	ha	Precipitation	879523.86	25.46
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	2575671	74.54
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha	Evaporation	-116083.22	3.36
Area Land Use Category 6 (Camp)	Ad6	0.0	ha	Total Outflow	3339111.7	96.64
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	64.5	ha			**%Total**
Lake Volume	V	1.85	10^6 m^3	Upstream Inflow	0	0
Hydrology				Atmosphere	16123	44.22
Upstream Hydraulic Inputs	Qi	0	m^3 yr^{-1}	Land Run Off	20334	55.78
Annual Unit Precipitation	Pr	1.36	m yr^{-1}	Development	0	0.00
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}	Sedimentation	-21145	58.00
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}	Total Outflow	15312	42.00
P Loading				Total Check		100.00
Upstream P Input	Pi	0	gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^{-2} yr^{-1}	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}			
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}			
Number of Dwellings	N_d	0	#			
Average number of Persons per Dwelling	N_u	2.20	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	0.5	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}			
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppt_i	879523.8638	m^3 yr^{-1}			
Total Evaporation Hydraulic Loss	Eo	116083.22	m^3 yr^{-1}			
Total Hydraulic Surface Run Off	Ql	2575671.009	m^3 yr^{-1}			
Total Hydraulic Input	Qt	3455195	m^3 yr^{-1}			
Areal Hydraulic Load	q_s	5.18	m yr^{-1}			
Total Hydraulic Outflow	Qo	3339111.652	m^3 yr^{-1}			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	16123	gm yr^{-1}			
Total Overland Run Off P Input	Je	20334	gm yr^{-1}			
Total Development P Input	Jd	0	gm yr^{-1}			
Total P Input	Jt	36457	gm yr^{-1}			
Lake P Retention Factor	Rp	0.58	n/a			
Lake Phosphorus Retention	Ps	21145	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.0046**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	15312	gm yr^{-1}			
Lake Mean Depth	z	2.9	m			
Lake Flushing Rate	FR	1.8	times yr^{-1}			
Lake Turnover Time	TT	0.55	yr			
Lake Response Time	RT(1/2)	0.13	yr			

Salmon R Long Lake model						
Input Parameters	**Symbol**	**Value**	**Units**	**Budgets**		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	420.0	ha			
Area Land Use Category 1 (Forest)	Ad1	299.1	ha			**%Total**
Area Land Use Category 2 (Clear Cut)	Ad2	103.5	ha	Upstream Inflow	65356924	92.6
Area Land Use Category 3 (Wetland)	Ad3	17.4	ha	Precipitation	1315803.2	1.86
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	3905881	5.53
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha	Evaporation	-173665.18	0.25
Area Land Use Category 6 (Camp)	Ad6	0.0	ha	Total Outflow	70404943	99.75
Area Land Use Category 7	Ad7	0.0	ha	Total Check		99.99
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	96.5	ha			**%Total**
Lake Volume	V	2.55	$10^6\ m^3$	Upstream Inflow	65356924	86.2
Hydrology				Atmosphere	24120	3.02
Upstream Hydraulic Inputs (Williams,Loon, and E	Qi	65356924	$m^3\ yr^{-1}$	Land Run Off	85882	10.76
Annual Unit Precipitation	Pr	1.36	$m\ yr^{-1}$	Development	0	0.00
Annual Unit Lake Evaporation	Ev	0.18	$m\ yr^{-1}$	Sedimentation	-71844	9.00
Annual Unit Hydraulic Runoff	Ru	0.93	$m\ yr^{-1}$	Total Outflow	726428	91.00
P Loading				Total Check		99.98
Upstream P Input (Williams,Loon, and East Lake	Pi	688270	$gm\ P\ yr^{-1}$			
Annual Unit Atmospheric P Deposition	Da	0.0250	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 1 P Export Coefficient	E1	0.0069	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 2 P Export Coefficient	E2	0.0625	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 3 P Export Coefficient*	E3	0.0031	$gm\ P\ m^{-2}\ yr^{-1}$	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 5 P Export Coefficient	E5	0.0350	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 6 P Export Coefficient	E6	0.0000	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 7 P Export Coefficient	E7	0.0000	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 8 P Export Coefficient	E8	0.0000	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 9 P Export Coefficient	E9	0.0000	$gm\ P\ m^{-2}\ yr^{-1}$			
Land Use Category 10 P Export Coefficient	E10	0.0000	$gm\ P\ m^{-2}\ yr^{-1}$			
Number of Dwellings	N_d	0	#			
Average number of Persons per Dwelling	N_u	2.20	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	$gm\ P\ cap^{-1}\ yr^{-1}$			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	$gm\ P\ m^{-2}\ yr^{-1}$			
Point Source Input 2	PS2	0	$gm\ P\ m^{-2}\ yr^{-1}$			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppt_i	1315803.198	$m^3\ yr^{-1}$			
Total Evaporation Hydraulic Loss	Eo	173665.1823	$m^3\ yr^{-1}$			
Total Hydraulic Surface Run Off	Ql	3905880.951	$m^3\ yr^{-1}$			
Total Hydraulic Input	Qt	70578608	$m^3\ yr^{-1}$			
Areal Hydraulic Load	q_s	72.97	$m\ yr^{-1}$			
Total Hydraulic Outflow	Qo	70404943.29	$m^3\ yr^{-1}$			
Upstream P Input	Ju	0	$gm\ yr^{-1}$			
Total Atmospheric P Input	Jd	24120	$gm\ yr^{-1}$			
Total Overland Run Off P Input	Je	85882	$gm\ yr^{-1}$			
Total Development P Input	Jd	0	$gm\ yr^{-1}$			
Total P Input	Jt	798272	$gm\ yr^{-1}$			
Lake P Retention Factor	Rp	0.09	n/a			
Lake Phosphorus Retention	Ps	71844	$gm\ yr^{-1}$			
Predicted Lake Phosphorus Concentration	[P]	**0.0103**	$mg\ L^{-1}$			
Lake Phosphorus Outflow	Jo	726428	$gm\ yr^{-1}$			
Lake Mean Depth	z	2.6	m			
Lake Flushing Rate	FR	27.61	times yr^{-1}			
Lake Turnover Time	TT	0.04	yr			
Lake Response Time	RT(1/2)	0.02	yr			

Granite Lake model (headwater lake)

Input Parameters	Symbol	Value	Units	Budgets		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	926.4	ha			
Area Land Use Category 1 (Forest)	Ad1	857.5	ha			**% Total**
Area Land Use Category 2 (Clear Cut)	Ad2	17.6	ha	Upstream Inflow	0	0
Area Land Use Category 3 (Wetland)	Ad3	51.3	ha	Precipitation	1140539.1	11.69
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	8615383.2	88.31
Area Land Use Category 5 (Residential Lots)	Ad5	0.0	ha	Evaporation	-150533.1	1.54
Area Land Use Category 6 (Camp)	Ad6	0.0	ha	Total Outflow	9605389.3	98.46
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	83.6	ha			**% Total**
Lake Volume	V	2.21	10^6 m^3	Upstream Inflow	0	0
Hydrology				Atmosphere	20907	22.56
Upstream Hydraulic Inputs	Qi	0	m^3 yr^{-1}	Land Run Off	71768	77.44
Annual Unit Precipitation	Pr	1.36	m yr^{-1}	Development	0	0.00
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}	Sedimentation	-36143	39.00
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}	Total Outflow	56532	61.00
P Loading				Total Check		100.00
Upstream P Input	Pi	0	gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^{-2} yr^{-1}	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}			
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}			
Number of Dwellings	N_d	0	#			
Average number of Persons per Dwelling	N_u	2.20	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	0.5	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}			
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppt_i	1140539.119	m^3 yr^{-1}			
Total Evaporation Hydraulic Loss	Eo	150533.0998	m^3 yr^{-1}			
Total Hydraulic Surface Run Off	Ql	8615383.241	m^3 yr^{-1}			
Total Hydraulic Input	Qt	9755922	m^3 yr^{-1}			
Areal Hydraulic Load	q_s	11.49	m yr^{-1}			
Total Hydraulic Outflow	Qo	9605389.261	m^3 yr^{-1}			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	20907	gm yr^{-1}			
Total Overland Run Off P Input	Je	71768	gm yr^{-1}			
Total Development P Input	Jd	0	gm yr^{-1}			
Total P Input	Jt	92675	gm yr^{-1}			
Lake P Retention Factor	Rp	0.39	n/a			
Lake Phosphorus Retention	Ps	36143	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.0059**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	56532	gm yr^{-1}			
Lake Mean Depth	z	2.6	m			
Lake Flushing Rate	FR	4.35	times yr^{-1}			
Lake Turnover Time	TT	0.23	yr			
Lake Response Time	RT(1/2)	0.08	yr			

Lewis Lake model

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl. of Lake Area)	Ad	747.1	ha
Area Land Use Category 1 (Forest)	Ad1	551.8	ha
Area Land Use Category 2 (Clear Cut)	Ad2	141.5	ha
Area Land Use Category 3 (Wetland)	Ad3	36.4	ha
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha
Area Land Use Category 5 (Residential Lots)	Ad5	17.4	ha
Area Land Use Category 6 (Camp)	Ad6	0.0	ha
Area Land Use Category 7	Ad7	0.0	ha
Area Land Use Category 8	Ad8	0.0	ha
Area Land Use Category 9	Ad9	0.0	ha
Area Land Use Category 10	Ad10	0.0	ha
Lake Surface Area	Ao	60.4	ha
Lake Volume	V	1.60	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs (Granite Lake)	Qi	9605389	$m^3 yr^{-1}$
Annual Unit Precipitation	Pr	1.36	$m yr^{-1}$
Annual Unit Lake Evaporation	Ev	0.18	$m yr^{-1}$
Annual Unit Hydraulic Runoff	Ru	0.93	$m yr^{-1}$
P Loading			
Upstream P Input (Granite Lake)	Pi	56532	$gm P yr^{-1}$
Annual Unit Atmospheric P Deposition	Da	0.0250	$gm P m^{-2} yr^{-1}$
Land Use Category 1 P Export Coefficient	E1	0.0069	$gm P m^{-2} yr^{-1}$
Land Use Category 2 P Export Coefficient	E2	0.0625	$gm P m^{-2} yr^{-1}$
Land Use Category 3 P Export Coefficient*	E3	0.0031	$gm P m^{-2} yr^{-1}$
Land Use Category 4 P Export Coefficient	E4	0.0081	$gm P m^{-2} yr^{-1}$
Land Use Category 5 P Export Coefficient	E5	0.0350	$gm P m^{-2} yr^{-1}$
Land Use Category 6 P Export Coefficient	E6	0.0000	$gm P m^{-2} yr^{-1}$
Land Use Category 7 P Export Coefficient	E7	0.0000	$gm P m^{-2} yr^{-1}$
Land Use Category 8 P Export Coefficient	E8	0.0000	$gm P m^{-2} yr^{-1}$
Land Use Category 9 P Export Coefficient	E9	0.0000	$gm P m^{-2} yr^{-1}$
Land Use Category 10 P Export Coefficient	E10	0.0000	$gm P m^{-2} yr^{-1}$
Number of Dwellings	N_d	40	#
Average number of Persons per Dwelling	N_u	2.20	n/a
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}
Phosphorus Load per Capita per Year	Si	800	$gm P cap^{-1} yr^{-1}$
Septic System Retention Coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	$gm P m^{-2} yr^{-1}$
Point Source Input 2	PS2	0	$gm P m^{-2} yr^{-1}$
Point Source Input 3	PS3	0	
Point Source Input 4	PS4	0	
Point Source Input 5	PS5	0	
Phosphorus Retention Coefficient	v	7.2	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppt_i	824028.4003	$m^3 yr^{-1}$
Total Evaporation Hydraulic Loss	Eo	108758.6978	$m^3 yr^{-1}$
Total Hydraulic Surface Run Off	Ql	6947584.011	$m^3 yr^{-1}$
Total Hydraulic Input	Qt	17377002	$m^3 yr^{-1}$
Areal Hydraulic Load	q_s	28.58	$m yr^{-1}$
Total Hydraulic Outflow	Qo	17268242.97	$m^3 yr^{-1}$
Upstream P Input	Ju	0	$gm yr^{-1}$
Total Atmospheric P Input	Jd	15105	$gm yr^{-1}$
Total Overland Run Off P Input	Je	133696	$gm yr^{-1}$
Total Development P Input	Jd	35200	$gm yr^{-1}$
Total P Input	Jt	240533	$gm yr^{-1}$
Lake P Retention Factor	Rp	0.2	n/a
Lake Phosphorus Retention	Ps	48107	$gm yr^{-1}$
Predicted Lake Phosphorus Concentration	[P]	**0.0111**	$mg L^{-1}$
Lake Phosphorus Outflow	Jo	192426	$gm yr^{-1}$
Lake Mean Depth	z	2.6	m
Lake Flushing Rate	FR	10.79	$times yr^{-1}$
Lake Turnover Time	TT	0.09	yr
Lake Response Time	RT(1/2)	0.05	yr

Budgets		
Hydraulic Budget (m^{-3})		
		%Total
Upstream Inflow	9605389	55.28
Precipitation	824028.4	4.74
Surface Run Off	6947584	39.98
Evaporation	-108758.7	0.63
Total Outflow	17268243	99.37
Total Check		100.00
Phosphorus Budget ($gm yr^{-1}$)		
		%Total
Upstream Inflow	9605389	23.5
Atmosphere	15105	6.28
Land Run Off	133696	55.58
Development	35200	14.63
Sedimentation	-48107	20.00
Total Outflow	192426	80.00
Total Check		99.99

*based on Dillon & Molot (1997)

Martin Lake model

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl. of Lake Area)	Ad	1145.8	ha
Area Land Use Category 1 (Forest)	Ad1	668.4	ha
Area Land Use Category 2 (Clear Cut)	Ad2	389.7	ha
Area Land Use Category 3 (Wetland)	Ad3	54.7	ha
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha
Area Land Use Category 5 (Residential Lots)	Ad5	33.1	ha
Area Land Use Category 6 (Camp)	Ad6	0.0	ha
Area Land Use Category 7	Ad7	0.0	ha
Area Land Use Category 8	Ad8	0.0	ha
Area Land Use Category 9	Ad9	0.0	ha
Area Land Use Category 10	Ad10	0.0	ha
Lake Surface Area	Ao	49.2	ha
Lake Volume	V	1.30	10^6 m^3
Hydrology			
Upstream Hydraulic Inputs (Salmon River L and	Qi	87673186	m^3 yr^{-1}
Annual Unit Precipitation	Pr	1.36	m yr^{-1}
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}
P Loading			
Upstream P Input (Salmon River L and Lewis La	Pi	918854	gm P yr^{-1}
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^{-2} yr^{-1}
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^{-2} yr^{-1}
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^{-2} yr^{-1}
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^{-2} yr^{-1}
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^{-2} yr^{-1}
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^{-2} yr^{-1}
Land Use Category 6 P Export Coefficient	E6	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^{-2} yr^{-1}
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^{-2} yr^{-1}
Number of Dwellings on or near Lakeshore	N_d	50	#
Average number of Persons per Dwelling	N_u	2.70	n/a
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}
Septic System Retention Coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm P m^{-2} yr^{-1}
Point Source Input 2	PS2	0	gm P m^{-2} yr^{-1}
Point Source Input 3	PS3	0	
Point Source Input 4	PS4	0	
Point Source Input 5	PS5	0	
Phosphorus Retention Coefficient	v	7.2	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppt_i	671615.2327	m^3 yr^{-1}
Total Evaporation Hydraulic Loss	Eo	88642.57361	m^3 yr^{-1}
Total Hydraulic Surface Run Off	Ql	10656111.15	m^3 yr^{-1}
Total Hydraulic Input	Qt	99000913	m^3 yr^{-1}
Areal Hydraulic Load	q_s	200.85	m yr^{-1}
Total Hydraulic Outflow	Qo	98912270.07	m^3 yr^{-1}
Upstream P Input	Ju	0	gm yr^{-1}
Total Atmospheric P Input	Jd	12311	gm yr^{-1}
Total Overland Run Off P Input	Je	302928	gm yr^{-1}
Total Development P Input	Jd	54000	gm yr^{-1}
Total P Input	Jt	1288093	gm yr^{-1}
Lake P Retention Factor	Rp	0.03	n/a
Lake Phosphorus Retention	Ps	38643	gm yr^{-1}
Predicted Lake Phosphorus Concentration	[P]	**0.0126**	mg L^{-1}
Lake Phosphorus Outflow	Jo	1249450	gm yr^{-1}
Lake Mean Depth	z	2.6	m
Lake Flushing Rate	FR	76.09	times yr^{-1}
Lake Turnover Time	TT	0.01	yr
Lake Response Time	RT(1/2)	0.01	yr

Budgets		
Hydraulic Budget (m^{-3})		
		%Total
Upstream Inflow	87673186	88.56
Precipitation	671615.23	0.68
Surface Run Off	10656111	10.76
Evaporation	-88642.574	0.09
Total Outflow	98912270	99.91
Total Check		100.00
Phosphorus Budget (gm yr^{-1})		
		%Total
Upstream Inflow	87673186	71.3
Atmosphere	12311	0.96
Land Run Off	302928	23.52
Development	54000	4.19
Sedimentation	-38643	3.00
Total Outflow	1249450	97.00
Total Check		99.97

*based on Dillon & Molot (1997)

McCoy's Pond Model						
Input Parameters	**Symbol**	**Value**	**Units**	**Budgets**		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	60.0	ha			
Area Land Use Category 1 (Forest)	Ad1	6.0	ha			**% Total**
Area Land Use Category 2 (Clear Cut)	Ad2	6.0	ha	Upstream Inflow	0	0
Area Land Use Category 3 (Wetland)	Ad3	9.0	ha	Precipitation	56768.175	9.23
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	558000	90.77
Area Land Use Category 5 (Residential Lots)	Ad5	36.0	ha	Evaporation	-7492.5	1.22
Area Land Use Category 6 (Roads & pavement)	Ad6	3.0	ha	Total Outflow	607275.68	98.78
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	4.2	ha			**% Total**
Lake Volume	V	0.08	10^6 m^3	Upstream Inflow	0	0
Hydrology				Atmosphere	1041	1.02
Upstream Hydraulic Inputs (Martin Lake)	Qi		m^3 yr^{-1}	Land Run Off	27546	26.96
Annual Unit Precipitation	Pr	1.36	m yr^{-1}	Development	73584	72.02
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}	Sedimentation	-33716	33.00
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}	Total Outflow	68455	67.00
P Loading				Total Check		100.0
Upstream P Input (-)	Pi		gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^2 yr^{-1}			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^2 yr^{-1}			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^2 yr^{-1}			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^2 yr^{-1}	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^2 yr^{-1}			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^2 yr^{-1}			
Land Use Category 6 P Export Coefficient	E6	0.3500	gm P m^2 yr^{-1}			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^2 yr^{-1}			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^2 yr^{-1}			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^2 yr^{-1}			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^2 yr^{-1}			
Number of Dw ellings on or near Lakeshore	N_d	320	#			
Average number of Persons per Dw elling	N_u	1.50	n/a			
Average Fraction of Year Dw ellings Occupied	N_{pc}	1	yr^{-1}			
Phosphorus Load per Capita per Year	Si	153	gm P cap^{-1} yr^{-1}			
Septic System Retention Coefficient	Rsp	1.0	n/a	All TP from STP Effluent		
Point Source Input from Trailer Park WWTP 480 pop * 624.2 g P/cap/yr	PS1	73584	gm P m^2 yr^{-1}			
Point Source Input 2	PS2	0	gm P m^2 yr^{-1}			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppt_i	56768	m^3 yr^{-1}			
Total Evaporation Hydraulic Loss	Eo	7493	m^3 yr^{-1}			
Total Hydraulic Surface Run Off	Ql	558000	m^3 yr^{-1}			
Total Hydraulic Input	Qt	614768	m^3 yr^{-1}			
Areal Hydraulic Load	q_s	15	m yr^{-1}			
Total Hydraulic Outflow	Qo	607276	m^3 yr^{-1}			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	1041	gm yr^{-1}			
Total Overland Run Off P Input	Je	27546	gm yr^{-1}			
Total Development P Input	Jd	73584	gm yr^{-1}			
Total P Input	Jt	102171	gm yr^{-1}			
Lake P Retention Factor	Rp	0.33	n/a			
Lake Phosphorus Retention	Ps	33716	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.1127**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	68455	gm yr^{-1}			
Lake Mean Depth	z	2	m			
Lake Flushing Rate	FR	7.29	times yr^{-1}			
Lake Turnover Time	TT	0.14	yr			
Lake Response Time	RT(1/2)	0.06	yr			

Lake Echo Model						
Input Parameters	**Symbol**	**Value**	**Units**	**Budgets**		
Morphology				**Hydraulic Budget (m^{-3})**		
Drainage Basin Area (Excl. of Lake Area)	Ad	1272.8	ha			
Area Land Use Category 1 (Forest)	Ad1	737.3	ha			**% Total**
Area Land Use Category 2 (Clear Cut)	Ad2	219.2	ha	Upstream Inflow	99519546	87.02
Area Land Use Category 3 (Wetland)	Ad3	62.5	ha	Precipitation	3011270.4	2.63
Area Land Use Category 4 (Hay Land)	Ad4	0.0	ha	Surface Run Off	11837040	10.35
Area Land Use Category 5 (Residential Lots)	Ad5	224.7	ha	Evaporation	-397440	0.35
Area Land Use Category 6 (Roads & pavement)	Ad6	29.1	ha	Total Outflow	113970416	99.65
Area Land Use Category 7	Ad7	0.0	ha	Total Check		100.00
Area Land Use Category 8	Ad8	0.0	ha			
Area Land Use Category 9	Ad9	0.0	ha	**Phosphorus Budget (gm yr^{-1})**		
Area Land Use Category 10	Ad10	0.0	ha			
Lake Surface Area	Ao	220.8	ha			**% Total**
Lake Volume	V	6.93	10^6 m^3	Upstream Inflow	99519546	60.6
Hydrology				Atmosphere	55200	2.54
Upstream Hydraulic Inputs (Martin Lake)	Qi	99519546	m^3 yr^{-1}	Land Run Off	370292	17.02
Annual Unit Precipitation	Pr	1.36	m yr^{-1}	Development	432000	19.86
Annual Unit Lake Evaporation	Ev	0.18	m yr^{-1}	Sedimentation	-261048	12.00
Annual Unit Hydraulic Runoff	Ru	0.93	m yr^{-1}	Total Outflow	1914349	88.00
P Loading				Total Check		100.0
Upstream P Input (Martin Lake & McCoys Pond)	Pi	1317905	gm P yr^{-1}			
Annual Unit Atmospheric P Deposition	Da	0.0250	gm P m^2 yr^{-1}			
Land Use Category 1 P Export Coefficient	E1	0.0069	gm P m^2 yr^{-1}			
Land Use Category 2 P Export Coefficient	E2	0.0625	gm P m^2 yr^{-1}			
Land Use Category 3 P Export Coefficient*	E3	0.0031	gm P m^2 yr^{-1}	*based on Dillon & Molot (1997)		
Land Use Category 4 P Export Coefficient	E4	0.0081	gm P m^2 yr^{-1}			
Land Use Category 5 P Export Coefficient	E5	0.0350	gm P m^2 yr^{-1}			
Land Use Category 6 P Export Coefficient	E6	0.3500	gm P m^2 yr^{-1}			
Land Use Category 7 P Export Coefficient	E7	0.0000	gm P m^2 yr^{-1}			
Land Use Category 8 P Export Coefficient	E8	0.0000	gm P m^2 yr^{-1}			
Land Use Category 9 P Export Coefficient	E9	0.0000	gm P m^2 yr^{-1}			
Land Use Category 10 P Export Coefficient	E10	0.0000	gm P m^2 yr^{-1}			
Number of Dwellings on or near Lakeshore	N_d	400	#			
Average number of Persons per Dwelling	N_u	2.70	n/a			
Average Fraction of Year Dwellings Occupied	N_{pc}	1	yr^{-1}			
Phosphorus Load per Capita per Year	Si	800	gm P cap^{-1} yr^{-1}			
Septic System Retention Coefficient	Rsp	0.5	n/a			
Point Source1	PS1	0	gm P m^2 yr^{-1}			
Point Source Input 2	PS2	0	gm P m^2 yr^{-1}			
Point Source Input 3	PS3	0				
Point Source Input 4	PS4	0				
Point Source Input 5	PS5	0				
Phosphorus Retention Coefficient	v	7.2	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppt_i	3011270.4	m^3 yr^{-1}			
Total Evaporation Hydraulic Loss	Eo	397440	m^3 yr^{-1}			
Total Hydraulic Surface Run Off	Ql	11837040	m^3 yr^{-1}			
Total Hydraulic Input	Qt	114367856	m^3 yr^{-1}			
Areal Hydraulic Load	q_s	51.62	m yr^{-1}			
Total Hydraulic Outflow	Qo	113970416.1	m^3 yr^{-1}			
Upstream P Input	Ju	0	gm yr^{-1}			
Total Atmospheric P Input	Jd	55200	gm yr^{-1}			
Total Overland Run Off P Input	Je	370292	gm yr^{-1}			
Total Development P Input	Jd	432000	gm yr^{-1}			
Total P Input	Jt	2175397	gm yr^{-1}			
Lake P Retention Factor	Rp	0.12	n/a			
Lake Phosphorus Retention	Ps	261048	gm yr^{-1}			
Predicted Lake Phosphorus Concentration	[P]	**0.0168**	mg L^{-1}			
Lake Phosphorus Outflow	Jo	1914349	gm yr^{-1}			
Lake Mean Depth	z	3.1	m			
Lake Flushing Rate	FR	16.45	times yr^{-1}			
Lake Turnover Time	TT	0.06	yr			
Lake Response Time	RT(1/2)	0.04	yr			

APPENDIX D

Component Study – Surface Water Use Objectives Questionnaire

Lake Echo Watershed Study

Water Quality Objectives Questionnaire Results Summary

101015.00 ● Draft ● October 2011

ISO 9001
Registered Company

Prepared for:
Halifax Regional Municipality

Prepared by:
CBCL LIMITED
Consulting Engineers

Lake Echo Water Quality Objectives Questionnaire Response Results

October 2011

Contents

Appendices

CHAPTER 1 LAKE ECHO WATER QUALITY QUESTIONNAIRE

1.1 Questionnaire Overview

The Lake Echo Water Quality Questionnaire was part of the Lake Echo Watershed Study. The Halifax Regional Municipality (HRM) commissioned this study to develop a solid understanding of the Lake Echo Watershed as an aid to future planning. The purpose of the questionnaire was to gather community input on future water use and objectives for the Lake Echo area. The objective was to find out how residents of the area use water bodies now and how they want to be able to use them in the future. The questionnaire is available as Appendix A.

The questionnaire was available online from **July 18 to September 16, 2011**. The survey was publicized through email distribution lists, posters, and a notice in the Eastern Gazette in the Municipal Councillors newsletter. There were **111 responses**. Questionnaire responses are summarized in the sections below.

1.2 Importance of Water Bodies

Respondents were provided with a list of water bodies in the area and asked to indicate the ways in which these water bodies were important to them. Overall, the most responses were provided for Lake Echo and Lawrencetown Lake. For all lakes, visual enjoyment, swimming and wildlife habitat were generally the highest choices, while boating and recreational fishing was also popular. Also, Lake Echo and Lawrencetown Lake were used for drinking water more often than the other lakes. Figure 1 shows the important values respondents indicated for each water bodies.

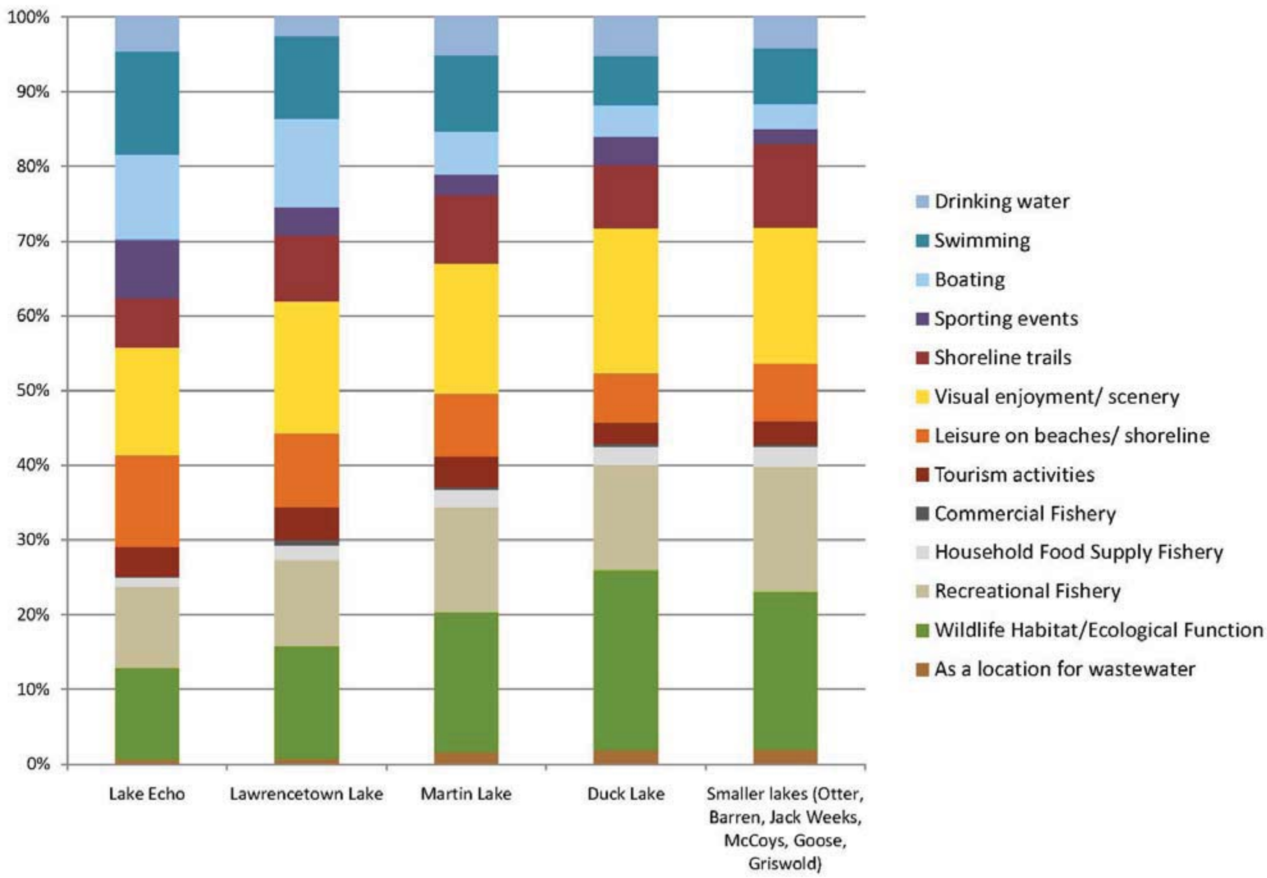


Figure 1: Water Bodies and Importance for Respondents

1.3 Concern about Water Bodies

In response to a question regarding concern about the lakes, the vast majority of respondents indicated a great deal of concern for all of the indicated lakes. Lake Echo, in particular, attracted the most amount of concern from respondents. Figure 2 shows the level of concern respondents indicated for each water body.

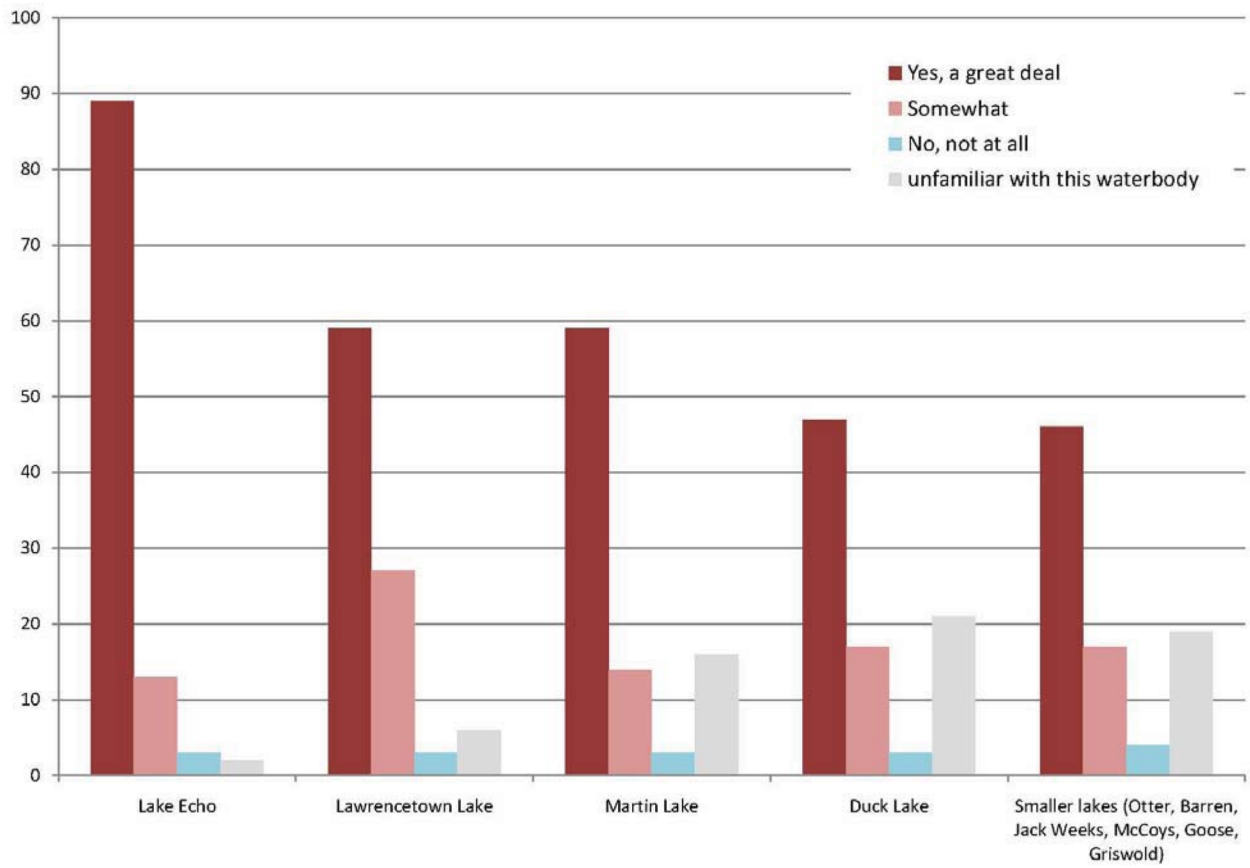


Figure 2: Level of Concern Respondents Indicated for Each Water Body

1.4 Future water quality

The Regional Plan recognizes the difficulties with achieving pristine conditions in every watershed. Respondents were asked what level of water quality they desired for each water body. The questionnaire showed respondents a scale that showed a movement from the LEAST stringent water quality requirements (left) to the MOST stringent water quality requirements (right). Respondents were asked to indicate the level of water quality requirements they would be satisfied with in the future.

Figure 3 shows the level of water quality respondents would be satisfied with in the future for each water body. Respondents identified Lake Echo and Martin Lake as water bodies that require the most stringent water quality requirements. For all lakes, 85% or more respondents indicated a desire for high requirements on fresh water bodies (Level 4 and 5). Very few respondents would be satisfied with low water quality requirements (Level 1 and 2).

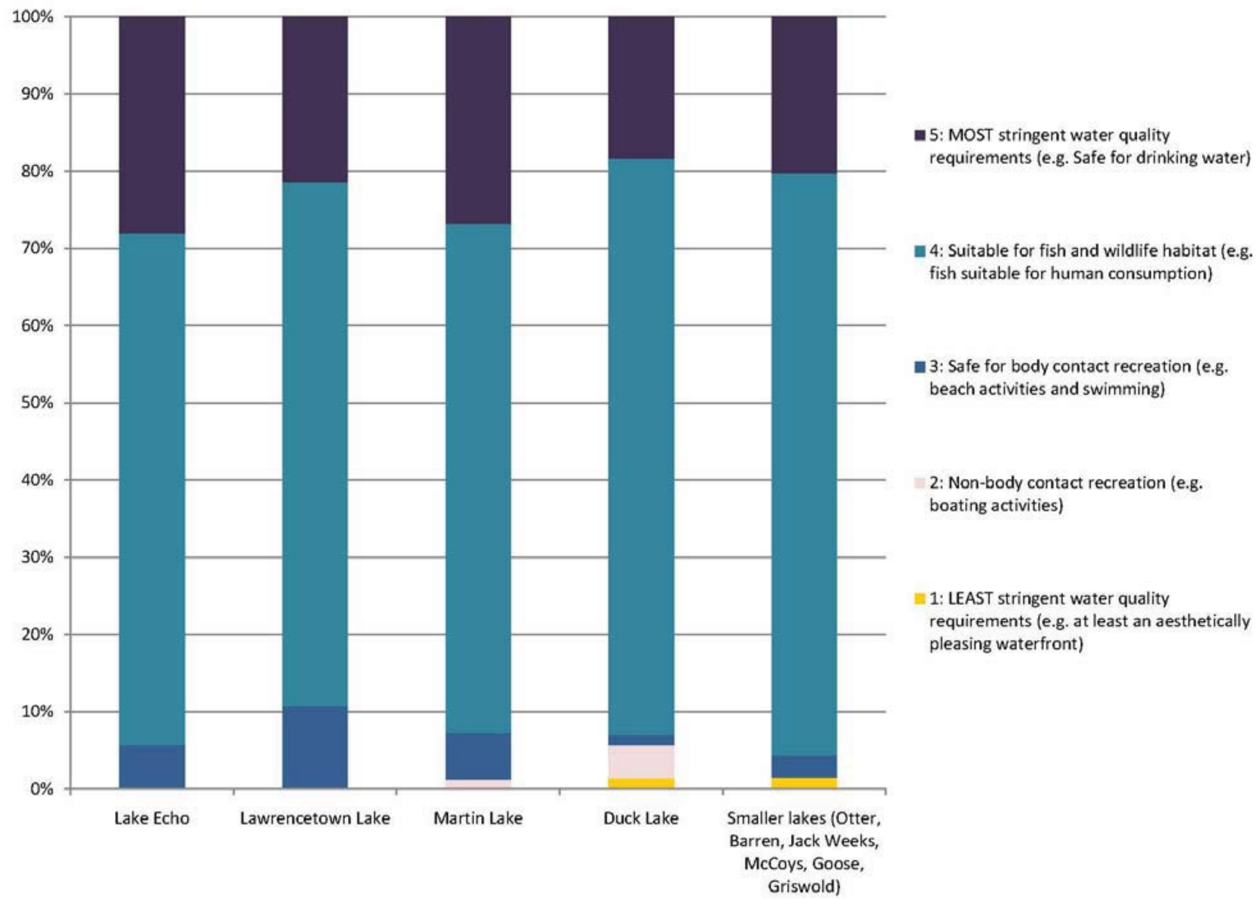


Figure 3: Level of Future Water Quality Respondents would be Satisfied With

1.5 Requirement for regular maintainance of on-site systems

Respondents were asked if people should be required to maintain their on-site septic systems on a regular basis, and if necessary replace their septic systems to prevent impacts on water quality in local water bodies. 95.4% of respondents said "yes."

1.6 Potential Sources of Contamination

Respondents were asked to describe any potential past or current sources of contamination in each water body. The most responses were received for Lake Echo and Lawrencetown Lake. Respondents described the following potential sources of contamination:

1.6.1 Potential contaminants of Lake Echo (70 responses)

- **Construction/excavation/development too close to the water (49 responses);**
- **Septic systems in general (domestic and school) and old or failed (24 responses);**
- **Automotive mechanic land use / scrap yards (9 responses);**
- **Chemical fertilizers and pesticides (7 responses);**

- Mineral extraction (4 response each);
- Roads / salt (3 responses);
- Gas and oil leaks - domestic and from boats (3 responses);
- Landfills / informal "dumps" (2 responses); and
- Tree cutting (1 response).

1.6.2 Potential contaminants of Lawrencetown Lake (31 responses)

- **Construction/excavation/development too close to the water (18 responses);**
- **Septic systems in general (domestic and school) and old or failed (10 responses);**
- **Chemical fertilizers and pesticides (7 responses);**
- **Automotive mechanic land use / scrap yards (6 responses);**
- Mineral extraction (3 response each);
- Gas and oil leaks - domestic and from boats (3 responses);
- Landfills / informal "dumps" (2 responses); and
- Roads / salt (1 responses).

1.6.3 Potential contaminants of Martin Lake (20 responses)

- **Construction/excavation/development too close to the water (11 responses);**
- **Septic systems in general (domestic and school) and old or failed (10 responses);**
- Chemical fertilizers and pesticides (4 responses);
- Tree cutting (2 responses);
- Mineral extraction (1 response each); and
- Roads / salt (1 responses).

1.6.4 Potential contaminants of Duck Lake (10 responses)

- **Construction/excavation/development too close to the water (9 responses);**
- **Septic systems in general (domestic and school) and old or failed (4 responses);**
- Chemical fertilizers and pesticides (3 responses);
- Tree cutting (1 responses); and
- Mineral extraction (1 response each).

1.6.5 Potential contaminants of other bodies of water

- McCoys Pond - Contaminated from sewer from the existing trailer park;
- Lakes in Upper Salmon river watershed near Halifax International Airport - acid runoff from runway construction;
- Partridge River - fertilizer & pesticides, failed septic systems; and
- River between Lake Echo & Lawrencetown Lake - construction near lake.

1.7 Additional Information or Concerns

Forty-five respondents provided additional comments at the end of the survey. Many respondents were re-emphasizing areas of concern indicated in responses to earlier questions and provided details on specific developments they were concerned with. Several commercial and trailer park developments raised the most concern among respondents. Furthermore, respondents indicated they would prefer stricter enforcement of existing laws on new development around water bodies, drinking water quality and septic/waste disposal.

APPENDIX A

Questionnaire

Lake Echo Watershed Study

Questionnaire Purpose: To gather community input on future water use and objectives for the Lake Echo area. We want to know how you use waterbodies in the area now and how you want to be able to use them in the future.

The HRM Regional Municipal Planning Strategy recognizes the importance of using watershed studies as the basis for developing community planning strategies.

This questionnaire is part of the Lake Echo Watershed Study. HRM has commissioned this study to develop a solid understanding of the Lake Echo Watershed as an aid to future planning. The study is designed to determine the opportunities for future development that are within the environmental capacity of land and receiving waters. The study will also assess options for servicing Lake Echo with a central piped water supply and small scale on-site or cluster septic systems. Your input will help determine the values you have for different waterbodies in your area so that water quality objectives may be recommended and acceptable scenarios for future development may be assessed.

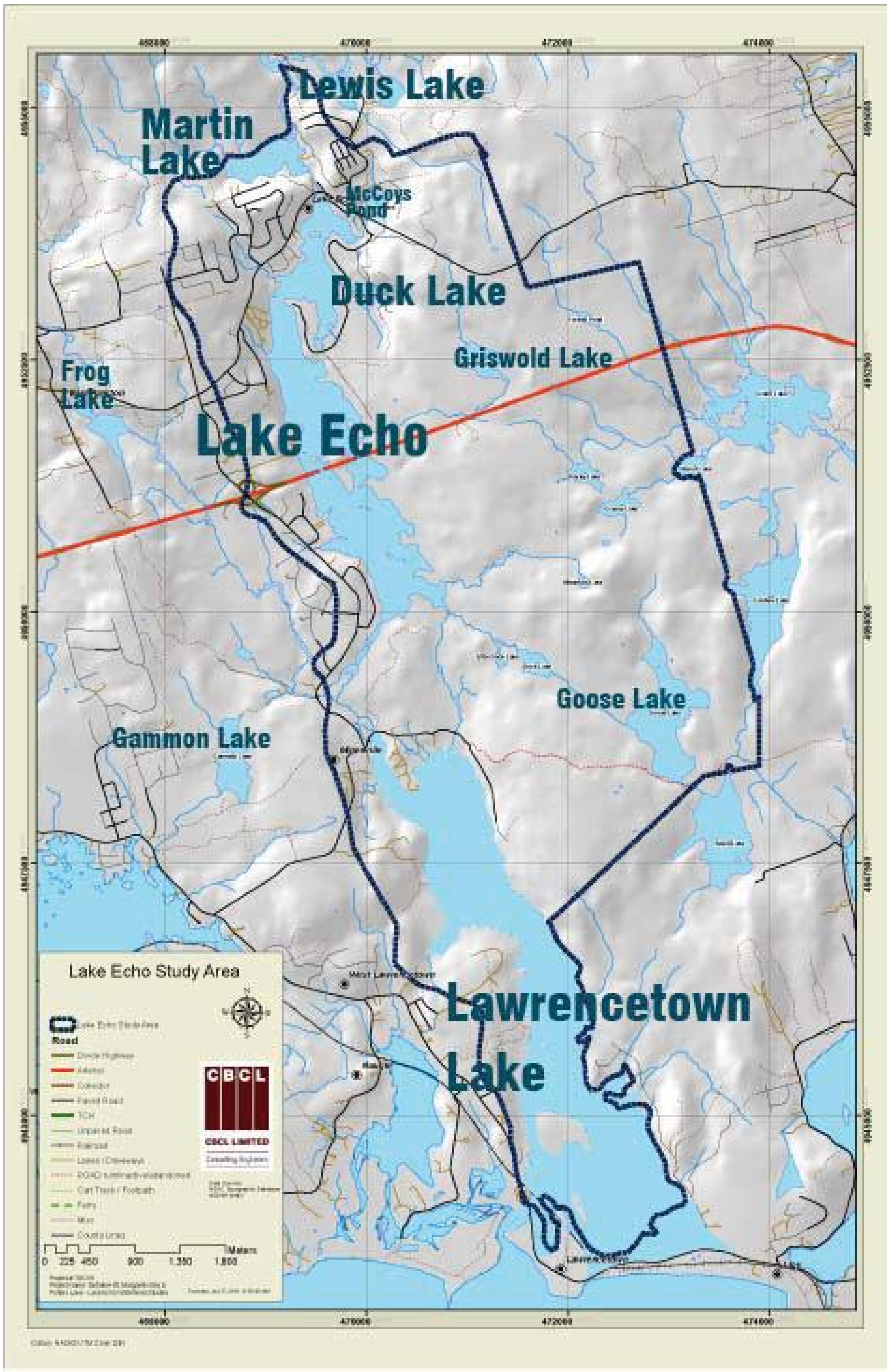
This questionnaire should take approximately 10 minutes to complete. There is a section at the end where you are welcome to provide additional comments.
The survey will be available until Friday September 16, 2011

If you have any questions, please contact:
Gordon Smith, Planner (gordons@cbcl.ca)
CBCL Limited
PO Box 606
Halifax, NS B3J 2R7
Phone: 902-421-7241
Fax: 902-423-3938

Thank you for your time!

CBCL LIMITED
Consulting Engineers

This survey asks questions about waterbodies within the Lake Echo Watershed Study Area shown within the dark blue boundary line below.



In what ways are these waterbodies in the Lake Echo area important to you? Please check all that apply.

	Drinking water	Swimming	Boating	Sporting events	Shoreline trails	Visual enjoyment/ scenery	Leisure on beaches/ shoreline	Tourism activities	Commercial Fishery	Household Food Supply Fishery	Recreational Fishery	Wildlife Habitat/Ecological Function	As loca fo waste
Lake Echo													
Lawrencetown Lake													
Martin Lake													
Duck Lake													
Smaller lakes (Otter, Barren, Jack Weeks, McCoys, Goose, Griswold)													

Other (please identify the waterbody and specify its importance to you)

Are you concerned about the water quality of these waterbodies?

	No, not at all	Somewhat	Yes, a great deal	unfamiliar with this waterbody
Lake Echo				
Lawrencetown Lake				
Martin Lake				
Duck Lake				
Smaller lakes (Otter, Barren, Jack Weeks, McCoys, Goose, Griswold)				

Other waterbodies you are concerned about (please specify waterbody and level of concern - somewhat concerned or concerned a great deal)

The Regional Plan recognizes the difficulties with achieving pristine conditions in every watershed. We want to know the level of water quality the community desires for each waterbody so the community can continue to enjoy and use waterbodies in their area as the population grows.

The scale below moves from the LEAST stringent water quality requirements (left) to the MOST stringent water quality requirements (right).

What is the minimum level of future water quality you would be satisfied with for each of these water bodies ?

	1: LEAST stringent water quality requirements (e.g. at least an aesthetically pleasing waterfront)	2: Non-body contact recreation (e.g. boating activities)	3: Safe for body contact recreation (e.g. beach activities and swimming)	4: Suitable for fish and wildlife habitat (e.g. fish suitable for human consumption)	5: MOST stringent water quality requirements (e.g. Safe for drinking water)	unfamiliar with this waterbody
Lake Echo	○	○	○	○	○	○
Lawrencetown Lake	○	○	○	○	○	○
Martin Lake	○	○	○	○	○	○
Duck Lake	○	○	○	○	○	○
Smaller lakes (Otter, Barren, Jack Weeks, McCoys, Goose, Griswold)	○	○	○	○	○	○

If required, add other waterbodies and indicate desired level of water quality requirements (1-5)

Should property owners be required to maintain their on-site septic systems on a regular basis, and if necessary replace their septic systems to prevent impacts on water quality in local lakes, streams and Lake Echo?

○ Yes

○ No

Comment

Establishing a Waste Water Management District would enable ongoing staff inspection and require that property owners regularly maintain and pump on-site septic and stormwater systems.

Would you be willing to pay for a Waste Water Management District through an area rate?

○ Yes

○ No

Comment

Current and former land uses and activities that can contaminate a waterbody include: gas stations, works yards, fuel/salt/chemical storage, sawmills, fertilizer and pesticides from farm fields, mines or aggregate extraction, landfills, failed septic systems, and others.

Please describe any potential sources of contamination in the following waterbodies.

Lake Echo	
Lawrencetown Lake	
Martin Lake	
Duck Lake	
Smaller lakes (Otter, Barren, Jack Weeks, McCoys, Goose, Griswold)	
Other waterbody (specify)	

If you are willing to be contacted for more information about the location of the potential contaminants you have identified, please provide your contact information below.

Name:	
City/Town:	
Email Address:	
Phone Number:	

Please provide any additional information or concerns you have about water quality in the Lake Echo Watershed Study area. Please be as specific as possible.

Thank you for your time completing this questionnaire and contributing to the Lake Echo Watershed Study.

APPENDIX E

Component Study – Habitats and Species at Risk

Contents

CHAPTER 1 BIOREGIONS

The habitats that encompass the study area include both that which is found inland and that which is found in the bay (the water environments). Habitat analysis refers to the consideration of the natural setting in which something lives. Generally this means looking at the biota (plants and animals) and how they may relate to surficial geology, hydrology and other environmental systems.

The Natural History of Nova Scotia (Davis and Browne, 1996) is the recognized classification system in describing our natural history and identifies three distinct districts within the study area as described below.

1.1 District 833: Eastern Shore Beaches

Davis and Browne (1996) describe this district, which makes up most of the study area south of Highway 107, as an indented, drowned coastline with headlands, long inlets and drumlin islands. Barrier beaches and spits are formed as coastal sediment is continually being reworked. The inlets provide important migration and overwintering habitat for waterfowl, and are considered to be drowned river estuaries. Large areas of tidal marsh can be found throughout this District.

In spring, the inlet areas are a stopover for several thousand Black Ducks and Canada Geese. The numbers peak again in October, making this an area with larger Black Duck and Canada Geese populations than anywhere else in Nova Scotia.

The inland areas south of Highway 107 are dominated by well-draining Halifax gravelly sandy loams derived from quartzite. The peninsulas and coastal areas in this district feature a variety of soils. On the western shore of Chezzetcook Inlet the dominate soils are well-draining Wolfville soils, which consist of a dark reddish brown loam to sandy clay loam. Areas with less relief, in particular between Porters Lake and Lawrencetown Lake, are covered by imperfectly draining Danesville soil. Other poorly to imperfectly draining soils, such as Aspotogan, Riverport and Peat, can be found in the coastal areas of this district, while pockets of well draining Bridgewater soils can be found around the communities of West Chezzetcook, Middle Porters Lake and West Lawrencetown (MacDougall et al. 1963).

Coastal White Spruce and Balsam Fir forest with maple and birch dominates the district. On old farmlands and drumlins, pure stands of White Spruce are common. Further back from the coast, there are spruce, fir, and pine stands.

1.2 District 413: Quartzite Barrens (Sub-district 413a, Halifax)

This district passes through the study area north of Highway 107 and south of an imagined east-west line along the orientation of Conrod Lake. The bedrock-dominated landscape which gives name to these barrens can best be described as a “ridge-swamp-swale” in seemingly endless repetition (Davis and Browne, 1996). In this district, the mantle of quartzite till ranges in thickness from 1 to 10 meters but averages less than 3 meters. Most of the study area within this district is covered by well-draining Halifax soil. A smaller area between Petpeswick Lake, Chezzetcook Lake and Conrod Lake around Highway 107 is covered by well-draining Bridgwater soil.

While the higher, broader ridges in this District are capped with American Beech, Yellow Birch, maple, the lower side slopes are dominated by spruce. Depressions are inhabited by Black Spruce and larch with patches of White Pine growing in sand. Broad swampy areas with Balsam Firm Black Spruce and Red Maple are common along edges of slow moving streams. Excessive shrub-dominated barrens occur in this District with birch, Red Maple and aspen depending on soil depth and drainage conditions.

1.3 District 453: Granite Ridge

The northern part of the study area falls within the Granite Ridge, a prominent 80-kilometre long ridge rising about 100 m above sea level along the eastern shore. Porters Lake follows a fault line across the ridge into a narrow gorge, while Lawrencetown Lake is a drowned river estuary. The surface of the granite is mostly covered by Gibraltar soils - well-drained, sandy loams derived from granite.

The vegetation common to this district includes Red Spruce, Balsam Fir, birch, Eastern Hemlock and White Spruce on well-drained soils with Black Spruce, and larch in wetter soils. Parts of the district have very thin soils and exposed bedrock where the vegetation has been reduced to a semi-barren state. Shade-intolerant aspen and birch typically colonize burnt areas in this area.

1.4 Cultural Environment:

Forest management predominates within the Granite Ridge area. Christmas tree farms have become a new industry in the region. Recent increases in the value of gold has caused interest in mining for this mineral to become reactivated in the Quartzite Barrens, which was the most productive gold mining area in Nova Scotia during the 1800’s. Today, Woodlot management occurs in the Quartzite Barrens. The drumlin fields of the Eastern Shore Beaches district have been used for small scale farming since the mid-1700s. Though in decline, fishing continues to be an important economic activity for some communities. Recreational activities such as bird-watching, hiking, camping and swimming are common in the Beach areas.

CHAPTER 2 **SPECIES AT RISK**

2.1 Introduction

To identify any rare biota located within the study area the following lists were reviewed: the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as well as those listed under the Species at Risk Act (SARA); Nova Scotia Endangered Species Act (NSESA); Nova Scotia Department of Natural Resources General Status of Wild Species List (NSDNR General Status); and the Atlantic Canada Conservation Data Centre (ACCDC) guidance list. Table 2.1 summarizes the definitions of rarity ranks associated with the referenced lists.

Table 2.1: Definitions of Rarity Rankings

ACCDC Ranks Definitions (ACCDC 2003)	
S1	Extremely rare throughout its range in the province (typically five or fewer occurrences or very few remaining individuals). May be especially vulnerable to extirpation.
S2	Rare throughout its range in the province (six to 20 occurrences or few remaining individuals). May be vulnerable to extirpation due to rarity or other factors.
S3	Uncommon throughout its range in the province, or found only in a restricted range, even if abundant at some locations (21 to 100 occurrences).
S4	Usually widespread, fairly common throughout its range in the province, and apparently secure with many occurrences, but the species is of long-term concern, e.g., watch list (100+ occurrences).
SU	Unrankable: Possibly in peril throughout its range in the province, but status uncertain: need more information. Used for new species not previously identified.
SX	Extinct/Extirpated: Believed to be extirpated within the province.
S#S#	Numeric range rank: A range between two consecutive numeric ranks. Denotes uncertainty about the exact rarity of the species, e.g., S1S2.
?	In exact or uncertain: For numeric ranks, denotes uncertainty, e.g., SE? denotes uncertainty of exotic status.
NSDNR General Status Rankings Definitions (NSDNR)	
Blue	No longer in Nova Scotia or extinct in wild
Red	Known to be or is thought to be at risk.
Yellow	Sensitive to human activities or natural events.
Green	Not believed to be sensitive, or at risk.

COSEWIC Ranks	
Endangered	A species facing imminent extirpation or extinction
Threatened	A species likely to become endangered if limited factors are not reversed
Special Concern	A species of concern because of characteristics that make it particularly sensitive to human activities or natural events**.**

Additional sources used to determine the regional distribution and habitat preferences for birds were the Atlas of Breeding Birds of the Maritime Provinces (Erskine, 1992) and Eastern Birds (Peterson, 1980). For plants, the additional source used was Roland's Flora of Nova Scotia (Zinck, 1998). The results of this screening are detailed in the following tables and brief overviews.

2.1.1 Species of Concern

In Nova Scotia, plant and animal species are tracked and designated at four levels. SARA and the Endangered Species Act represent legislative designations while the Nova Scotia Department of Natural Resources (NSDNR) and ACCDC provide technical tracking lists.

The purpose of this watershed study was to identify opportunities of development in the study area based on several aspects of the environment and of the surrounding communities. One of the specific tasks of this study was to identify natural corridors and critical habitats for terrestrial and aquatic species of interest and of concern. In the 5km radius of the ACCDC screening no biologically significant sites or managed areas were identified.

2.2 Discussion

2.2.1 Birds

Nine bird species of concern were identified during this study (Table 2.2).Six species have been federally and/ or provincially legislated as species of concern under COSEWIC and the Nova Scotia Endangered Species Act.

Table 2.2: Bird Species of Concern

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Harlequin Duck	*Histrionicus histrionicus*	Species of Concern	Endangered	Yellow	S2N
American Peregrine Falcon	*Falco peregrinus anatum*	Species of Concern	Threatened	Red	S1B
Piping Plover	*Charadrius melodus*	Endangered	Endangered	Red	S1B
Roseate Tern	*Sterna dougallii*	Endangered	Endangered	Red	S1B
Common tern	*Sterna hirundo*			Yellow	S3B
Arctic Tern	*Sterna paradisaea*			Yellow	S3B
Bobolink	*Dolichonyx oryzivorus*			Yellow	S3B

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Red Knot rufa	*Bucephala clangula*	Endangered		Yellow	S2B
Rusty Blackbird	*Euphagus carolinus*	Species of Concern		Yellow	S3B

American Peregrine Falcon (*Falco peregrinus anatum*)

The American peregrine falcon was listed as threatened under COSEWIC in 2000. They breed throughout North America and have been known to use traditional nesting cliffs within the Maritimes, however numbers and exact location of the breeding sites are dynamic. Based on ACCDC records the closest sighting of the American peregrine falcon from the study area was less than 10 km away. It is a migratory species, with breeding areas in Nova Scotia restricted to exposed cliffs, most notably around the Bay of Fundy and the Minas Basin in Cumberland, Colchester, Hants, Kings and Victoria counties and in Inverness County. The probability of this species residing in the project site is low.

Habitat Requirements:

- Large cliff faces (61 m tall x 150 m long) with multiple nesting ledges, near water bodies (habitat for prey);
- Abundant prey source (shorebirds, ducks, small-medium sized birds); and
- Minimal human disturbances, such as road construction, blasting, recreational activities.

Terns (*Sterna spp.*)

The Arctic tern (*Sterna paradisaea*), and common tern (*Sterna hirundo*) have been designated Yellow or species of concern by the Nova Scotia Department of Natural Resources. The common tern prefers temperate climates including inland and coastal areas where there are shallow waters for feeding and sandy or gravelly shores for nesting. Unlike the common tern, the Arctic tern prefers cooler coastal areas and prefers to forage further out to sea. Both species of tern were observed less than 10km away from the study area.

Habitat Requirements:

- Colonial nesters on sandy, gravelly or sparsely vegetated shorelines. Will avoid nesting where shrubbery or woody vegetation is present;
- Are more deep water (ocean) feeders diving after schools of fish, but can be found more inshore; and
- Prefer nesting on islands, but will next along secluded beaches.

The roseate tern (*Sterna dougallii*) is listed as endangered under the NS Endangered Species Act and COSEWIC. It is therefore legislated under the Species at Risk Act. The roseate tern has similar habitat preferences to the common and arctic tern but physiologically, the roseate tern has a deeper forked tail and has a more slender appearance. The coastal habitat within the study area is consistent with the breeding site preference of the roseate tern, and the closest record is within 9km of the project area. The likelihood of tern species residing along the coastal areas is high depending on water temperature and availability of food. Potential impacts to this species should be evaluated on a project by project basis.

Habitat Requirements:

- Prefer rocky coast lines or islands, secluded beaches, and salt marsh islands;
- Will nest in vegetation, driftwood or rock crevices which provide moderate cover;
- These divers prefer to forage in shallower waters (< 10m) with sandy bottoms for schools of fish; and
- Very sensitive to human disturbances and often abandon nesting sites.

Piping Plover (*Charadrius melodus*)

The piping plover was legislated under the Species at Risk Act as Endangered in 2001. Fifty to sixty pairs breed along the Atlantic shoreline. Populations have not increased, notwithstanding conservative efforts due to declining nesting habitat quality and predation amongst other disturbances limiting species reproductive success. Piping plover prefer beach breeding areas and will make their nest in soft sand or gravel. This species has been recorded breeding on Conrads Island and the Barrier beaches in the study area would provide suitable habitat for piping plovers. As with the Roseate Tern impacts to this species should be evaluated at the project level.

Habitat Requirements:

- Prefer to nest on coastal beaches containing dunes, pools, and sand pits away from the water. Need beaches greater than a hectare;
- Forage around pools, tidal flats, and beaches for invertebrates; and
- Adults are tolerant to human presence, but nests and young are severely impacted by human activities/disturbances such as ATVs or beach maintenance.

Rusty Blackbird (*Euphagus carolinus*)

The rusty blackbird is a species of special concern under COSEWIC and is therefore legislated under the Species at Risk Act. The Rusty Blackbird is infrequent throughout Nova Scotia, where it typically inhabits wetlands, peat bogs, marshes, swamps and dry pasture edges. Breeding birds are usually seen from late March through mid-April. The Rusty blackbird has been observed approximately 11km from the center of the project site (ACCDC, 2010). The possibility of this species residing in the study area is moderate and impacts to this species should be considered in future development.

Habitat Requirements:

- Often found around wetlands, forested wetlands (coniferous), edges of watercourses or water bodies ;
- Degradation or elimination of wetlands will have a significant impact on the population ; and
- Prefer to nest in coniferous trees or a dense shrub layer, close to a water source which provides habitat for their prey source (invertebrates, insect larvae, snails).

Harlequin Duck (*Histrionicus histrionicus)*

The harlequin duck is a winter resident which breeds in western and northern North America. Small groups are widely distributed from The Bay of Fundy coast to Cape Breton. It is listed as endangered under the NS Endangered Species Act and a Species of Concern by COSEWIC. The nearest sighting was the 50km from the study area making the likelihood of it being in the study area low.

Habitat Requirements:

- Prefer to reside and nest near turbulent waters such as fast moving streams, or rocky coastlines;
- These diving ducks forage underwater for mollusks, crustaceans, and small fish;
- They require cover for nesting sites which can be located on the ground, small cliff ledge, or in a tree cavity; and
- Sensitive to disturbances such as logging practices, aquaculture, hunting, boating activities, etc Will only tolerate moderate human presence and will abandon sites if human activity becomes too much.

Red Knot rufa (*Calidris canutus rufa)*

The red knot rufa is a medium sized shore bird that visits the coastal regions of Nova Scotia during migration during the summer and fall. It is written in literature that there are as few as 15000 left in the wild. It is considered to be an endangered species by COSEWIC. This species as declined greatly in a short period of time and risks becoming extinct.

Habitat Requirements:

- When migrating, these birds prefer coastal areas with large sand and mudflats, salt marches, and brackish waters;
- Feed primarily on horseshoe crab eggs and invertebrates; and
- Numbers are impacted due to depletion of their main food source (horseshoe crabs), wetland degradation or elimination, and pollution.

2.2.2 Plants

Eleven plant species of concern were identified as having been seen in the area (20km), or as having habitat preferences similar to what is found in the study area (Table 2.3).

Table 2.3: Plant Species of Concern

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Ghost Antler Lichen	*Pseudevernia cladonia*	Species of Concern			S2
Boreal Felt Lichen (Atlantic)	*Erioderma pedicellatum*	Endangered	Endangered	Red	S1S2
Coast Pepper-Bush	*Clethra alnifolia*	Species of Concern	Vulnerable	Red	S1S2
Eastern White Cedar	*Thuja occidentalis*		Vulnerable	Red	S1S2
Long branched Frostweed	*Helianthemum canadense*		Endangered		S1

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Moonwort Grape-Fern	*Botrychium lunaria*			Red	S1
Wiegand's Wild Rye	*Elymus wiegandii*			Red	S1
Seabeach Groundsel	*Senecio pseudoarnica*			Yellow	
Larger Canadian St. John's Wort	*Hypericum majus*			Red	S1
Cut-Leaved Coneflower	*Rudbeckia laciniata*			Yellow	S2
Hairy Lettuce	*Lactuca hirsuta*			Yellow	S2

Ghost Antler Lichen (*Pseudevernia cladonia*)

The Ghost Antler Lichen has been federally legislated as a Species of Concern. The species is a chalky white, finely branched macrolichen occurring on twigs of conifers in cool montane and coastal spruce-fir forests in eastern North America. It is very patchily distributed in New Brunswick and Nova Scotia, probably owing to dispersal limitations. In Nova Scotia and New Brunswick, some population losses are attributable to logging and housing development. The severity of the threats is offset by the abundance of the species over a broad area and potential discovery of large populations on some mountain tops in Quebec. It is possible that this species could occupy the study area as the nearest sighting was at a distance of 23km. Therefore it is recommended that a more detailed screening be conducted on a project by project basis.

Habitat Requirements:

- Prefers areas that are cool, humid, or coastal coniferous forests (balsam fir and red spruce) with high occurrences or fog or cloud cover;
- Occurs frequently in mature or over mature forest;
- Logging operations and land developments have been a key reason for the decline in populations; and
- It does not respond well after major disturbances, and has limited dispersal capabilities for regeneration.

Coast Pepper-Bush *(Clethra alnifolia)*

Coast pepper-bush is both federally and provincially legislated as a vulnerable species of special concern. Its preferred habitat includes the shores of lake headwaters, sandy woods, swamps and thickets. There is one recorded observation of the species within 100km of the project site, approximately 25km away (ACCDC, 2010). The likelihood of this species residing within the project area is moderate.

Habitat Requirements:

- Found in wet woods, thickets, wetlands, and near lakes and streams;
- Is tolerant to brackish waters, but needs moist soils for establishment; and
- Sensitive to natural disturbances such as wind and ice scour.

Larger Canadian St. John's Wort *(Hypericum majus)*

The larger Canadian St. John's wort has been listed by NSDNR as a Red species. It has been sighted in both Halifax County and Victoria County, and was recorded less than 25km away from the study area. Its preferred habitat consists of wet or dry open soil. The likelihood of this species residing within the project boundaries is moderately high due to the presence of wetland complexes scattered throughout the site.

Habitat Requirements:

- Grows along ponds, lakesides (low, wet areas), calcareous soils;
- Associated with riparian habitats (often completely submerged); and
- Threats to populations include the creation of dams, destruction of wetlands, and competition from invasive species.

Boreal Felt Lichen, Atlantic Population (*Erioderma pedicellatum*)

The boreal felt lichen is both federally and provincially legislated as endangered. The lichen prefers to grow on the branches or stems of conifers such as balsam fir, black spruce, or white spruce. On rare occasions, it can also be found on red maple. The lichen has a bluish gray appearance and is usually 2-5cm in diameter. There was one observation of this species within 12 km of the project site and multiple other sightings within 20km of the project site.

Habitat Requirements:

- Found only in mature or over-mature forests, primarily balsam fir or black/white spruce;
- Prefers to grow on slopes with a northern aspect with cool and moist conditions throughout the year;
- Development of new lichen is dependent on the relationship between the spores of adult lichen and a species of liverwort; and
- Very sensitive to acid rain and air pollutants, both of which are possible causes of the drastic decline in numbers. Deforestation is another threat to the survival of this species.

2.2.3 Invertebrates

23 species of invertebrates, nine from the Order Odonata and 12 Lipodoptera and one marine species from the Unionidae family as species of concern were identified as having been seen in the area, or as having habitat preferences similar to what is found in the study area (Table 2.4). One species is described below.

Table 2.4: Invertebrate Species of Interest

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Monarch	*Danaus plexippus*	Species of Concern		Yellow	S2B

Monarch Butterfly (*Danaus plexippus*)

The monarch butterfly was federally legislated in 1997 and was reconfirmed in 2001 as a species of Special Concern. Although the monarch population is quite abundant over its entire range, it's highly restricted and vulnerable in its winter range. Its preferred habitat consists of open habitats such as fields, meadows, marshes and roadsides. Based on ACCDC records the closest observed sighting of the species was approximately 26km away from the site. The likelihood of this species residing in the project site is moderately low.

Habitat Requirements:

- Found in open fields and meadows that specifically contain milkweed and flowering plants which are a source of food for Monarch larvae and adults; and
- The eradication of milkweed can threaten the status of Monarchs. Milkweeds can be poisonous to livestock.

2.2.4 Fish

Fish species of interest within the study area have been assessed based on desktop surveys, literature review and discussions with representatives from the Department of Fisheries and Oceans and the Provincial Department of Fisheries and Aquaculture, Inland Division.

Three species of concern were identified as being within certain distances of the study area and have been discussed below (Table 2.5).

Table 2.5: Fish Species of Concern

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Atlantic Salmon	*Salmo salar*	Endangered	N/A	Red	S2
Atlantic Salmon (Inner Bay of Fundy)	*Salmo salar*	Endangered	N/A	Red	S2
Striped Bass	*Morone saxatilis*	Threatened	N/A	Red	S1

Atlantic Salmon (*Salmo salar*)

The Atlantic salmon was listed by COSEWIC as an endangered species in 2001. Atlantic salmon are anadromous, spending part of their life feeding and growing during long migrations in the sea, and then return to reproduce in the fresh water stream where they hatch. Atlantic salmon that are ready to spawn begin moving up rivers from spring through fall. They often return to sea immediately before winter or remain in the stream until spring. The young salmon that emerge in April to July migrate down-estuary in the spring. Records of sightings indicate that this species is likely present within close proximity of the study area.

Atlantic Salmon – Inner Bay of Fundy (*Salmo salar*)

Inner Bay of Fundy Atlantic salmon have been listed as endangered under the Species at Risk Act (SARA) since 2003 and are now at risk of becoming extinct. Their rapid decline has been attributed to low marine survival and possibly factors such as tidal barriers and commercial salmon farms. A recovery strategy has been developed and includes identification of their critical habitat. Inner Bay of Fundy Atlantic salmon are not typically found within the vicinity of the study area, but have been sighted within 24 km. Their presence there is still unlikely.

Habitat Requirements:

- Various requirements depending on the stage of development;
- For rearing of eggs and young, a substrate of gravel or cobble with well-oxygenated water with temperatures below 10 °C;
- The egg and alevin/fry stage is highly susceptible to sedimentation in the watercourses (suffocation);
- Poor logging practices (insufficient watercourse buffering) and agriculture (pesticide runoff) heavily impact Atlantic salmon numbers;
- Juveniles tolerate warmer waters (less than 25°C), but still require well-oxygenate and clean water. Prefer water depths of 10 – 61cm and velocities of 30-92 cm/sec. As they develop into the smolt stage, access to the ocean is required; and
- Adults require access to their natal grounds for spawning. Prefer water temperatures below 23°C and dissolved oxygen content above 5 ppm.

Striped Bass (*Morone saxatalis*)

Striped bass populations have been listed by NSDNR as a Red species and are considered threatened under COSEWIC. Shubenacadie River is one of the few rivers in Atlantic Canada with a self-sustained striped bass population. The Stewiacke River, a large tributary to the Shubenacadie is the main spawning habitat for this species. The lead cause in population decline for this species has been attributed to habitat change. The likelihood of this species residing near the study area is low, as the nearest record is 31 km.

Habitat Requirements:

- Inhabit coastal surge, inshore bars and reeds, tidal rips, bays and estuaries;
- Habitat loss or alterations such as dykes, culverts, and causeways greatly affect spawning, rearing, and wintering habitat;
- Highly successful spawning has occurred in waters with:
  - Suitable current (> 30 cm/s to maintain egg suspension);
  - Salinity (0.70 – 1.5 ppt, < 5 ppt);
  - Water temperatures below 22°C; and
  - Dissolved oxygen (> 3 mg/l).
- As the striped bass proceeds through its life stages (egg - larvae - juvenile-adult), It becomes more tolerant to this factors.

Fish Species not of Concern

Other fish species of interest that are not considered to be of concern of being endangered by the federal or provincial regulatory bodies and are known to reside in the project site include: brook trout (*Salvelinus fontinalis*), white perch (*Morone Americana*), rainbow smelt (*Osmerus mordax*), smallmouth bass (*Micropterus dolomieui*), white sucker (*Catostomus commersoni*), and golden shiner (*Notemigonus crysoleucas)* (T. Marshall, personal comm. December, 2010).

2.2.5 Mammals

Three species of concern were identified as having been seen in the 100km area, although only one species was within 30km of the study area.

Table 2.6: Mammal Species of Concern

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Moose	*Alces alces*	Endangered	Endangered	Red	S1

Moose (*Alces alces*)

Moose in Nova Scotia are comprised of two genetically different and distinct populations i.e. the mainland population and the Cape Breton population. The mainland population is comprised of less than 1000 individuals. The mainland moose is listed by the *Nova Scotia Endangered Species Act* as Endangered; and hunting of the mainland moose is illegal.

Moose inhabit boreal forests across Canada and northern United States and prefer near-climax vegetation with shrubby growth. Moose feed on aquatic plants in summer and the preferred food in the winter includes certain hardwoods and balsam fir. The closest sighting of moose to the study area was 30km away, most likely away from populated areas.

Habitat Requirements:

- Prefer mature mixed forests (providing cover and food source) with minimal human presence;
- Correlation between deciduous shrub abundance and moose presence; and
- Wetlands and areas with aquatic vegetation are important habitats in the summer periods.

2.2.6 Reptiles

Only one species of reptile were observed near the study area.

Table 2.7: Reptile Species of Concern

Common Name	Scientific Name	COSEWIC	NS Endangered Species Act	NSDNR	ACCDC Rating
Wood turtle	*Clemmys insculpta*	Threatened	Vulnerable	Yellow	S3

Wood Turtle (*Clemmys insculpta*)

The wood turtle has been federally legislated as a species of concern and provincially as a vulnerable species. The closest observation of the species recorded under ACCDC to the Project site was less than 9km. The wood turtle typically congregates in small populations of up to 100 individuals near riparian habitat characterized by high depositional sandy banks that are scoured by winter and spring floods. The presence of this species within the study site is moderate and impacts should be evaluated on a project to project basis.

Habitat Requirements:

- Prefer to live in riparian habitats or floor plains;
- Three main necessities to wood turtles habitats are a river or stream, sandy substrate for nesting purposes, and a forested area;
- Prefer clean streams and rivers with a hard substrate, not a clay or mud; and
- Spend a lot of time on land in the summer in wet to moist hardwood or coniferous forests with dense understories.

2.3 Contraints to Development

The upland vegetation, the forest associations and plant communities found in the study area are common throughout the Eastern Shore. While this vegetation is not rare, it is sensitive to disturbance. The forest cover protects the coastal and lake environments from pollution. The primary constraints of the study area for residential development from a habitat perspective would be disturbance to the coastal and lake environments as a result of loss of forest cover on the uplands.

The management of sediment transport from highly erodable thin soils on the forested uplands down onto the surrounding estuarine environments will be critical in protecting the coastal and lake habitats. Slope and aspect mapping are useful tools in identifying where development might occur to minimize erosion. Clear cutting, and other forest management practices in conjunction with how land is cleared and developed should be scrutinized very carefully prior to development. This is particularly critical in areas where pyritic slates are found (see Figure #). Where the bedrock is exposed leaching of heavy metals and aluminum as well as acid runoff can occur damaging downstream environments. Wildlife in aquatic environments is particularly susceptible to acidification. While the eggs of many aquatic organisms are directly affected, reduced productivity can also affect species higher up the food chain. Salmon populations are also particularly sensitive to increased acidification.

Regeneration of forest environments on areas where land is disturbed or burned is difficult once sources of nutrients have been removed. Consideration should also be given to how contaminants from development (i.e. salt runoff from highways and streets) will be managed will help preserve the fragile coastal and lake environments. Development guidelines and a development ethic should be adopted in ensuring that development in this area can occur alongside the fragile coastal and lake environments that attract people to settle in the area.

CHAPTER 3 REFERENCES

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APPENDIX F

Component Study – Evaluation of Alternate Wastewater Servicing Options

Contents

CHAPTER 1 BACKGROUND

HRM has received an application for a 240 hectare development in the Lake Echo and Porters Lake area. A plan, Lake Echo Case 01278, dated December 19, 2011 has been received, and correspondence indicates that 315 units are proposed as follows:

1. Areas A and B: 189 mobile home and modular home units, B includes Open Space Design for Modular homes, (189 units in 114 hectares, Classic Open Space Design Concept).
2. Area C: 126 units using the Hybrid Open Space Design Concept).

HRM is completing watershed studies to investigate a range of environmental issues within watersheds (study areas) affected by the Regional Municipal Planning Strategy for Lake Echo and Porters Lake, and CBCL, as consultant for the project, has been requested to provide comments on wastewater servicing options that could be considered for the developments. It is stressed that the comments are for the education and use of HRM personnel only, and that the developer would have its' own consultant (Design Engineer) evaluate the options and submit documents to Nova Scotia Environment for approval.

Applicable documents that the Design Engineer would refer to include the following:

- A Guide to Open Space Design Development in Halifax Regional Municipality;
- Nova Scotia Environment On-Site Sewage Disposal Systems Technical Guidelines; and
- Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage.

CHAPTER 2 AREA C, PROPOSED HYBRID OPEN SPACE DEVELOPMENT

Documentation indicates that Area C is to be developed using the Hybrid Open Space Design concept. Under this concept, the maximum density is 1 unit per hectare.

It is assumed that the proposed lots will be serviced using individual wells and individual on-site sewage disposal systems, and therefore will have to meet the requirements of the Nova Scotia Environment On-Site Sewage Disposal Systems Technical Guidelines.

Site assessments will be conducted by a QP1 and/or QP2. Depending on soil conditions, NSE requirements for minimum lots sizes range from 2700 m^2 with 37 m width to 9000 m^2 with 76 m width. The 1 hectare requirements will therefore supersede the NSE lot size requirements. A lot width requirement, however, is not indicated in the Open Space guidelines, and may be indicated by the NSE requirements.

The soil and site conditions, along with the estimated wastewater flows, based on the number of bedrooms in the units, will allow for the selection and design of the appropriate on-site sewage disposal system for each of the lots. Typical system options include the following:

- C1 Contour trench;
- C2 Contour trench;
- C3 Contour trench;
- Mound;
- Area Bed;
- Multiple Trench; and
- Peat Treatment.

CHAPTER 3 AREAS A AND B, PROPOSED CLASSIC OPEN SPACE DEVELOPMENT

Under the Classic Open Space concept, the units are clustered and serviced by one or more large "communal" wastewater collection and treatment systems.

If the communal wastewater system is an on-site sewage disposal system, the Nova Scotia Environment On-Site Sewage Disposal Systems Technical Guidelines apply. If a wastewater treatment facility is to be used, the Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage apply. Expansion of the above follows:

3.1 On-Site Sewage Disposal System Options

As indicated above, typical on-site sewage disposal systems include the C1, C2, and C3 trenches, Mound; Area Bed, Multiple Trench, and Peat Treatment. The Area Bed, Multiple Trench, and Peat Treatment system, however, are not suitable for large systems. The Contour and Mound systems are used for large systems, but the minimum length that can be used is 15 m per 1000 Lpd. On this basis, the total length of contour or mound that would be required for 189 units, assuming 1000 Lpd per unit, is 2835 m. If cluster of 15 units were serviced, the required minimum lengths of the systems would be 225 m. These requirements, along with requirements for a replacement system and the required separation distances, indicate that the on-site system option is typically not feasible at this scale.

3.2 Wastewater (Sewage) Treatment System Options

The Atlantic Canada Wastewater Guidelines Manual for Collection, Treatment, and Disposal of Sanitary Sewage has site consideration guidelines for locating sewage treatment facilities. The site separation requirements are summarized as follows:

- For Mechanical Plants (Includes lagoons):
  - 150 m from residences;
  - 30 m from commercial-industrial developments;
  - 30 m from nearest property line; and
  - Lesser separation distances to residences may be adopted (odour control).

- For Sand Filters (and Textile Filters):
  - 30 m from potable water supply wells;
  - 100 m from water supply wells immediately down slope;
  - 3 m from any lot boundary; and
  - 9 m down slope of any lot boundary.

A previous plan attached with the application indicated multiple areas for wastewater treatment facilities. The plan, however, did not indicate how wastewater is to be collected and treated, and discussions of wastewater collection and treatment follow.

3.2.1 Wastewater Collection

3.2.1.1 Conventional Collection

Municipalities typically use conventional collection systems. Conventional sewers consist of 200 mm minimum size collection pipes (typically PVC) and pre-cast concrete manholes located at all pipe intersections and at changes in pipe direction and grade. The maximum spacing between manholes is typically about 100 m. Manhole costs are a major component of the cost of a conventional system. Buildings located higher than the gravity sewer discharge by gravity, while buildings below the collection pipe must use a pump to discharge to the collection system.

3.2.1.2 Small Diameter Gravity Sewers (SDGS)

A Small Diameter Gravity Sewer (SDGS) is used in conjunction with septic tanks. Septic tanks are used to hold the solids and grease, and the effluent is discharged to small diameter (75 mm or larger) collection pipes. Buildings located higher than the collection pipe discharge by gravity, while buildings below the collection pipe must use a pump to discharge to the collection pipe. The term Septic Tank Effluent Gravity (STEG) is also used.

3.2.1.3 Septic Tank Effluent Pump (STEP) System

A Septic Tank Effluent Pump (STEP) system consists of a septic tank for pre-treatment, and a pump used to force the effluent through a small diameter pressure line to a collection pipe. The collection pipe operates as a forcemain in a STEP system.

3.2.1.4 Grinder Pump (GP) System

The GP system consists of the pumping of raw wastewater instead of septic tank effluent. Since solids are handled, a higher quality grinder pump is required than would be required in the STEP system. A grinder pump station is used to service a single home or a cluster of homes. The collection pipe typically operates as a forcemain in a GP system.

The topography of the development would have to be evaluated to determine the most feasible option. The SDGS and STEP options require septic tanks at each of the lots. The GP option would have a pump at each of the lots, or at a small cluster of lots, and large capacity septic tanks at the treatment site.

3.2.2 Wastewater Treatment and Disposal

3.2.2.1 WASTEWATER TREATMENT

The Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage indicate the required type of treatment, based on flows, and the required quality of effluent, based on the discharge location. For flows of less than 6 m^3 per day, an on-site sewage disposal system is required. For flows of 6 m^3 per day to 200 m^3 per day, the preferred treatment systems, in order of preference, are as follows:

- In ground;
- Seasonal discharges;
- Secondary with land (spray) disposal; and
- Treatment with discharge to Receiving Water.

Seasonal discharges, although indicated in the Guidelines, are no longer being considered as acceptable by NSE because of quality issues in the "stored" effluent, and therefore does not appear to be an option for this project.

Land disposal of secondary effluent requires very large areas of land, and a full environmental assessment would be required. This does not appear to be an option for this project.

The discharge of effluent to a receiving body of water would typically require an effluent with less than 10 mg/L for BOD and SS. A Receiving Water Study (RWS) however, would be required, to ensure that the receiving water is capable of accepting the effluent without detrimental effects. This option does not appear to be feasible for this development.

The use of an in ground system, however, appears to be an option, and the following is provided for discussion purposes.

Re-circulating Sand Filter (RSF) or Re-circulating Textile Filter (RTF) have typically been used for developments of this size. These systems, commonly called packed-bed biological systems, produce a high quality effluent that can be discharged in-ground.

A packed-bed biological filtration system is a system by which treatment is achieved by passing clarified wastewater through a media where micro-organisms attached to the media utilize the soluble organic material and nutrients in the waste stream during cellular synthesis. Variations of packed-bed biological filtration systems include the following:

- Intermittent Filters (Sand or Peat); and
- Re-circulating Filters (Sand, Gravel, Glass or Textile).

Because of size requirements, intermittent filters (sand and peat) are used only when treating small flows, i.e., one or two homes, and are typically used to replace a malfunctioning on-site sewage disposal system on an individual lot. Intermittent filters are therefore not an option for this development.

The re-circulating sand filter, re-circulating gravel filter, re-circulating glass filter, and re-circulating textile filter, referred to collectively as re-circulating filters, are wastewater treatment system options for producers of small to medium wastewater flow volumes and strength. The use of sand, gravel, and textile as a media has been successful. The use of glass as a media however, is still evolving.

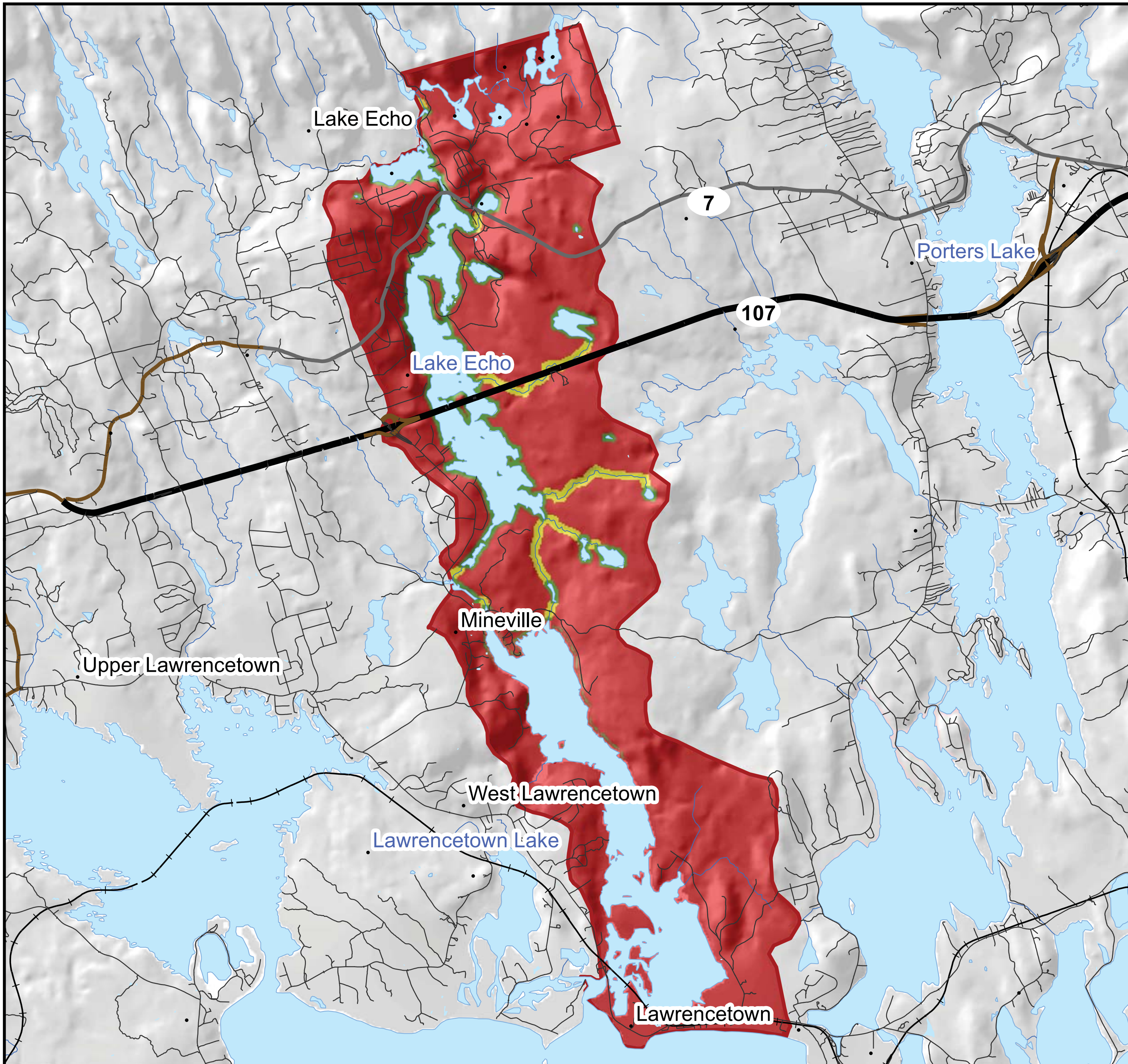
Re- circulating filter design features include a septic tank (either at the source of waste generation or at the treatment site); a re-circulation tank, distribution pumps; distribution valves, multiple filter beds or multiple textile filter modules; splitter valves, flow monitoring, effluent disinfection, and effluent disposal.

The re-circulating filters work by combining septic tank effluent with filtrate from the treatment system in a re-circulation tank, which is referred to as mixed effluent. The mixed effluent is pumped to the filter system where it is uniformly distributed over the filter media and percolates down through the media where naturally occurring micro-organisms biodegrade organic particles and physical filtering action reduces inorganic suspended solids. The filter effluent is collected by an underdrain system and conveyed back to the re-circulation tank where a splitter valve diverts 20% of the flow to discharge, and returns 80% to the recirculation tank.

A Pre-Design investigation will be required by NSE to determine if in-ground disposal of effluent is an option, and if so, under what conditions. To date, options approved by NSE have included “dispersal” systems adjacent to natural wetlands or engineered wetlands, and “drip irrigation”. In all cases, however, NSE has required that the effluent be maintained within the property boundary, or that the effluent flows from the site, through the sub soil, into a receiving body of water without flowing through neighbouring properties. As a result, for large flows, the calculations to determine the drip irrigation system “irrigation area” requirements have to be supplemented with a calculation of “lateral flow” requirements for the same flow. Of concern is that with the drip irrigation system, the effluent will move vertical until an impermeable soil is encountered, and then has to move horizontally.

APPENDIX G

Component Maps – Land Desirability



HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area

View

- Ocean Front/ Lake Front
- Ocean/Water View/River Front
- No Water Views
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Views

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

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N E S W

0 550 1,100 2,200 Meters

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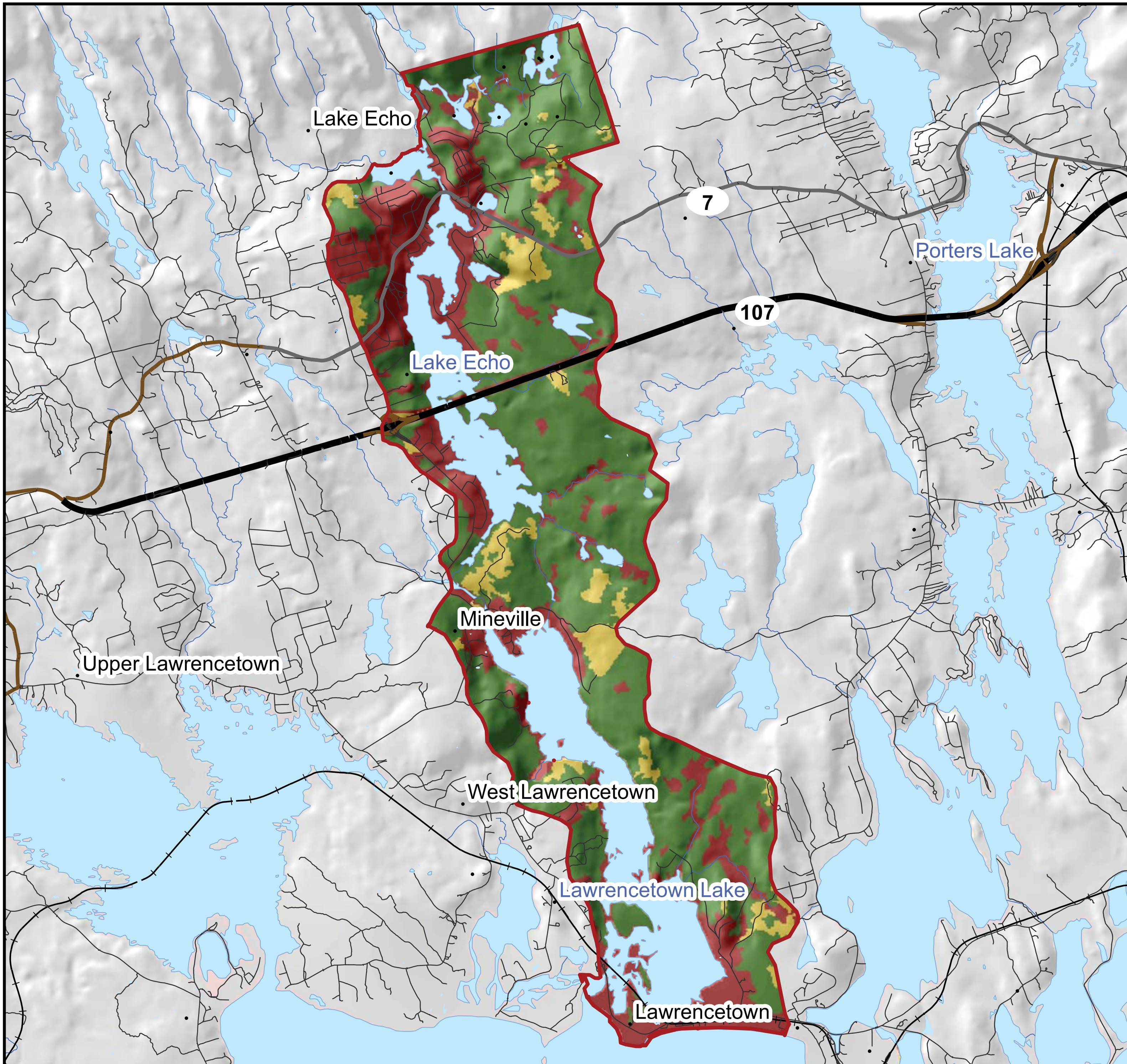

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area
- **Vegetation**
  - Mature
  - Immature
  - Other
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Vegetation

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters
Projected Coordinate System: NAD_1983_UTM_Zone_20N
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N W E S

0 550 1,100 2,200 Meters

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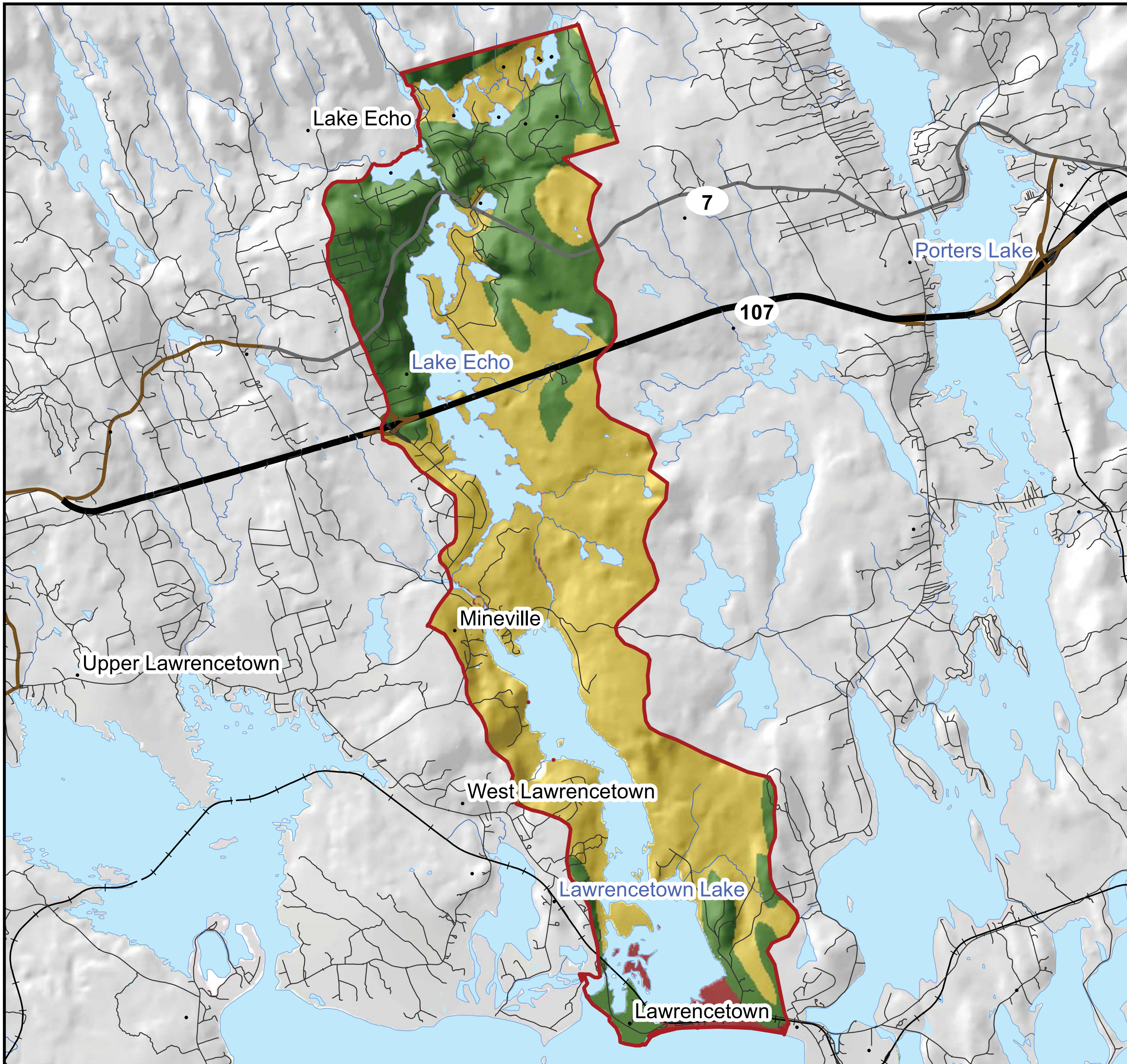

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area
- **Soil Type**
- Dry
- Imperfectly Drained
- Wet and Wet Organic
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Soil Type

Drawn: VF	**Date: May 2012**
Checked: GS	**CBCL Project # 101015.00**
Approved: MD	

Appendix G

Notes:

Map Parameters
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N W E S

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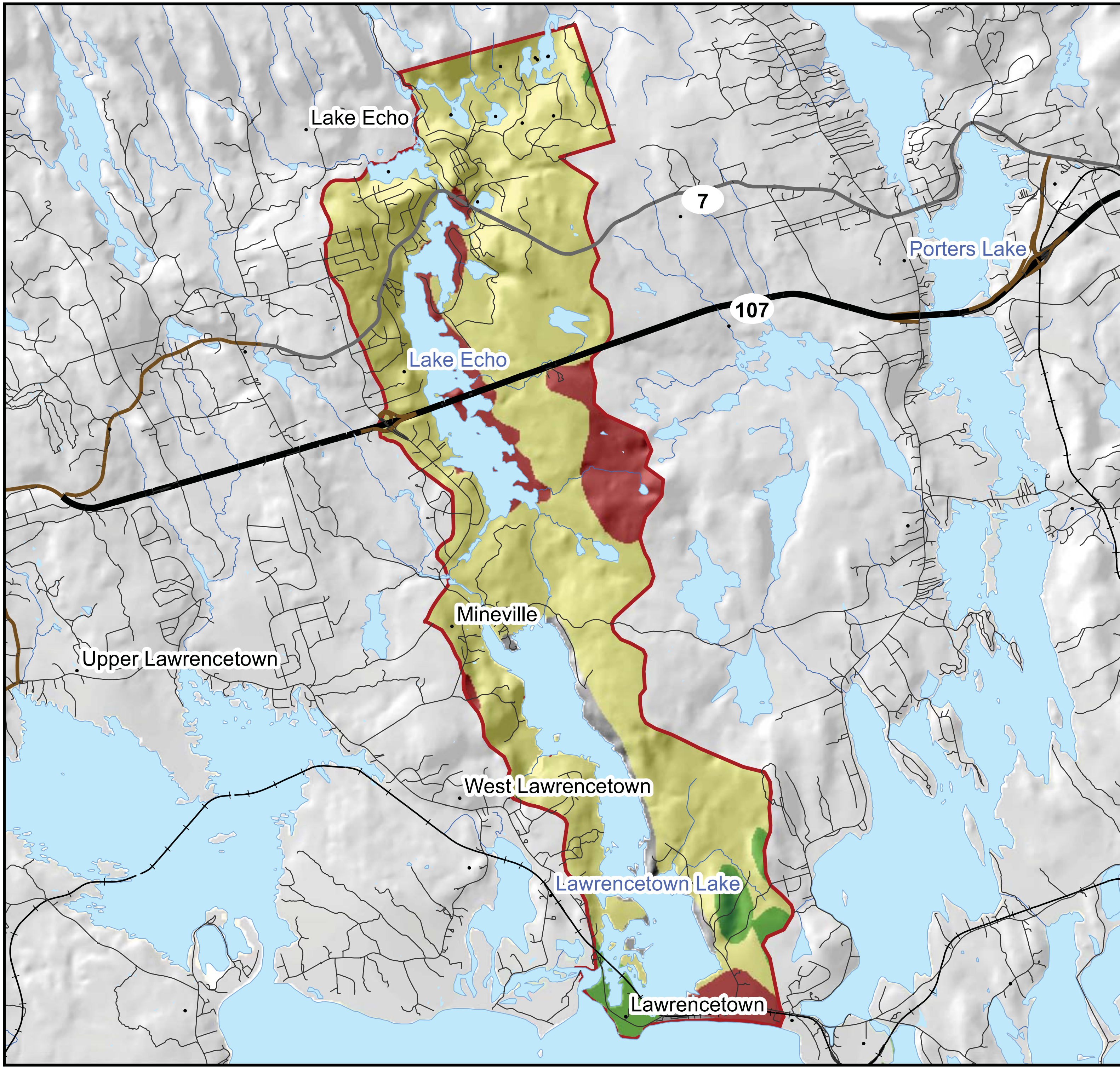

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area

Soil Condition

- Thick Till
- Thin Till
- Disturbed Soil and Bedrock Condition
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Soil Condition

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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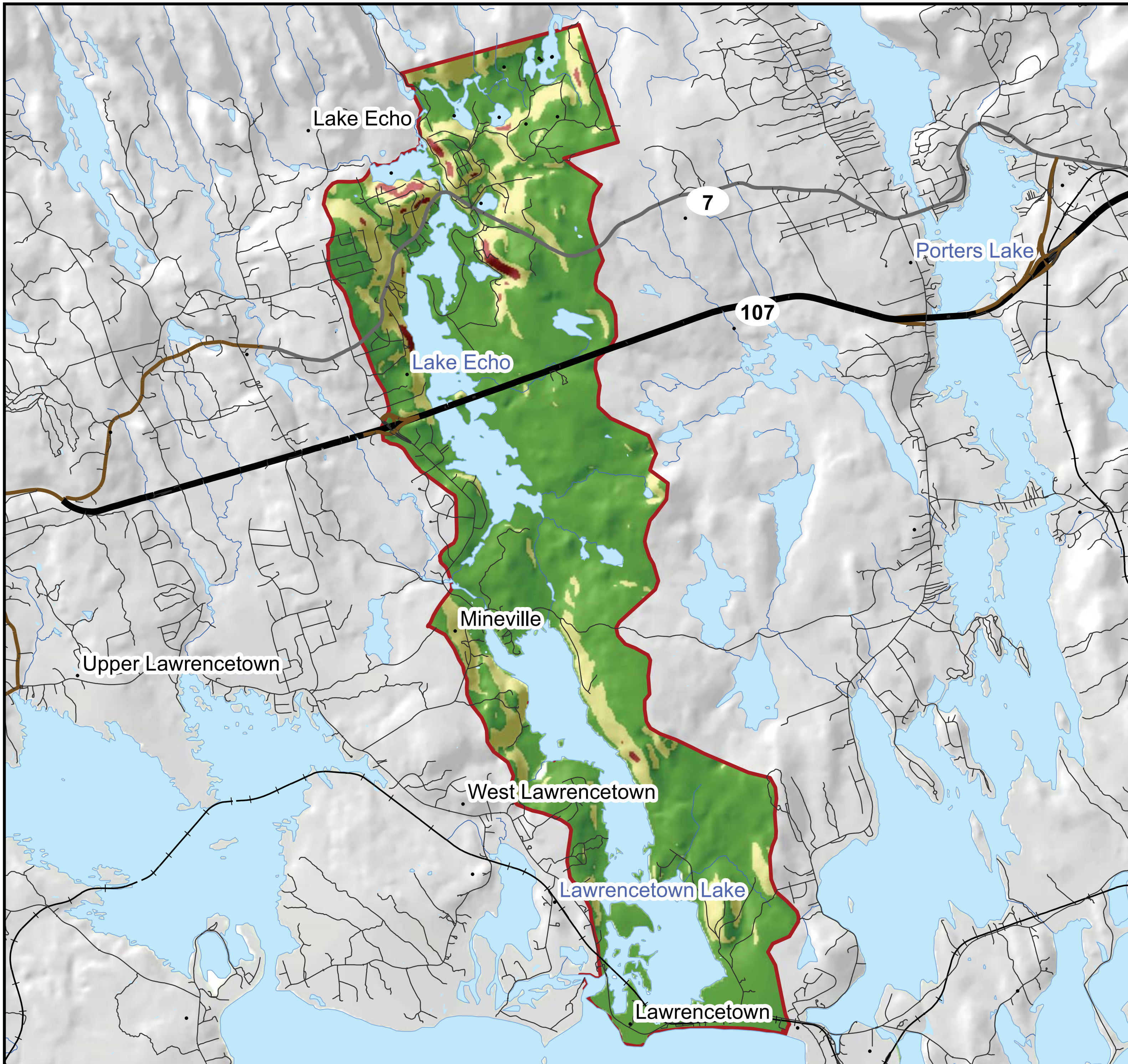

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area

Slope

- 0- 8 %
- 8 - 20 %
- > 20%
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED
Consulting Engineers

Slope

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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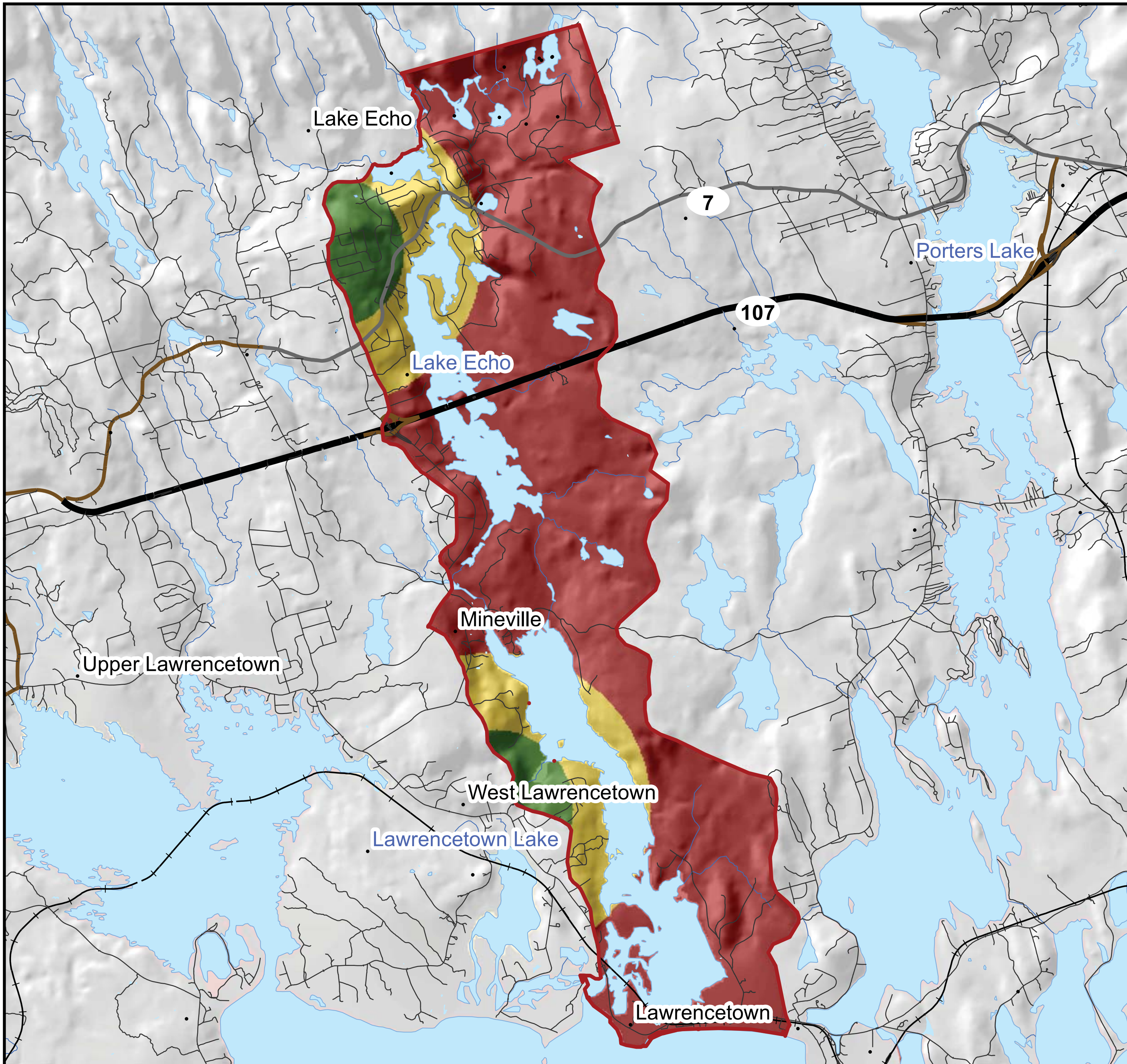

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area

School Access

- within 1 Km
- 1 - 2 Km
- > 2 Km
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED
Consulting Engineers

School Access

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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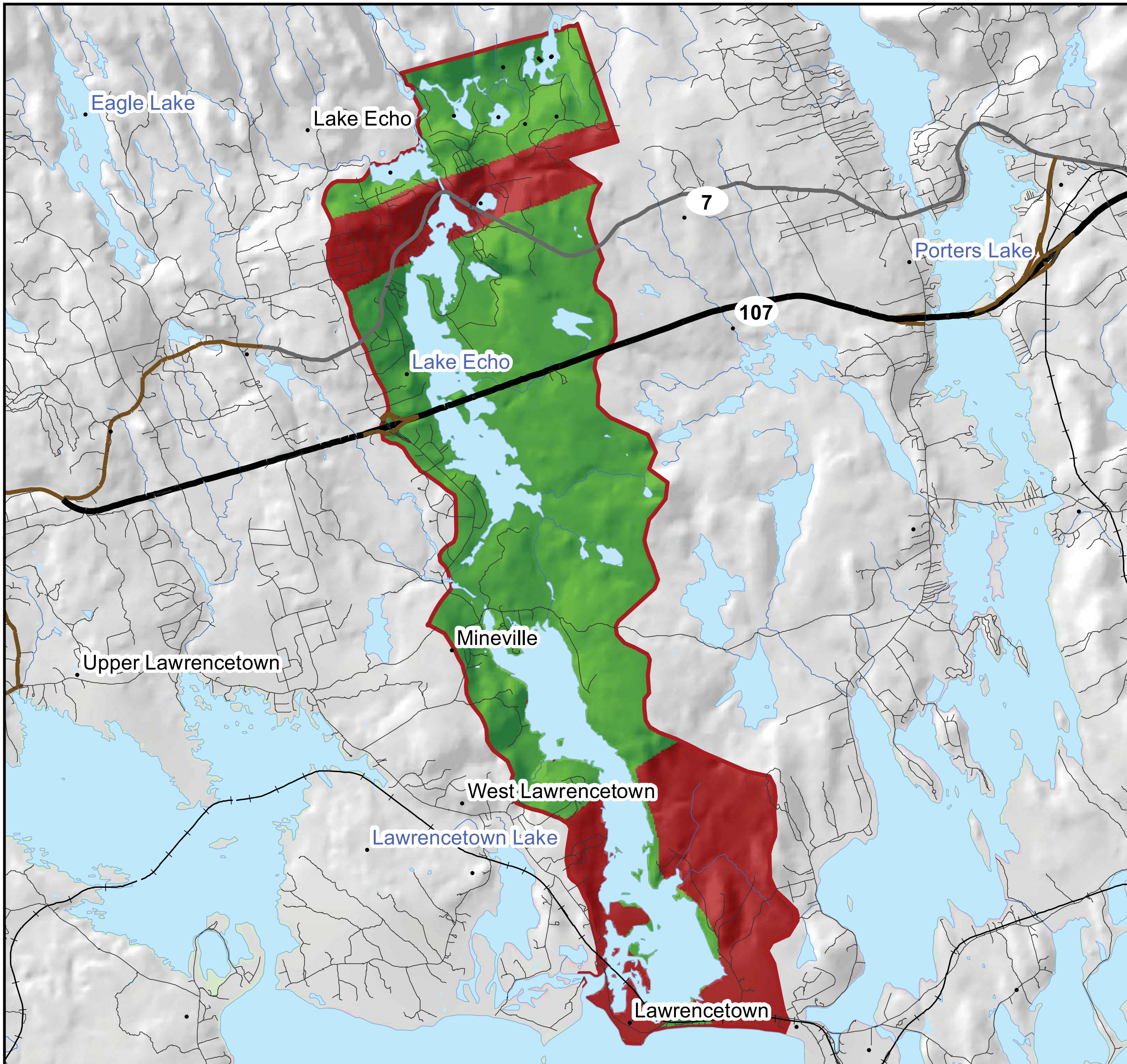

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area
- **Pyretic Slates**
  - Absent
  - Present
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Pyretic Slates Potential

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters
Projected Coordinate System: NAD_1983_UTM_Zone_20N
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N W E S

0 550 1,100 2,200 Meters

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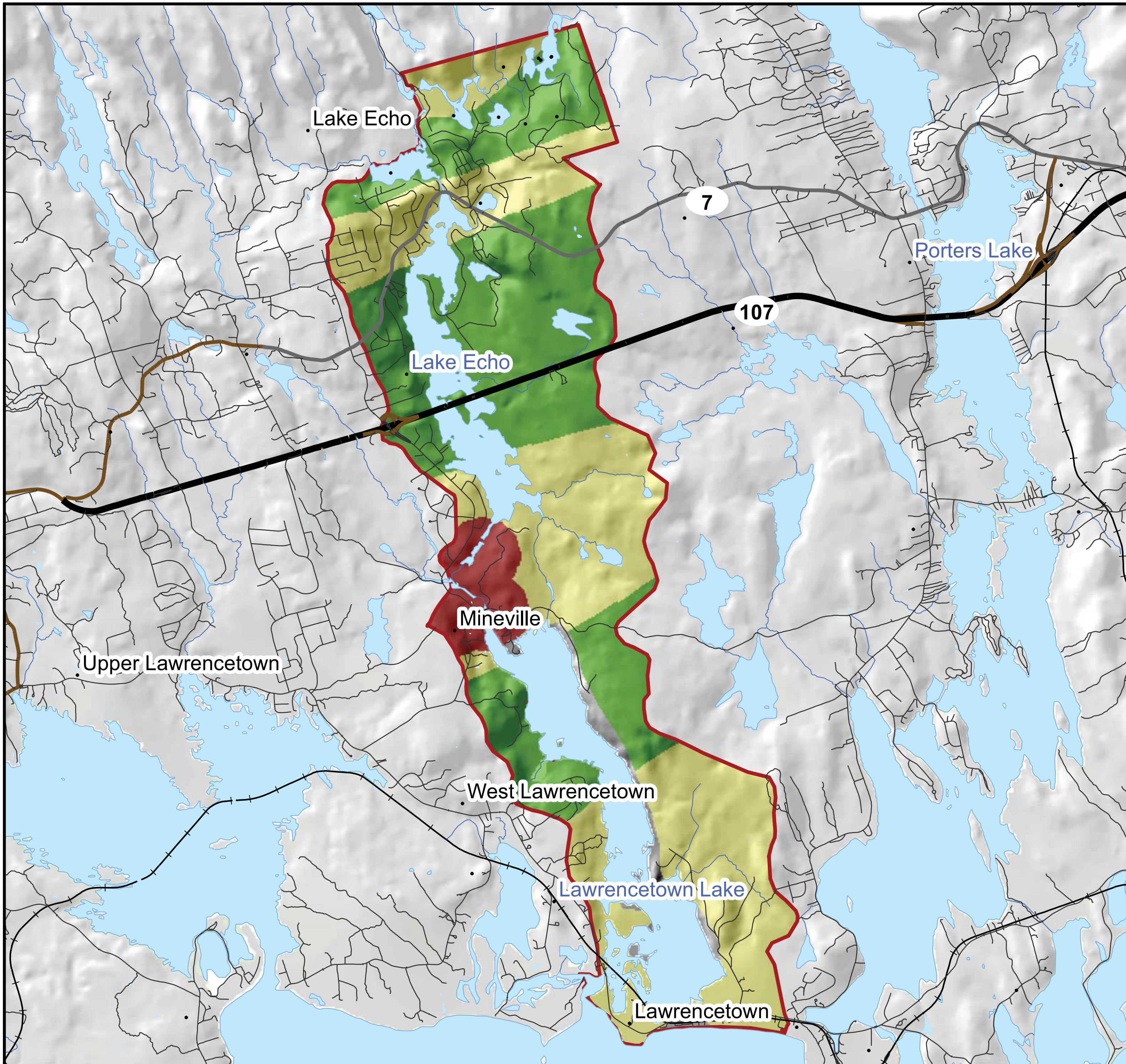

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

- Study Area
- **Aspect**
- Class B
- Class C and D
- Class E
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED
Consulting Engineers

Groundwater Potential

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters
Projected Coordinate System: NAD_1983_UTM_Zone_20N
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0 550 1,100 2,200 Meters

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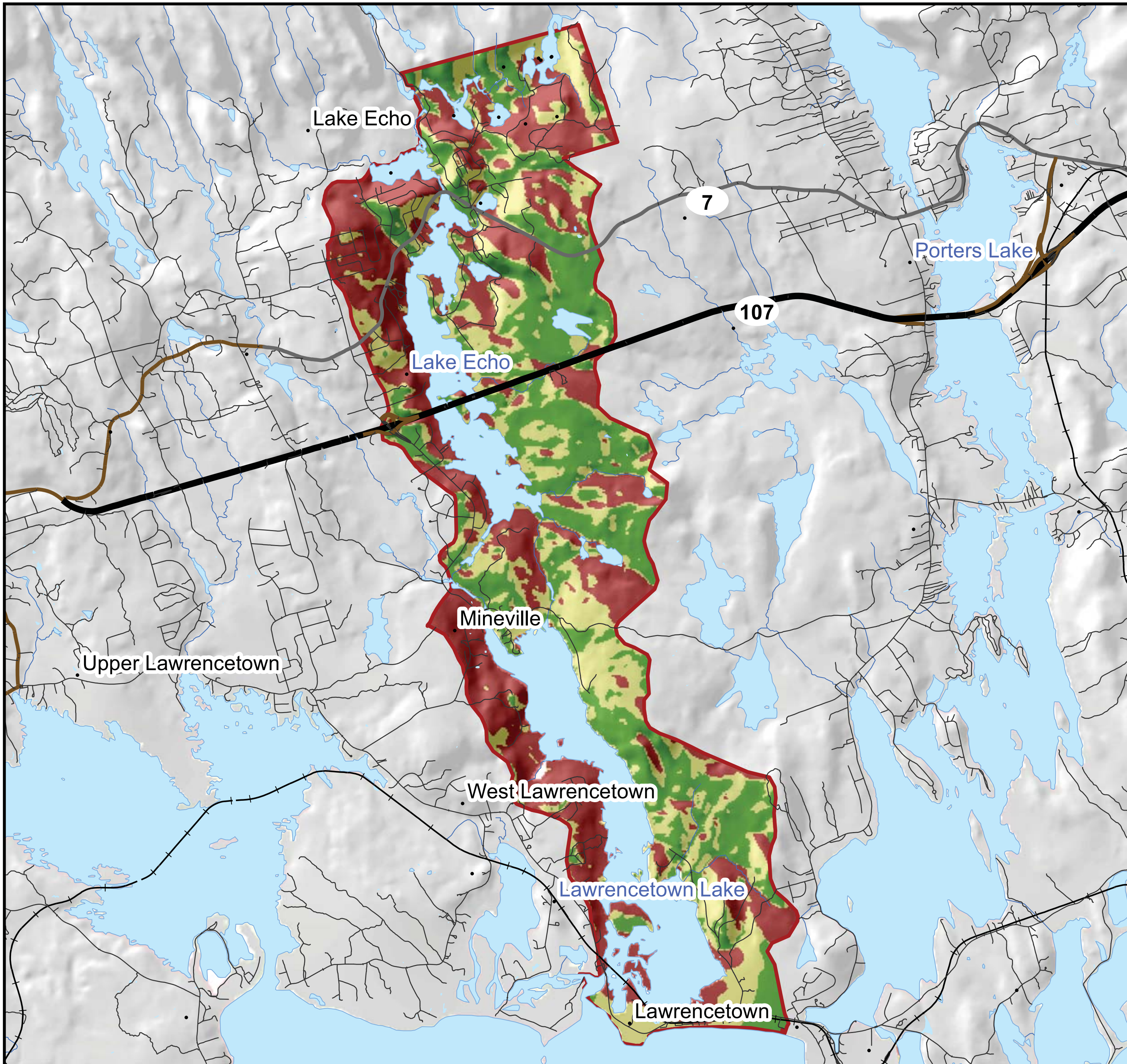

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Aspect

- Study Area
- South, South West
- Southeast, West
- None
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED
Consulting Engineers

Aspect

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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N W E S

0 550 1,100 2,200 Meters

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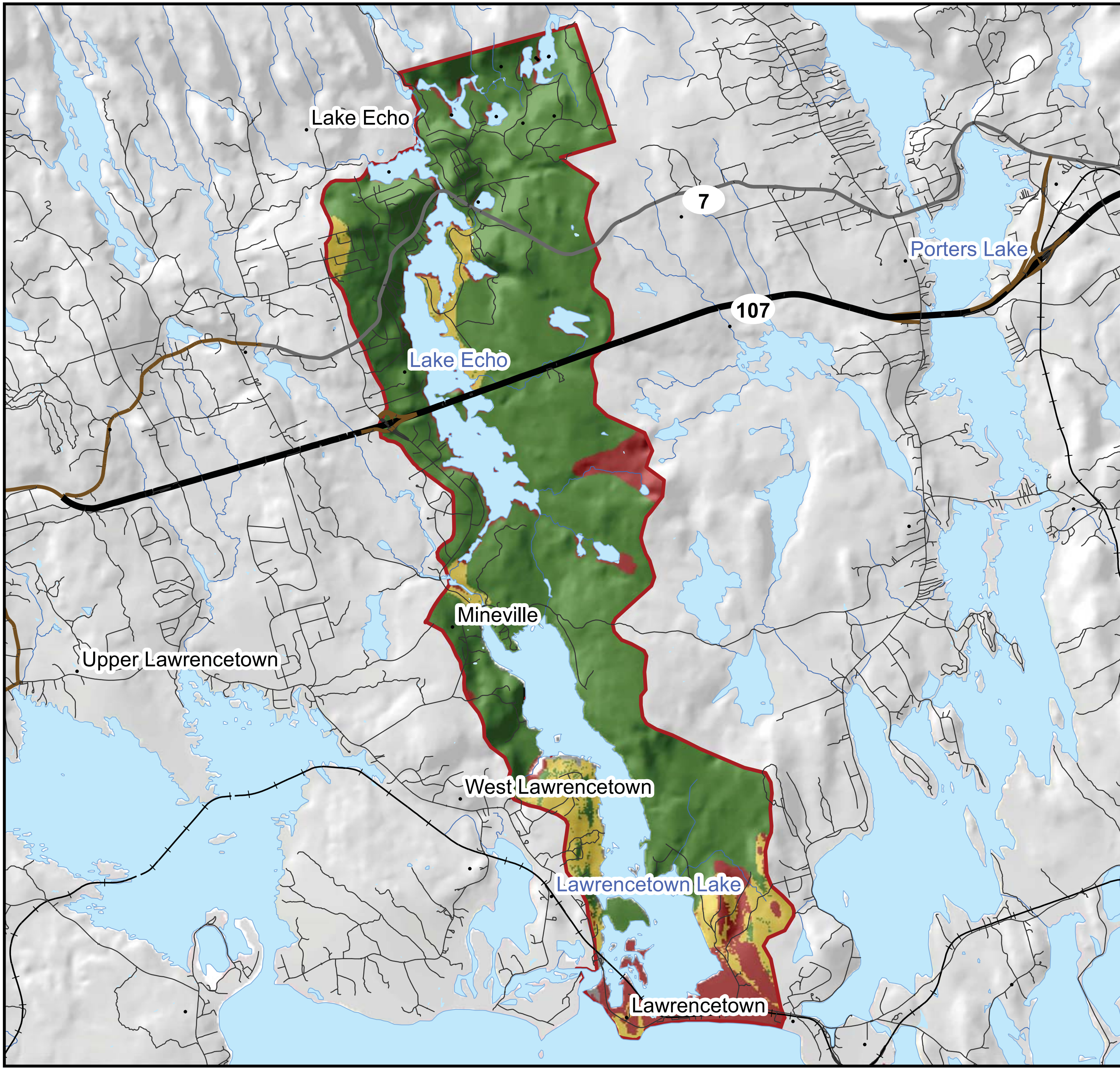

HALIFAX REGIONAL MUNICIPALITY

Lake Echo Watershed/Servicing Study

Study Area

Onsite Treatment Capability

- Most Suitable
- Mean
- Least Suitable
- Rivers
- Streets
- Trunk Highway
- Divided Highway
- Arterial
- Collector
- Railroad

CBCL LIMITED Consulting Engineers

Onsite Treatment Capability

Drawn: VF	Date: May 2012
Checked: GS	CBCL Project # 101015.00
Approved: MD	

Appendix G

Notes:

Map Parameters

Projected Coordinate System: NAD_1983_UTM_Zone_20N
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APPENDIX H

Sanitary Survey

Contents

Appendices

A Survey Questionnaire

B Notice to Homeowners

CHAPTER 1 INTRODUCTION

The Lake Echo Sanitary Survey was conducted in developed areas along Lake Echo and in areas of Mineville.

1.1 Survey Procedure

The Sanitary Survey was conducted by means of a door to door survey conducted by CBCL personnel. A copy of the survey questionnaire used is attached as Appendix A.

A notice regarding the watershed studies and the investigation of a range of environmental issues within the watershed(s) or sub-watersheds (study areas) affected by the Regional Plan for the Lake Echo area was prepared by CBCL, approved by HRM, and delivered by CBCL personnel to properties identified for the survey. Copies of the notice are attached as Appendix B.

In general, the Sanitary Survey was conducted in two parts. Personnel visited the properties and requested homeowner participation for the following:

Part 1:
Participation in the completion of a sanitary survey questionnaire;

Part 2:
A maximum of 40 property owners could participate in a more detailed investigation which included the collection of an untreated well water sample for analyses for bacteriological quality, general chemistry, and metals; and dye testing of the on-site sewage disposal system.

The notice indicated approximate times during which the survey would be conducted, and requested residents to contact CBCL if they would like to participate.

The sanitary survey was completed between November 2, 2011 and November 28, 2011. In general, the survey consisted of the following:

- Completion of the questionnaire;
- Preparation of a sketch of the property;
- Where applicable, water quality sampling and dye testing was performed;

- General discussions with respondents as required; and
- Monitoring of properties where dye testing was performed.

Copies of the analyses of water quality results were delivered to the respective properties and, where required, discussions were held with the homeowners in regards to the water quality.

1.2 Sanitary Survey Results

A total of 176 properties were visited during the Sanitary Survey. The survey areas are provided in Figure H.2.1.

Survey questionnaires were completed on 72 properties out of the 176 properties, for a participation rate of 40.9 %.

Twenty three (23) homeowners participated in the water sampling and dye testing protocol, for a participation rate of 13.1 %.

1.2.1 Lake Echo Area Results

The Lake Echo area surveyed included homes on the water surrounding Lake Echo. The survey area started on Echo Forest drive and continued around the lake to the end of Ponderosa Drive. A total of 126 properties were visited.

Survey questionnaires were completed on 51 properties out of the 126 properties, for a participation rate of 40.5 %. Fifteen (15) homeowners participated in the water sampling and dye testing protocol, for a participation rate of 11.9 %.

The occupants at one property (0.8 %) were home during the site visit, but indicated that they did not want to participate in the survey.

The majority of homes in the area appear to be permanent homes.

1.2.2 Mineville Area Results

The area of Mineville included in the survey consisted of the Dempster Crescent and Candy Mountain Road areas. A total of 50 properties were visited.

Survey questionnaires were completed on 21 properties out of the 50 properties, for a participation rate of 42.0 %. Eight (8) homeowners participated in the water sampling and dye testing protocol, for a participation rate of 16.0 %.

The occupant at one property (2.0 %) were home during the site visits, but indicated that they did not want to participate in the survey.

The majority of homes in the area appear to be permanent homes.

CHAPTER 2 **LOT SIZES**

Minimum lot sizes prior to the 1970's were typically up to 1394 m^2 or 1860 m^2 , with lot widths of 23 m to 30 m respectively.

Current lot size requirements as indicated in the Nova Scotia Environment On-site Sewage Disposal Systems Technical Guidelines, 2009 (Technical Guidelines) are as indicated in Table 2.1.

Table 2.1: Minimum Lot Size Requirements for Developments Utilizing On-Site Sewage Disposal Systems (1)

Depth of Permeable Soil (mm)	Minimum Lot Area (m^2)	Minimum Lot Width (m)
0 – 149	9,000	76
150 – 299	6,800	60
200 – 600	4,500	53
Deeper than 600 on a waterfront lot (2)	3,716	45
601 – 899	3,150	37
900 and deeper	2,700	37

(1) For systems with a daily flow greater than 1,500 Lpd, larger lots areas and widths may be required.
(2) A waterfront lot is a lot that contains or is proposed to contain a system in which a portion of the system is or will be located within 60 m of a surface watercourse or marine water body.

Lot sizes in the survey area were determined using data in the Nova Scotia Property Online Database and are summarized in Table 2.2.

Table 2.2: Lot Sizes

Location	Properties Visited	Area (m^2)				
		< 1,500	1,500 – 2,700	2,700 – 4,500	4,500 – 9,000	>9,000
Lake Echo Area						
Echo Forest Dr.	20	3	14	3	0	0
Lake Echo West Area	25	9	12	2	0	2
Old Lake Echo Rd.	20	20	0	0	0	0
Ponderosa Dr.	61	23	31	7	0	0
Mineville						
Dempster Cr.	28	0	15	12	1	0
Candy Mountain Rd.	22	10	12	0	0	0

A review of the data indicates generally small lot sizes throughout the different survey areas. Of the 176 properties visited during the survey, 147 (83.5 %) properties have lot sizes of less 2,700 m^2, and 65 (36.9 %) properties have lot sizes of less than 1,500 m^2.

Lot sizes were generally small in the Lake Echo area, especially in the Old Lake Echo Road area where all twenty properties visited during the survey consisted of lot areas of less than 1,500 m^2.

The two areas surveyed in Mineville were separated geographically, with the Dempster Crescent area consisting of larger lots than in Lake Echo, and the Candy Mountain Road area consisting of smaller lot similar to those in the Lake Echo area.

CHAPTER 3 **WASTEWATER SYSTEMS**

3.1 Lake Echo Area

The construction type of on-site sewage disposal systems in the Lake Echo area of the survey is summarized as follows:

- 41 systems (80 %) are area bed systems;
- 3 systems (6 %) are chamber systems;
- 2 systems (4 %) are contour type systems;
- 2 systems (4%) are mound systems;
- 1 system1 (2%) is a sloping sand filter system;
- 1 system (2 %) is a holding tank; and
- 1 property (2 %) has an unknown system.

Forty five of the respondents (88 %) indicated that they pump out their septic tanks at a frequency of more than once in five years.

3.2 Mineville Area

The construction type of on-site sewage disposal systems in the Mineville area of the survey is summarized as follows:

- 13 systems (62 %) are area bed systems;
- 7 systems (33 %) are contour type systems; and
- 1 property (5 %) has an unknown system.

Nineteen (90 %) of the respondents indicated that they pump out their septic tanks at a frequency of more than once in five years.

CHAPTER 4 WATER SUPPLY SYSTEMS

4.1 Water Supply Sources

4.1.1 Lake Echo Area

Out of the 51 sanitary surveys conducted, the following was found:

- 41 drilled well supplies;
- 9 dug well supplies; and
- 1 lake water supply;

Water supplies along Lake Echo were mainly drilled wells in all the surveyed areas. The dug well water supplies were found on properties with homes located close to the lake.

4.1.2 Mineville Area

Out of the 21 sanitary surveys conducted, the following was found

- 13 drilled well supplies; and
- 8 dug well supplies

Properties on Dempster Crescent that were surveyed consisted of an even number of drilled and dug well. Water supplies along Candy Mountain Road were mainly drilled wells.

4.2 Water Quality

4.2.1 Drilled Wells

Samples of untreated water were collected from 18 drilled wells to determine representative water quality.

Health based Maximum Acceptable Concentrations (MACs) as established by the Guidelines for Canadian Drinking Water Quality (GCDWQ) were exceeded for parameters as follows:

- Seven wells had Coliform Bacteria;
- One well had E. Coli;
- Eight wells had elevated arsenic concentrations;

- Six wells had elevated turbidity; (Elevated turbidity is typically associated with poor well construction and/or elevated concentrations of iron and manganese); and
- Five wells had elevated lead concentrations.

Aesthetic Objectives (AO) as established by the Guidelines for Canadian Drinking Water Quality (GCDWQ) were exceeded for parameters as follows:

- Seven wells had elevated iron and/or manganese concentrations;
- Two wells had an elevated pH; and
- One well had an elevated colour.

4.2.2 Dug Wells

Samples of untreated water were collected from 5 dug wells to determine representative water quality.

Health based Maximum Acceptable Concentrations (MACs) as established by the Guidelines for Canadian Drinking Water Quality (GCDWQ) were exceeded for parameters as follows:

- Four wells had Coliform Bacteria;
- One well had E. Coli;
- Three wells had elevated turbidity; (Elevated turbidity is typically associated with poor well construction and/or elevated concentrations of iron and manganese); and
- One well had an elevated lead concentration.

Aesthetic Objectives (AO) as established by the Guidelines for Canadian Drinking Water Quality GCDWQ) were exceeded for parameters as follows:

- Three wells had elevated iron and/or manganese concentrations; and
- Two wells had elevated aluminium concentrations.

4.3 Water Treatment

Water treatment equipment in use in each area is summarized in Table 4.1.

Table 4.1: Water Treatment

Location	Properties Surveyed	Homes With Treatment	Water Treatment Equipment			
			Sediment Filter	Ultraviolet Disinfection	Water Softener	Reverse Osmosis
Lake Echo	51	28	15	9	11	5
Mineville	21	18	13	3	6	3

* Some homes have multiple treatment units

Discussions with homeowners indicate reverse osmosis units appear to have been installed to remove arsenic concentrations from the water. This, however, was not confirmed through sampling. Sediment filters and water softeners were generally installed by homeowners to address the concern of hard water and elevated iron and manganese levels.

During the survey home owners were asked if they drink their water. In the Lake Echo area, three of the fifty one respondents indicated that they do not drink the water. In the Mineville area, five of the twenty one respondents indicated that they do not drink the water, four of whom live on Candy Mountain Road. The majority of the homeowners surveyed on the Candy Mountain Road indicated a concern with the quality of drinking water since the fire in 2009. The concern is due to increased runoff from the burnt area.

CHAPTER 5 WASTEWATER SYSTEM OVERVIEW

5.1 Lake Echo Area

5.1.1 Echo Forest Drive

Echo Forest Drive is located on the west side of Porters Lake, off Highway No. 7. The area consists of smaller lot areas, with seventy percent of the lots surveyed being between 1,500 and 2,700 m2. Homes in the area were generally built between 1970 and 1990. Seven surveys were completed in the area with three properties being suspect or inadequate. The overall area does not appear to be a major concern, but small lots and general age of homes indicates concerns with inadequate systems.

One dye test was carried out in the area on a system identified as being suspect. The test, however, was negative. One homeowner in the area indicated concerns with the adequacy of on-site sewage disposal systems, and identified the water quality in Lake Echo deteriorating over the past few years which effects recreational swimming in the lake.

5.1.2 Lake Echo West Area

The Lake Echo West area consists of homes located on Arbour Hill, Robina Drive, Linda Lane and Highway No. 7, all located on the west side of Lake Echo. The homes surveyed in the area consisted of small lot sizes with twenty one of the twenty five lots being less than 2,700 m2, and nine of the twenty five being less than 1,500 m2. Homes in the area were built during different times, mainly between 1950 and 2000. The area of concern in the survey area is located on Highway No. 7, where older homes were built close to the lake. Three of the four surveys completed on Highway No. 7 consisted of suspect or inadequate systems.

Four dye tests were carried out in the area, but all four tests were negative. One homeowner in the area indicated concerns with the adequacy of on-site sewage disposal systems, while multiple homeowners identified the trailer park as a concern for contaminating Lake Echo.

5.1.3 Old Lake Echo Road Area

The Old Lake Echo Road area consists of Old Lake Echo Road and Lakefront Drive, both located off the north end of Lake Echo. Similar to the Lake Echo West area, homes in the area were built over a range of years, generally between 1950 and 2000. Of the twenty homes visited during the survey, all twenty lot areas were less than 1,500 m2, and were water front lots. Five of the eleven properties in the area contained suspect or inadequate systems. This area is a concern, with all the lots being very small and homes located close to the lake.

Two dye tests were carried out in the area, but both tests were negative. Homeowners in the area did not indicate concerns with the adequacy of on-site sewage disposal systems, however multiple homeowners identified the trailer park as concern for contaminating Lake Echo.

5.1.4 Ponderosa Drive

Ponderosa Drive is located on the east side of Lake Echo and the area surveyed was the largest section of the survey. The homes surveyed on Ponderosa Drive had small lot areas with fifty four of the sixty one lots surveyed being less than 2,700 m2, and twenty three being less than 1,500 m2. Homes on Ponderosa Drive were built in different phases over the years, but the majority or the homes appear to be built between 1970 and 1980. The area of concern is located in the north section of Ponderosa Drive. Three of the eight surveys completed in the north section consisted of suspect or inadequate systems, with several other homes that were not surveyed also appearing to have suspect systems.

Eight dye tests were carried out in the area, but all eight tests were negative. Two homeowners in the area indicated concerns with the adequacy of on-site sewage disposal systems, both located in the north section of Ponderosa Drive.

5.2 Mineville

5.2.1 Dempster Crescent

Dempster Crescent is located in Mineville on the southwest side of Lake Echo. The area consists of lot sizes ranging between 1,500 and 4,500 m2, with none of the lot areas being less than 1,500 m2. Homes in the area were generally being built between 1970 and 2000. Eleven surveys were completed with no systems being suspect or inadequate. The area does not appear to be a concern.

Six dye tests were carried out in the area, all on properties which originally appeared to suspect. The six tests, however, were negative. Homeowners in the area did not indicate concerns with the adequacy of on-site sewage disposal systems.

5.2.2 Candy Mountain Road

Candy Mountain Road is located in Mineville on the northeast side of Lawrencetown Lake. The homes surveyed on Candy Mountain Road consisted of small lot sizes with all twenty two lot areas being less than 2,700 m2, and ten being less than 1,500 m2. Homes in the area were generally built between 1960 and 2000. Ten surveys were completed, with four systems being suspect or inadequate. This area is a concern with the lots being small and homes being located close to the lake.

Two dye tests were carried out in the area, but both tests were negative. Four of the ten homeowners surveyed in the area indicated concerns with the adequacy of on-site sewage disposal systems. The majority of the homeowners surveyed also expressed concerns with their water supplies since the fire in 2009. The large amount of runoff that flows through from the wooded area through the properties to the lake is a major concern.

CHAPTER 6 WATER SUPPLY OVERVIEW

6.1 Water Quantity

6.1.1 Lake Echo Area

The survey indicated that water supplies in the Lake Echo area, mainly from drilled wells, provide an acceptable quantity of water. One homeowner in the area, with a dug well water supply, indicated water shortage problems during dry summer.

6.1.2 Mineville Area

The survey indicated that the water supplies on Dempster Crescent Road and Candy Mountain Road in the Mineville area were a mix of dug and drilled wells. Homeowners in the area did not indicate water shortage issues.

6.2 Water Quality

6.2.1 Drilled Wells

Seven of the eighteen drilled wells indicated elevated total coliform bacteria, and one well had E. Coli. Coliform bacteria and E. Coli are commonly associated with poor well construction. Other quality issues included elevated iron and/or manganese, turbidity, and color.

Elevated lead was found in five samples, but is likely related to the plumbing system, as some sampling locations did not allow for adequate flushing of the piping system prior to sample collection.

Nine wells in the survey area, six of which were in Mineville, had elevated arsenic concentration.

Water treatment equipment in use generally includes sediment filters, disinfection, softeners, and reverse osmosis.

6.2.2 Dug Wells

Four of the five dug wells had coliform bacteria, and one well had E. Coli. Other quality issues included elevated iron and/or manganese concentrations, and elevated color.

Elevated aluminum was found in two samples. The guideline for aluminium, however, was specifically designed to apply only to drinking water treatment plants using aluminum-based coagulants, and therefore is not applicable for wells

Water treatment equipment in use generally included sediment filters, disinfection, and reverse osmosis.

CHAPTER 7 SANITARY SURVEY SUMMARY

7.1 Wastewater Component

Table 7.1 summarizes the wastewater component of the sanitary survey.

Table 7.1: Summary of Wastewater Component of the Sanitary Survey

Area	Number of Homes Visited	Number of Surveys Completed	Number of Dye Tests Completed	Did Not Want to Participate	Number of Suspect or Inadequate Systems
Lake Echo Area	126	51 (40.5%)	15 (11.9%)	1 (0.8%)	15 (29.4%)
Mineville Area	50	21 (42.0%)	8 (16.0%)	1 (2.0%)	4 (21.1%)
Total	176	72 (40.9%)	23 (13.1%)	2 (1.1%)	19 (26.4%)

The findings indicate a participation rate of 40.5% in the Lake Echo area and 42% in the Mineville area, for a total participation rate of 40.9%. Participation in the dye testing program was higher compared to previous surveys, resulting is a participation rate of 11.9% in Lake and 16% in Mineville.

The number of suspect or inadequate systems was 15 (29.4 %) in Lake Echo and 4 (21 %) in Mineville.

7.2 Water Component

Table 7.2 summarizes the water component of the sanitary survey.

Table 7.2: Summary of Water Component of the Sanitary Survey

Area	Number Homes Surveyed	Number of Drilled Wells	Number of Dug Wells	Number of Lake Water Users	Number of Water Samples Collected
Lake Echo Area	51	41	9	1	15
Mineville Area	21	13	8	0	8
Total	72	54	17	1	23

In general, drilled wells are more prevalent in Lake Echo, and Mineville consisted of a split between drilled and dug wells.

APPENDIX A

Survey Questionnaire

APPENDIX B

Notice to Homeowners

APPENDIX I

Review of Wastewater Treatment Options for Lake Echo: Case 01278

Contents

CHAPTER 1 BACKGROUND

HRM has received an application for a 240 hectare development in the Lake Echo and Porters Lake area.

A plan, Lake Echo Case 01278, dated December 19, 2011 has been received, and correspondence indicates that 315 units are proposed as follows:

1. Areas A and B: 189 mobile home and modular home units, B includes Open Space Design for Modular homes, (189 units in 114 hectares, Classic Open Space Design Concept).
2. Area C: 126 units using the Hybrid Open Space Design Concept.

HRM is completing watershed studies to investigate a range of environmental issues within watersheds (study areas) affected by the Regional Municipal Planning Strategy for Lake Echo and Porters Lake, and CBCL, as consultant for the project, has been requested to provide comments on wastewater servicing options that could be considered for the developments. It is stressed that the comments are for the education and use of HRM personnel only, and that the developer will have its' own consultant (Design Engineer) evaluate the options and submit documents to Nova Scotia Environment (NSE) for approval.

Applicable documents that the Design Engineer would refer to include the following:

- A Guide to Open Space Design Development in Halifax Regional Municipality;
- Nova Scotia Environment On-Site Sewage Disposal Systems Technical Guidelines(Technical Guidelines); and
- Atlantic Canada Standards and Guidelines Manual for the Collection, Treatment and Disposal of Sanitary Sewage (Wastewater Manual).

CHAPTER 2 AREA C, PROPOSED HYBRID OPEN SPACE DEVELOPMENT

Documentation received indicates that Area C is to be developed using the Hybrid Open Space Design concept. Under this concept, the maximum density is 1 unit per hectare.

It is assumed that the proposed lots will be serviced using individual wells and individual on-site sewage disposal systems, and therefore the on-site sewage disposal systems will have to meet the requirements of the On-Site Sewage Technical Guidelines.

Site assessments will be conducted by a QP1 and/or QP2. Depending on soil conditions, NSE requirements for minimum lots sizes range from 2700 m2 with 37 m width to 9000 m2 with 76 m width. The 1 hectare requirements will therefore supersede the NSE lot size requirements. A lot width requirement, however, is not indicated in the Open Space guidelines, and may be indicated by the NSE requirements.

The soil and site conditions, along with the estimated wastewater flows, based on the number of bedrooms in the units, will allow for the selection and design of the appropriate on-site sewage disposal system for each of the lots. Typical system options include the following:

- C1 Contour trench;
- C2 Contour trench;
- C3 Contour trench;
- Mound;
- Area Bed;
- Multiple Trench; and
- Peat Treatment.

CHAPTER 3 AREAS A AND B, PROPOSED CLASSIC OPEN SPACE DEVELOPMENT

Under the Classic Open Space concept, the units are clustered and serviced by one or more large "communal" wastewater collection and treatment systems.

If the communal wastewater system is an on-site sewage disposal system, the Nova Scotia Environment On-Site Technical Guidelines apply.

If a wastewater treatment facility is to be used, the Atlantic Canada Wastewater Manual applies.

Expansion of the above follows:

3.1 On-Site Sewage Disposal System Options

As indicated above, typical on-site sewage disposal systems include the C1, C2, and C3 trenches, Mound, Area Bed, Multiple Trench, and Peat Treatment. The Area Bed, Multiple Trench, and Peat Treatment system, however, are not suitable for large systems and should not be considered for the project. The Contour and Mound systems are used for large systems, but the minimum length that can be used is 15 m per 1000 Lpd (three bedroom unit). On this basis, the total length of contour or mound that would be required for 189 units, assuming 1000 Lpd per unit, is 2835 m. If cluster of 15 units were serviced, the required minimum lengths of the systems would be 225 m. These requirements, along with requirements for a replacement system and the required separation distances, indicate that the on-site system option is typically not feasible at this scale.

3.2 Wastewater (Sewage) Treatment System Options

The Atlantic Canada Wastewater Guidelines Manual for Collection, Treatment, and Disposal of Sanitary Sewage, known as the Wastewater Manual, has site consideration guidelines for locating sewage treatment facilities. The site separation requirements are summarized as follows:

- For Mechanical Plants (Includes lagoons):
  - 150 m from residences;
  - 30 m from commercial-industrial developments;
  - 30 m from nearest property line; and

- Lesser separation distances to residences may be adopted (odour control).
- For Sand Filters (and Textile Filters):
  - 30 m from potable water supply wells;
  - 100 m from water supply wells immediately down slope;
  - 3 m from any lot boundary; and
  - 9 m down slope of any lot boundary.

A previous plan attached with the application for the development indicated multiple areas for wastewater treatment facilities. The plan, however, did not indicate how wastewater is to be collected and treated, and discussions of wastewater collection and treatment follow.

3.1.1 Wastewater Collection

3.1.1.1 Conventional Collection

Municipalities typically use conventional collection systems. Conventional sewers consist of 200 mm minimum size collection pipes (typically PVC) and pre-cast concrete manholes located at all pipe intersections and at changes in pipe direction and grade. The maximum spacing between manholes is typically approximately 100 m. Manhole costs are a major component of the cost of a conventional system. Buildings located higher than the gravity sewer discharge by gravity, while buildings below the collection pipe must use a pump to discharge to the collection system.

3.1.1.2 Small Diameter Gravity Sewers (SDGS)

A Small Diameter Gravity Sewer (SDGS) is used in conjunction with septic tanks. Septic tanks are used to hold the solids and grease, and the effluent is discharged to small diameter (75 mm or larger) collection pipes. Buildings located higher than the collection pipe discharge by gravity, while buildings below the collection pipe must use a pump to discharge to the collection pipe.

The term Septic Tank Effluent Gravity (STEG) is also used for this application.

3.1.1.3 Septic Tank Effluent Pump (STEP) System

A Septic Tank Effluent Pump (STEP) system consists of a septic tank for pre-treatment, and an effluent pump used to force the effluent through a small diameter pressure line to a collection pipe. The collection pipe operates as a forcemain in a STEP system.

3.1.1.4 Grinder Pump (GP) System

The GP system consists of the pumping of raw wastewater instead of septic tank effluent. Since solids are handled, a grinder pump is required, as opposed to an effluent pump that is used in the STEP system. A grinder pump station is used to service a single home or a cluster of homes. The collection pipe typically operates as a forcemain in a GP system.

The topography of the development would have to be evaluated to determine the most feasible option wastewater collection option. The SDGS and STEP options require septic tanks at each of the lots. The GP option would have a pump at each of the lots, or at a small cluster of lots, and adequately sized septic tanks at the treatment site. Requirements for septic tank capacities are provided in the On-Site Technical Guidelines.

3.1.2 Wastewater Treatment

The Wastewater Manual indicates the required type of treatment, based on flows, and the required quality of effluent, based on the discharge location.

For flows of less than 6 m3 per day, an on-site sewage disposal system is required. For flows of 6 m3 per day to 200 m3 per day, the preferred treatment systems, in order of preference, are as follows:

- In ground;
- Seasonal discharges;
- Secondary with land (spray) disposal; and
- Treatment with discharge to Receiving Water.

3.1.2.1 Seasonal Discharges

Seasonal discharges, although indicated in the Guidelines, are currently not considered as acceptable by NSE because of quality issues in the “stored” effluent, and therefore this option is not feasible.

3.1.2.2 Land Disposal

Land disposal of secondary effluent requires very large areas of land, and a full environmental assessment would be required. This option does not appear to be feasible.

3.1.2.3 Discharge to a Receiving Water

The discharge of effluent to a receiving body of water would typically require an effluent with less than 10 mg/L for BOD and SS, respectively. A Receiving Water Study (RWS) would be required to ensure that the receiving water is capable of accepting the effluent without detrimental effects. This option does not appear to be feasible for this development.

3.1.2.4 Inground

The use of an in ground system, however, appears to be an option, and the following is provided for discussion purposes.

Re-circulating Sand Filters (RSF) or Re-circulating Textile Filters (RTF) have typically been used for developments of this size. These systems, commonly called packed-bed biological systems, produce a high quality effluent that can be discharged in-ground.

A packed-bed biological filtration system is a system by which treatment is achieved by passing clarified wastewater through a media where micro-organisms attached to the media utilize the soluble organic material and nutrients in the waste stream during cellular synthesis. Variations of packed-bed biological filtration systems include the following:

- Intermittent Filters (Sand or Peat); and
- Re-circulating Filters (Sand, Gravel, Glass or Textile).

Because of size requirements, intermittent filters (sand and peat) are used only when treating small flows, i.e., one or two homes, and are typically used to replace a malfunctioning on-site sewage disposal system on an individual lot. Intermittent filters are therefore not an option for this development.

The re-circulating sand filter, re-circulating gravel filter, re-circulating glass filter, and re-circulating textile filter, referred to collectively as “re-circulating filters”, are wastewater treatment system options for producers of small to medium wastewater flow volumes and strength. The use of sand, gravel, and textile as a media has been successful. The use of glass as a media, however is still evolving.

Re- circulating filter design features include a septic tank (either at the source of waste generation or at the treatment site); a re-circulation tank, distribution pumps; distribution valves, multiple filter beds or multiple textile filter modules; splitter valves, flow monitoring, effluent disinfection, and effluent disposal.

The re-circulating filters work by combining septic tank effluent with filtrate from the treatment system in a re-circulation tank, which is referred to as mixed effluent. The mixed effluent is pumped to the filter system where it is uniformly distributed over the filter media and percolates down through the media where naturally occurring micro-organisms biodegrade organic particles and physical filtering action reduces inorganic suspended solids. The filter effluent is collected by an underdrain system and conveyed back to the re-circulation tank where a splitter valve diverts 20% of the flow to discharge, and returns 80% to the recirculation tank.

A detailed investigation will have to be conducted by the Design Engineer to determine if in-ground disposal of effluent is an option, and if so, under what conditions. To date, options approved by NSE have included “dispersal” systems adjacent to natural wetlands or engineered wetlands, and “drip irrigation”. In all cases, however, NSE has required that the effluent be maintained within the property boundary, or that the effluent flows from the site, through the sub soil, into a receiving body of water without flowing through neighbouring properties. As a result, for large flows, the calculations to determine the drip irrigation system “irrigation area” requirements have to be supplemented with a calculation of “lateral flow” requirements for the same flow. Of concern is that with the drip irrigation system, the effluent will move vertical until an impermeable soil is encountered, and then has to move horizontally.

CHAPTER 4 **HRM ISSUES**

Because of the scale of the project, it is recommended that HRM planning staff meet with the developer, the project consultant, and NSE personnel to discuss the development concept and the roles of the respective parties. The following comments, however, are provided as a summary of the above, and for general knowledge.

The On-Site Technical Guidelines will apply where on-site sewage disposal systems are to be used. The proposed lots will be assessed by a Qualified Person (QP1 and/or QP2), and a report on the soil conditions and recommended types of systems will be submitted to NSE for review and approval at the subdivision stage. At the building permit stage, NSE will require the submission of a detailed plan and specifications of the system to be constructed on an individual lot basis. After review and approval by NSE, a Permit to Construct will be issued. The on-site sewage disposal system will then be constructed by a Licensed Installer, and the qualified person will inspect the system and provide a report to the owner and NSE.

The On-Site Technical Guidelines and the Wastewater Manual will apply where a small diameter wastewater collection and treatment system is considered. A key requirement is the need for a Pre-Design Investigation. It is recommended, however, that a meeting of all parties be held prior to the initiation of the Pre-Design Investigation to ensure that all issues are clearly understood.

The Pre-Design Investigation should include, but not be limited to, the components listed below. Comments are included where applicable.

- Wastewater Characteristics:
  - Expected to be typical residential wastewater.
- Wastewater flows:
  - NSE requirements are based on the number of bedrooms in a unit;
  - 1000 Lpd is used for a 3 bedroom unit;
  - What is the number of bedrooms per unit?
  - Will there be a request to design using less than 3 bedroom units?
- Wastewater Collection System Options:
  - Small Diameter Gravity Sewer System option;
    - Septic Tanks are at the individual units
  - Septic Tank Effluent Pumping Option;

- Pump at individual units?
  - Pump serving a number of units?
- Grinder Pump Option;
  - Pump at individual units?
  - Pump serving a number of units?
- Septic Tank Locations and Capacities;
- At the units;
- At the treatment site?

- Effluent Disposal:
  - Drip Irrigation Option;
- Where will the effluent go?
  - Dispersal adjacent natural wetland option;
  - Dispersal into a constructed wetland option.

It is stressed that effluent disposal requirements are a key issue and should be discussed with NSE personnel at the Concept Development stage to ensure that the Pre-Design addresses all the issues. As indicated previously, effluent disposal options approved by NSE have included “dispersal” systems adjacent to natural wetlands or engineered wetlands, and “drip irrigation”. NSE, however, requires that the effluent be maintained within the property boundary, or that the effluent flows from the site, through the sub soil, into a receiving body of water without flowing through neighbouring properties. On this basis it is critical that the proposed areas for drip irrigation be properly evaluated to determine both the vertical and horizontal flow components of the effluent.