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Environmental Sciences Ltd.

Assessment of Municipal Site Evaluation Guidelines for Waterfront Development in Eastern Ontario's Lake Country

Prepared for: Mississippi Valley Conservation Authority, Rideau Valley Conservation Authority and Cataraqui Region Conservation Authority

Job #: J130040

April 10, 2014

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Matt Craig
MVCA Manager of Planning and Regulatory Services
10970 Highway 7
Carleton Place, ON K7C 3P1

Dear Mr. Craig:

Re: Assessment of Municipal Site Evaluation Guidelines in Eastern Ontario's Lake Country

We are pleased to submit this report that assesses the utility of continued use of site evaluation guidelines particularly as these guidelines apply to development on the Canadian Shield lakes. Water quality trends proved inconclusive for the majority of the lakes in question because of data limitations. We were, however, able to identify and recommend site evaluation guidelines which will minimize impacts of continuing development on water quality in the study area via an in-depth review of the "Rideau Lakes Basin Carrying Capacities and Proposed Shoreland Development Policies" (Michalski and Usher, 1992), a variety of shoreline development policies in other municipal legislation, and scientific literature focused on the subject.

Please do not hesitate to contact me if you have any questions concerning the results of the study.

Sincerely,

Hutchinson Environmental Sciences Ltd.

Brent Parsons
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Signatures

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Executive Summary

The purpose of this study was to determine the continued validity of site evaluation guidelines (Michalski and Usher 1992) for waterfront development which were developed to complement the Rideau Lakes Study. This was also done to validate use of the tool in other watersheds (MVCA and CRCA), with similar site conditions. We also evaluated nutrient concentrations in a number of study lakes and completed a literature review. The challenges associated with the evaluation of nutrient concentrations limited the ability to determine trends on a large spatial scale in this study. Phosphorus concentrations have been relatively variable at sites in the MVCA, and generally declined at lake sites in the RVCA and CRCA. Declining phosphorus concentrations in RVCA lakes are quite consistent post-2002, indicating that the site evaluation guidelines produced by Michalski and Usher have been effective or, at the least, have not allowed the potential phosphorus loading from shoreline development to overcome any reductions resulting from regional changes.

The Rideau Lakes study (Michalski and Usher, 1992) was thorough and provided an abundance of information at both the regional and site-specific scales that allowed for development of effective policy aimed at reducing the impacts of shoreline development on water quality. Our review of site evaluation guidelines included an update to the site-specific biophysical criteria and references to specific policies in other municipalities in Ontario which are proactive and take an “environment first” type of approach to protecting water quality. Mitigation measures were also presented and discussed in terms of site-specific criteria in hopes that they are incorporated in planning policies as needed.

Waterfront development can have a variety of impacts and is often assessed in terms of recreational water quality, as defined by total phosphorus and its relationship to algal growth, water clarity and dissolved oxygen. Waterfront development can introduce phosphorus into surface water by migration from septic systems and contaminants contained in stormwater runoff from cleared areas. Therefore, site specific factors such as slope, soil type and vegetation are very important in mitigating development impacts and are commonly studied as part of the development approval process. Other factors such as fish and wildlife habitat, other riparian areas, hazardous lands, existing development, crowding, boat use and aesthetics should also be considered during waterfront development applications and can sometimes be addressed though the same factors that mitigate water quality impacts such as increased lot sizes or increased vegetation coverage. Through proper planning, policy development, lake stewardship and education, the impacts of shoreline development can be greatly reduced. The site evaluation guidelines produced by Michalski and Usher (1992) were an excellent first step in minimizing impacts of shoreline development. Through our assessment we have recommended modifications and additional considerations for adoption as planning tools.

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1. Introduction and Project Understanding

The Cataraqui Region Conservation Authority (CRCA), Mississippi Valley Conservation Authority (MVCA) and Rideau Valley Conservation Authority (RVCA) retained Hutchinson Environmental Sciences Ltd. (HESL) to complete an assessment of existing site evaluation guidelines for waterfront development. The current guidelines were developed in 1993 based on the "Rideau Lakes Basin Carrying Capacity and Proposed Shoreland Development Policies" (Michalski and Usher, 1992) with the intent of providing a) site specific criteria to evaluate the suitability of a lake shore site to support development and b) Best Management Practices that could be implemented to protect the natural environment and water quality during site development. They included the following primary determinants of development sensitivity: slope height and angle, soil depth and type, and vegetation cover. The science related to waterfront development, and methods for and understanding of on-site waste water treatment in particular, have evolved since the guidelines were implemented in 1993. The current project was therefore initiated to review recent findings where warranted and update the guidelines to reflect the current understanding of development stressors, including factors influencing water quality on recreational lakes, and what site-specific factors can be managed to protect the aquatic system.

The Ontario government no longer plays a role in the review of all waterfront development applications. Municipalities therefore require sufficient tools to meet their obligations under the Ontario Provincial Policy Statement (Ontario Ministry of Municipal Affairs and Housing, 2014). Where they exist, Conservation Authorities (CAs) assist municipalities in this regard. Changes reflected in the new PPS (2014) further emphasize the Province's interest in protecting water quality through proper planning; namely environmental lake capacity must be considered by Planning Authorities and water resource systems that require protection, improvement and restoration now include shoreline areas in addition to groundwater features, hydrologic functions, natural heritage features and areas, and surface water features. Site evaluation guidelines are integral components of waterfront development policies both during and after development. Any guidelines must consider the impacts of development on water quality and other natural heritage features such as fisheries, wetlands, vegetation, wildlife and Species at Risk. Protection of these natural heritage features are generally addressed in municipal Official Plan policies.

Water quality was the primary consideration in this assessment and review. Shoreline development has been linked to the potential for elevated nutrient inputs (Dillon et al. 1994; Paterson et al. 2006) which, in turn, can cause a host of problems including reduced water clarity, reduced hypolimnetic oxygen and the proliferation of algal blooms. Algal blooms are a common concern because of aesthetic and health concerns associated with algae, namely blue-green algae (or cyanobacteria). The public reporting of algal blooms in Ontario increased significantly from 1994 to 2009 (Winter et al. 2011) which is consistent with world-wide trends. Climate change is a potent catalyst for further expansion of algal blooms (Paerl and Huisman, 2008) and therefore the importance of appropriate site evaluation guidelines and best management practices to limit nutrient loading to lakes is more important than ever before.

Slope and soil characteristics examined under the current guidelines are important determinants of the potential for phosphorus from shoreline development to migrate to a lake and the resultant potential for water quality degradation, while Best Management Practices such as stormwater management, shoreline buffers and the design of septic systems provide options for mitigating phosphorus enrichment.

Evaluation criteria and mitigating options were examined through a literature review so that appropriate criteria could be identified and mitigation measures could be recommended in the updated site evaluation guidelines to best protect water quality in the study area.

Our review of the current site evaluation guidelines included:

- A general assessment of lake characteristics and data on water quality in the study area;
- A comprehensive literature review of existing site evaluation guidelines and mitigation techniques related to waterfront development; and,
- Development of updated site evaluation guidelines based on a) the effectiveness of those which have been in place in the Rideau Valley watershed for the past 20 years and b) the literature review.

2. Evaluation of Lake Characteristics

Water quality information was gathered from the Ministry of Environment's (MOE) Lake Partner Program and from the three Conservation Authorities' water quality monitoring programs in an attempt to characterize trends. Total phosphorus (TP) concentrations were evaluated because shoreline development can increase TP levels as a result of sewage inputs and impacts from site alteration and clearing. Phosphorus also commonly limits biological productivity such as algae growth. The goal of the review was to provide an indication of the impacts of development on water quality both temporally and spatially that could be used in combination with the literature review to infer the effectiveness of existing site evaluation guidelines in the Rideau Valley.

Each CA provided a list of representative lakes which are relatively heavily developed, and are sampled as part of their respective water quality monitoring programs. Specific challenges with MOE Lake Partner data included changes which have been made to the sampling program which increased the reliability of MOE data since 2000. In 2000 and thereafter, duplicates were collected which increased sample precision and since 2003 samples have been filtered, decreasing the artificial inflation of TP concentrations because of the inclusion of zooplankton in samples (Clark et al. 2010). Nonetheless, we focused on Lake Partner data because the water quality data collected by the three CAs was collected using differing study designs and was not easily comparable. We focused on lakes where data was collected for at least ten consecutive years to ensure any trends were based on dependable data. Trends were assessed through linear regression models such as Ordinary Least Squares, Generalized Least Squares or non-parametric trend analysis, depending on the status of statistical assumptions.

The lakes included:

- Mississippi Valley Conservation Authority: Kashawakamak, Mazinaw and Sharbot Lakes;
- Rideau Valley Conservation Authority: Otty and Upper Rideau Lakes; and,
- Cataraqui Region Conservation Authority: Buck, Charleston, Indian and Loughborough Lakes.

Details of the water quality evaluation are presented in Appendix A while general findings are presented in the following paragraphs

2.1 Results

2.1.1 Mississippi Valley Conservation Authority

Phosphorus concentrations increased at five out of six sites between 2002 and 2012. However, Kashawakamak Lake – Site 3 was the only site where the p value (0.08) inferred that the trend was close to being statistically significant and since all sites displayed high variability between years, confidence in the trend analysis is not very high. In order to increase the confidence in future assessments, changes should be made to the monitoring program as outlined in Appendix A.

2.1.2 Rideau Valley Conservation Authority

Variability between years declined sharply in both Otty and Upper Rideau Lakes after Lake Partner methodologies improved around 2002. Phosphorus declines between 2002 and 2012 at both sites in Upper Rideau Lake and in Otty Lake were statistically significant, according to Mann-Kendall tests. Relatively low annual variability and high statistical significance at the three sites increases confidence in the trend of declining TP concentrations. Phosphorus concentrations were only assessed at three sites so additional data is required to determine if the trend can be expanded to a larger spatial scale.

2.1.3 Cataraqui Region Conservation Authority

Charleston Lake, Indian Lane and Loughborough Lake all exhibited declining trends in TP that were often statistically significant. The trends were sometimes exacerbated by elevated values before methodologies improved sampling precision, but after the early 2000s declining trends were still obvious, indicating that a trend is occurring regardless of sampling methodology.

2.2 Summary

The majority of the lakes and their respective watersheds under question are located on the Precambrian Shield and several lakes on the Canadian Shield in south central Ontario have displayed a decrease in TP concentration over the last decade in the absence of increased human activity in their watersheds, suggesting that this may be a regional scale process (Eimers, 2009; Quinlan et al., 2008; Yan et al., 2008). Trends in nutrient concentrations appear to be either sporadic (MVCA) or declining (RVCA, CRCA) in the study area, which parallels trends in other parts of Ontario. These trends may be related to regional processes but one can also infer that waterfront policies have been effective such that potential phosphorus enrichment from shoreline development has not masked or otherwise overridden regional declines.

3. Current Site Evaluation Guidelines

We focused our review on the current site evaluation guidelines recommended in the “Rideau Lakes Basin Carrying Capacities and Proposed Shoreland Development Policies” (the ‘Rideau Lakes Study”, Michalski and Usher, 1992). The Rideau Lakes Study focused on evaluating the capacity of a variety of lakes for development in terms of lake trophic state, existing development, fisheries and boating. The findings were used to provide context for policy direction. Site parameters such as soil, slope and site drainage were considered on a regional scale in line with regulations at that time and more specific development capabilities were developed based on the same biophysical site characteristics at a greater level of detail. The coarse regional information allowed lands to be categorized into four classes while a scoring system for site-specific biophysical site information determined the shoreline setback, with the understanding that greater setbacks were required to protect water quality where site characteristics increased the potential for phosphorus to migrate between a septic system and a lake.

3.1 Assessment Criteria

3.1.1 General Site Suitability

Site suitability assessment criteria in the Rideau Lakes Study focused on soil conditions, slope and site drainage, as presented in “Facts about Septic Tank Systems” (MOE, 1983) and “Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems” (MOE, 1982). The type, depth and particle size of soil on the site were discussed qualitatively; flat slopes were preferred with increasing limitations posed by steeper slopes up to 25%, after which steeper slopes were deemed to be unacceptable. At least 0.5 m of soil was required above the maximum ground water table for drainage through either natural soil with an acceptable infiltration rate or imported fill with the same acceptable infiltration rate. Four classes of land development capability were established based on these characteristics:

- Class 1: lands having predominantly good development capabilities, requiring no or little site modification (mainly level to gently sloping, well drained, and having deep (>1.5 m), sandy and/or loamy soils);

- Class 2: lands having fair development capability, requiring moderate amounts of site modification (characterized by the widespread occurrence of minor constraints such as imperfect site drainage, shallow but continuous soil cover over bedrock, or moderately steep slopes), or lands having good development capability moderately interspersed with areas of major constraints;

- Class 3: lands having poor development capability, requiring extensive site modifications (characterized by the widespread occurrence of two or more minor constraints and the local occurrence of major constraints); and,

- Class 4: lands generally unsuitable for development without excessive site modifications (dominated by major constraints, such as wetlands with moderate to deep organic deposits, or steep bedrock outcrops).

3.1.2 Specific Biophysical Site Characteristics

Biophysical site characteristics were examined by Michalski and Usher (1992) to determine shoreline setbacks via a scoring system. The authors acknowledged that the approach "has not been developed on the basis of reams of data collected in a rigorous and scientific fashion; rather, it represents the results of our experience in applying and implementing development setbacks in a wide range of biophysical landscapes across Ontario for a variety of environmental protection and resource management purposes." A number of references were cited by Michalski and Usher (1992) to lend credibility to the attributes of individual site characteristics and the subsequent development scores.

A description of the biophysical site characteristics and their ability to attenuate phosphorus from development are presented in Table 1. Specific criteria and scores for biophysical criteria are shown in Table 2. Table 3 includes score ranges and recommended shoreline setbacks for each range.

Table 1. Biophysical characteristics used to score development capability (Michalski and Usher, 1992).

Site Characteristic	Site Description	Capability/Constraint Attributes
Soil Conditions	Gravel, very coarse sand	Generally unsuitable as filter mediums for tile fields due to excessively rapid permeability; necessitates fill importation for raised tile beds
	Sandy loams and loamy sands	Well suited as filter mediums
	Fine sandy loams, loams, and silty loams	Moderately well suited as filter mediums
	Clay loams and moderately dense clays	Poorly suited as filter mediums due to slow internal drainage characteristics; necessitates fill importation for partially to fully raised tile beds
	Dense clays and bedrock	Unsuitable as filter mediums; necessitate fill importation to develop fully raised beds and mantles
Slope Class	Level (0-3%)	Most desirable condition, high capability requiring no site modification
	Low (4%-8%)	Minor constraint, may require slight modification of tile field installation or regrading
	Moderate (9%-15%) to steep (16%-25%)	Poorly suited for tile fields, necessitating special tile field installation methods and/or extensive regrading
	Very steep (>25%)	Unacceptable for installing tile fields without regrading or filling
Site Drainage Class	Well drained	Most desirable condition for tile beds; high capability requiring no site modification
	Moderately drained	Moderately well suited for tile beds, but may necessitate slight site modification through minimal fill importation
	Poorly drained	Poorly suited for tile beds, necessitating importation of moderate to high volumes of suitable fill material to develop required distance between adsorption trenches and maximum water table elevation
	Very poorly drained	Unsuitable without very high volumes of fill; unacceptable where sites are subject to flooding

Table 2. Biophysical criteria and resulting development scores.

Site Characteristic	Criteria			Score
Soil Depth	**Depth (cm)**			
	>150			0
	100-150			2
	75-100			4
	50-75			6
	25-50			8
	<25			10
Soil Texture	**Type**	**Percolation Rate**	**Phosphorus Retention Capability**	
	Coarse sand and gravel	Excessively rapid	Low	10
	Silty clay and clay	Low to impermeable	High	7
	Well-graded sands	Permeable to moderate	Low to medium	5
	Silty sand, clayey sand, silt and fine sand	Moderate to low	Medium to high	3
	Sandy loam	Moderate to low	Medium to high	3
	Loam	Permeable to moderate	Medium to high	0
Slope	**Slope Class**			
	0%-9%			0
	10%-25%			5
	>25%			10
Vegetation	**Vegetation Cover Type**			
	Undisturbed woodlands, old fields, and meadows			0
	Disturbed woodlands, old fields, and meadows			3
	Close-seeded legumes (clover, alfalfa) and rotation meadows			5
	Row crops			7
	Fallow fields and base bedrock outcrops			10

Table 3. Biophysical site scores and recommended horizontal setback distances.

Total Score	Recommended Horizontal Setback Distance (m)
36-40	90
31-35	80
26-30	70
21-25	60
16-20	50
11-15	40
≤10	30

3.1.3 Summary

The “Rideau Lakes Basin Carrying Capacities and Proposed Shoreland Development Policies” (Michalski and Usher, 1992) contains an abundance of information that is well cited and is still relevant today, including the capability of regional and biophysical site characteristics to attenuate the movement of phosphorus between a septic system and surface water. The Ontario Building Code (Ontario Ministry of Municipal Affairs and Housing, 2006) requires a minimum 15m setback of a septic system tile field from surface water – the setbacks of 30-90m (Table 3) recommended by Michalski and Usher (1992) therefore represent a substantial increase in protection over the Ontario Building Code requirements and have been provided for in local Official Plans in the Rideau Watershed for many years.

4. Site Evaluation Guidelines Literature Review

Site assessment criteria are discussed and new findings since the publication of the Rideau Lakes study are presented in this section. Mitigation measures are presented which minimize the impacts of development on water quality and are discussed in terms of a site’s development suitability. Other tools are discussed which assess development capacity through alternative approaches yet are still ultimately focused on water quality.

4.1 Assessment Criteria

Mitigation measures related to shoreline development can be very effective. At the same time, their application and criteria for their use in planning need to consider and incorporate the specific conditions under which a mitigation method was tested and an understanding of how it will be applied in practice. These concerns are addressed in the following sections on the development of assessment criteria.

4.1.1 Soils

The 2006 Ontario Building Code and Guide for Sewage Systems (Ontario Ministry of Municipal Affairs and Housing, 2006) includes a variety of site features to consider when locating infiltration fields, including soil characteristics. Soils are an integral component of assessment criteria for site development because they impact the effectiveness of the sewage system and are a primary factor in the determination of buffer effectiveness (Beacon Environmental, 2012), depending on soil depth, percolation rate and resulting ability to retain phosphorus. Fine texture soils are better at phosphorous removal but they have lower percolation rates. The 2012 Ontario Building Code accounts for the hydraulic loading rates of the receiving soil and therefore overland flow should not be a problem if septic systems are designed, constructed, and inspected correctly. There are no definitive guidelines in the Ontario Building Code (Part 8, Sewage Systems) to account for the optimum sand/soil fill to be used to provide long-term attenuation of phosphorus but in terms of determining general site suitability, moderately coarse soils are generally the most appropriate for buffering and the construction of tile fields.

The Township of McKellar requires an evaluation of soil depth, type and moisture during shoreline development applications (Township of McKellar Official Plan, 1994). The District of Muskoka requires a variety of soil characteristics to be assessed through Water Quality Impact Assessments which are required on lakes that are considered to be either “highly sensitive” or “over-threshold” (District Municipality of Muskoka Official Plan, 2010). Criteria include soil character, depth and chemistry:

- Soil character includes type, texture, colour and compaction, to a maximum depth of 1.0 m;
- Soil depth along the flow path of the proposed tile field, to a maximum distance of 30 m downgradient, with depths recorded at a minimum of 20 points; and,
- Soil chemistry analysis for phosphorus adsorption, $CaCO_{3,}$ extractable iron, extractable aluminum, and percolation rate estimated from particle size for the native soils.

Soil assessment criteria are also discussed in the “Lakeshore Capacity Assessment Handbook” (Province of Ontario, 2010). Assessment criteria are targeted for proposals on “at capacity” lakes and sites must contain the following characteristics to justify development:

- Sufficient depth (> 3 m);
- Native and undisturbed;
- Non-calcareous (< 1% $CaCO_3$);
- Acid-extractable concentrations of iron and aluminum of > 1% by weight; and,
- Unsaturated zone of at least 1.5 m depth between the tile bed and the shallowest extent of the water table.

The District of Muskoka’s and the Province of Ontario’s soil assessment criteria are based on “sensitive” or “at-capacity” lakes. Some of the chemical analyses can be expensive and do not need to be completed in all cases. General soil characteristics should always be examined because at the very least it provides a general idea of the site’s suitability for the creation of a tile bed and basis for the production of an appropriate Erosion and Sediment Control Plan. In addition, research conducted since 1992 shows that soils containing high Fe and Al, and which are non-calcareous (< 1% $CaCO_3$) provide substantial long-term retention and mineralization of up to 95% of septic system phosphorus. Consideration of mineral content in native soils, and incorporation of non-calcareous and mineral rich soils into septic system tile fields therefore provides the opportunity to provide substantial additional protection for nutrient –sensitive lakes. Details are provided in Section 4.2.2.

Figure 1 presents a visual display of which soil assessment criteria should be determined along a line of impact, as defined by the size of the development and sensitivity of the site.

Figure 1. Recommended soil assessment criteria (top) and biophysical criteria (bottom) sorted along a site sensitivity gradient.

4.1.2 Slope

Slope impacts a site's suitability for a sewage treatment system and the effectiveness of the shoreline buffer (Figure 2). Wenger (1999) claimed that slopes greater than 25% (rise/run = 1/4) are not effective buffers and buffer width should increase by two feet each % up to 25%. Woodard and Rock (1995) found that slopes up to 13% (1/7.7) are able to effectively attenuate sediments and phosphorus if vegetation is well established and forest litter is present but steeper slopes necessitate increased buffer width. Results are varied throughout other literature but ultimately, steeper slopes decrease effectiveness and it is recognized that increased buffer width and the introduction of vegetation can help mitigate steep slopes (Beacon Environmental, 2012). Very steep slopes near water can also result in landslides during development and need to be addressed from a hazardous lands perspective.

The District of Muskoka requires slopes to be classified into categories of 0 - 9% (1/9), 10 (1/10) - 25% (1/4) and > 25%. Contour information at 5 m intervals is available from Ontario Base Mapping which when combined with field investigations, is generally sufficient for site investigations. Slope categories should include a category that is >25% because these areas should not count towards shoreline buffers and > ~13% because these slopes necessitate a wider buffer depending on the proposed development and incorporation of other mitigation measures.

Slope should be also explained in the context of site drainage so that stormwater retention and any Erosion and Sediment Control plans can be completed.

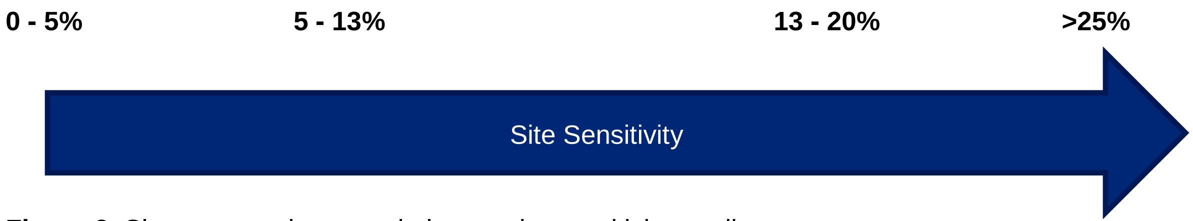

Figure 2. Slope categories sorted along a site sensitivity gradient.

4.1.3 Vegetation

Vegetation communities impact the success of phosphorus and sediment attenuation through interception and infiltration of stormwater runoff and retention of septic phosphorus in the shoreline buffer (Figure 3). For these purposes, characterizing vegetation in the proposed development envelope and in the shoreline buffer should include classifying the canopy and understory with the description accompanied by photographs. Planting should be considered at sites where vegetation has been previously cleared from the proposed shoreline buffer to improve the buffering capabilities of the site. Any plantings should consider the existing vegetation community and focus on native, tolerant species with deep rooting potential.

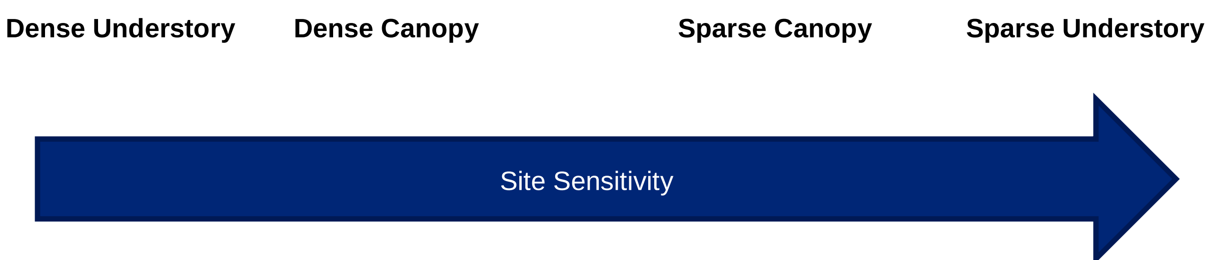

Figure 3. Vegetation abundance sorted along a site sensitivity gradient.

4.1.4 Natural Heritage Features

Fish habitat, wildlife habitat, Species at Risk, natural hazards, etc. must be considered in conjunction with water quality issues as per general Environmental Impact Assessment requirements. These issues are outside of the scope of this study, but in creating requirements for waterfront development it is important to ensure that these issues are still addressed.

4.2 Mitigation Measures

4.2.1 Shoreline Buffer

Shoreline buffers are a well-studied mitigation measure associated with waterfront development. The availability of information results from the well-known and established effectiveness of native, dense shoreline buffers in mitigating the impacts of stormwater and septic effluent though filtering, infiltration and attenuation. The effectiveness depends on a wide variety of site specific factors (e.g. slope), which were discussed in Section 4.1, and characteristics of the buffer itself.

A shoreline buffer refers to the vegetated portion of lands adjacent to waterbodies. It does not refer to a setback or distance from a given feature in which native vegetation is removed, because it is the vegetative components of the buffer that provide the majority of ecological benefits. Buffers filter sediment and other pollutants, and absorb nutrients from runoff, thereby helping to mitigate impacts of stormwater and septic use. Shoreline buffers also provide a host of ecological services including (North Carolina Department of Environment and Natural Resources Bulletin):

- Protects bank from erosion;
- Performs effective flood control;
- Provides canopy and shade;
- Provides food and habitat for wildlife;
- Protects property values; and
- Provides aesthetic value.

Zhang et al. (2010) found that buffer width can explain 35 - 60% of variance in removal efficacy for sediment, pesticides, nitrogen and phosphorus but site characteristics such as soils, slope and vegetation are also important considerations. Buffer size recommendations, as they relate to water quality function, are variable because of different site conditions but also some inconsistency in site designs and different measures of "effective" attenuation of water quality (Beacon Environmental, 2012). Most studies demonstrate that buffers from 9 - 30 m provide more effective attenuation than smaller buffers and 30 m buffers provide effective water quality protective functions (Dillaha *et al.* 1985; Dillaha *et al.*1986; Dillaha 1989; Magette *et al.* 1986; Environmental Law Institute 2008; Wenger 1999). The benefit of a 30 m buffer with subsequent ecological benefits is also supported by a thorough examination by Knutson and Naef (1997):

- Maintenance of 50 to 100% shading of the stream is assured at 30 m;
- Maintenance of large woody debris requires 30 m to 50 m;
- 90% sediment removal at a 2% grade requires 30 m or more;
- Removal of nutrients and coliform bacteria requires 4 m to 36 m (30 m is cited most often);
- Bank erosion control requires a minimum of 30 m; and
- Aquatic invertebrates, salmonid fish and reptiles and amphibians all require a 30 m buffer strip.

30 m is also the recommended buffer size for stream environments by Environment Canada and the Ministry of Natural Resources in "How Much is Enough?" (2013) and the Natural Heritage Reference Manual for "Natural Heritage Policies of the Provincial Policy Statement" (2010) based on recommendations in the majority of literature reviewed.

A 30m buffer provides a variety of ecological services, including improvements to water quality in most cases but wider buffers should be considered where the biophysical criteria indicate increasing site sensitivity (Figure 4).

Minimal Buffer (30m) | **Larger Buffer**

Moderately Coarse Soils	**Coarse or Fine Soils**
Deep Soils	**Shallow Soils**
Flat Terrain	**Steep Terrain**
Dense Vegetation	**Sparse Vegetation or Transformation to Ornamental Lawn**

Figure 4. Recommended buffer width (top) and biophysical criteria (bottom) sorted along a site sensitivity gradient.

An “Activity Area” is the area within the shoreline buffer that includes man-made structures such as docks and boathouses and provides access to the water. The Activity Area can be controlled through policy to ensure that the majority of the shoreline buffer remains natively vegetated and thus functional. Percentages vary for different types of development but for typical residential development a maximum activity area of 25% is common (City of Kawartha Lakes Official Plan, 2012; City of Greater Sudbury, 2004; District Municipality of Muskoka, 2010). A maximum upset is also often included in many municipal policies so that large areas are not cleared on large lots. Maximum upsets include 15 m (Parks Canada, 2010) and 23 m (City of Greater Sudbury, 2013). Current RVCA policies are based on the Parks Canada approach.

4.2.2 Sewage Systems

The impacts of sewage systems should be considered in terms of both design and maintenance. In 2010 the Ontario Building Code added Maintenance Inspections; Division C, Part 1.10, to allow a municipality to enforce a discretionary Maintenance Inspection Program. The Township of McKellar requires “continued maintenance of sewage treatment systems by regular pump-outs and inspections” (Township of McKellar Official Plan, 2009) which is generally believed to be every 3 to 5 years (Ministry of Municipal Affairs and Housing, 2006). Septic re-inspection programs are completed by many Municipalities and Conservation Authorities throughout Ontario, including MVCA and RVCA, in order to identify septic systems with some benchmark of failure such as soft ground or ponding. The re-inspection programs are important in diagnosing failing septic systems, many of which were designed for much less use than they receive, and to increase awareness because it is ultimately the homeowner’s responsibility to ensure their septic system is operating effectively (Ontario Building Code, 2006, Section 8.9.2.3 (2)) and is in compliance with OBC regulations.

It has been proven that adsorption of phosphate on charged soil surfaces and mineralization of phosphate with iron and aluminum can immobilize septic phosphorus (Robertson et al., 1998; Robertson, 2003, Zurawsky et al. 2004). The mineralization process, which is a permanent reaction, is particularly effective in acidic and mineral rich groundwater in Precambrian Shield settings, leading to robust and long-term phosphorus removal when specific fill types are used for filter bed construction (Robertson, 2012) or considered in the native soils between the tile field and surface water. The Township of McKellar's Official Plan includes provisions for "the implementation of septic systems that bind phosphorus so there is limited migration of the nutrient in to the waterbody". Furthermore, work by Michael Michalski utilized "B" horizon Precambrian Shield soils which are orange/brown in colour and have appropriate characteristics (i.e. phosphorus adsorption, extractable iron, extractable aluminum, and percolation rate) to successfully retain sewage-related phosphorus through absorption and mineralization on a development on South Kushog Lake, a sensitive lake trout lake in Haliburton County. Water samples were collected from five locations in the leaching bed from 2003 to 2012 and phosphorus concentrations compared to concentrations at the outlet of the septic tank. Average annual reduction ranged from 97 - 99.9%, leading the MOE to accept the findings and release a financial security imposed by a decision of the Ontario Municipal Board (letter Castro (MOE) to Newhook (Algonquin Highlands Oct, 29, 2013)). These findings indicate long-term adsorption or complexing of septic phosphorus in the tile field soils which is consistent with the research findings of Robertson et al (see above) from other similar studies with septic systems constructed with imported and native acidic soils on the Precambrian Shield.

There are other tertiary septic system options which are commercially available and are aimed at reducing the impacts of septic effluent on water quality. These technologies should be sought out where site conditions indicate increased site sensitivity to reduce impacts of development on adjacent waterbodies.

Many tertiary treatment systems are not utilized because of increased costs. The use or importation of "B" horizon Precambrian Shield soils, however, is not overly expensive if such soils are found on site or nearby and efforts should be made to ensure this filtering medium is used in all such situations. The use of such soils should be guided by a requirement that they have the following characteristics:

- Non-calcareous (< 1% $CaCO_3$) to ensure that nitrification reactions in the tile field maintain the acidic conditions which favour mineralization;

- Acid-extractable concentrations of iron and aluminum of > 1% (>10,000 ppm) by weight to ensure mineralization.

Conventional Septic System and Leaching Bed | **Tertiary Treatment**

Moderately coarse soils | **Coarse or fine soils**
Deep Soils | **Shallow Soils/Bedrock**
Flat Terrain | **Steep Terrain**
Dense Vegetation | **Sparse Vegetation**

Figure 5. Recommended septic system (top) and biophysical criteria (bottom) sorted along a site sensitivity gradient.

4.2.3 Erosion and Sediment Control

An Erosion and Sediment Control (ESC) plan can help mitigate the impacts of development in the short term (i.e. Construction Mitigation Plan) and long-term (i.e. Stormwater Management Plan) by encouraging infiltration of stormwater to the subsurface. A construction mitigation plan should be developed to (Certified Inspector of Erosion and Sediment Control, 2011):

- Utilize a multi-barrier approach;
- Retain existing vegetation;
- Minimize land disturbance area;
- Slow down and retain runoff to promote settling;
- Divert runoff from problem areas;
- Minimize slope length and gradient of disturbed areas;
- Maintain overland sheet flows and avid concentrate flows; and
- Store/stockpile soil away from watercourses, drainage features, and tops of steep slopes.

A variety of best management practices (BMPs) can be employed to accomplish these goals depending on the site conditions. The effectiveness of BMPs is contingent on proper installation and maintenance, including inspection, details of which should be monitored by a certified environmental professional.

Stormwater management features include provisions to maximize infiltration and limit stormwater runoff. The District Municipality of Muskoka Official Plan (2010) policies include proper re-contouring, discharging of roof leaders, use of soak away pits and other measures to promote infiltration. Other specific design options for consideration include: grassed and vegetated swales, filter strips, roof leaders and French drains have proven to be effective. Site characteristics and the nature of the proposed development will dictate the appropriateness of these and other stormwater management tools.

4.3 Other Considerations

4.3.1 Lakeshore Capacity Assessment

Lakeshore Capacity Assessments are often required as part of shoreline development applications through Official Plan policies. In the Lakeshore Capacity Assessment Handbook (Province of Ontario 2010), it is recommended that lakeshore capacity assessments should be considered under the following circumstances:

- When developing or updating official plans;
- If significant improvements to road access to a lake are being considered, or have occurred, increasing the use of residences from seasonal to extended seasonal or permanent;
- If development (i.e., new planning approvals) are being considered within 300 m of a lake or a permanently flowing stream within its watershed;
- If significant or unusually large amounts of development are proposed for a lake beyond the 300 m boundary;
- If water quality problems (such as elevated levels of phosphorus, loss of water clarity, or algal blooms) are noted;
- If lake trout populations are present;
- If changes in fisheries have been noted, especially diminishing populations of coldwater species such as Lake Trout; and,
- If cottagers or year-round residents raise concerns about the effects of development on water quality.

Lakeshore capacity assessments based on variants of the Provincial Approach (Hutchinson 2002) have also been used by the District Municipality of Muskoka (Gartner Lee Ltd. 2005) or are under development by the Cities of Greater Sudbury and Elliot Lake, to set lake-specific policies based on differences between current and modelled background TP concentrations. Often times the accuracy of lakeshore capacity models do not provide defensible development capacities and the proven ability of mineral rich soils in the tile fields of domestic sewage systems to mitigate phosphorus limits their application as proposed by the Province of Ontario (2010). Phosphorus-based capacity models should be used as a 'piece of the puzzle' when evaluating shoreline development applications but are best used to estimate lake sensitivities to phosphorus loading instead of absolute development capacities. This can be done by modelling a standard areal load of phosphorus and evaluating the % change in concentration from modelled background levels. These "sensitivities" give a good indication on how lakes may respond to phosphorus inputs.

4.3.2 Recreational Carrying Capacity

Recreational Carrying Capacity is generally assessed through changes to the amount of boaters on a lake as a result of a proposed waterfront development. Capacity is considered for safety purposes but boating traffic can have negative impacts on water quality through the generation of wakes which erode soft shorelines. Eroded soil degrades water quality and is a source of phosphorus that will reduce light penetration, diminish recreational values and aesthetics, as well as cause direct and indirect impacts to fish, invertebrates and aquatic plants (Kerr 1995). Sediment re-suspension can increase phosphorus concentrations, thereby increasing primary production and reducing dissolved oxygen concentrations through the decomposition of organic matter.

A standardized approach to assess the current and proposed level and type of boating activity does not exist in Ontario. The Township of McKellar (2009) does include provisions that aim to recognize the carrying capacities of each water body from a boating perspective because after a certain limit, recreational boating can reduce the attractiveness for shoreland residents and potentially jeopardize public safety. As a result, recreational carrying capacity studies can be triggered by proposed developments which are greater than 3 lots in that Township. Nevertheless, adoption and implementation of boating capacity is not commonly practiced in Ontario and capacity limits based on boating type or density are not enforceable.

The Official Plan of Seguin Township, Ontario (May 2012) includes a provision for recreational capacity on lakes. It allows for 1 residential unit for every 1.6 ha of lake surface area or 1 tourist unit for every 0.8 ha. This approach reduces crowding of the lake, limits the number of boats and is easily implemented.

4.3.3 Lake Trout

The Ontario Ministry of Natural Resources (MNR) is responsible for managing fish habitat and in that role the MNR supports the enforcement of development capacities on some lakes. Lake Trout are a sensitive fish and have specific temperature and oxygen requirements including a criterion of 7 mg/L of dissolved oxygen, measured as the Mean Volume-Weighted Hypolimnetic Dissolved Oxygen at the end of summer. Excessive additions of phosphorus can cause increased consumption of oxygen from deeper portions of a lake through decomposition of algae and this may degrade the cold water habitat favoured by lake trout in the late summer period.

The habitat requirements for Lake Trout may be more restrictive than the recreational water quality requirements of humans, and it is possible that the MNR will consider a lake to be at capacity because of concerns related to oxygenated Lake Trout habitat even though the lake may have capacity from a recreational use perspective. Where the MNR has identified Lake Trout habitat concerns related to water quality, they may also work with the MOE to set their own limits on the amount of shoreline development permitted on a lake. We note, however, that any shoreline development policies or practices that reduce phosphorus loading would also allow additional development with no impact to Lake Trout habitat – this was the basis of the South Kushog Lake decision on phosphorus abatement cited in Section 4.2.2.

5. Assessment of Site Evaluation Guidelines

The purpose of this study was to determine the continued validity of the site evaluation guidelines (Michalski and Usher 1992) for waterfront development which were developed to complement the Rideau Lakes Study. In order to assess the site evaluation guidelines we evaluated nutrient concentrations in a number of study lakes and completed a literature review. The challenges associated with the evaluation of lake characteristics limited the ability to determine trends on a large spatial scale in this study. Phosphorus concentrations have been relatively variable at sites in the MVCA, and generally declined at lake sites in the RVCA and CRCA. Declining phosphorus concentrations in RVCA lakes are quite consistent post-2002, indicating that the site evaluation guidelines produced by Michalski and Usher have been effective or, at the least, have not allowed the potential phosphorus loading from shoreline development to overcome any reductions resulting from regional changes.

The Rideau Lakes Study (Michalski and Usher, 1992) was thorough and provided an abundance of information at both the regional and site-specific scales that allows for development of effective policy aimed at reducing the impacts of shoreline development on water quality. Our review of site evaluation guidelines included an update to the site-specific biophysical criteria and references to specific policies in other municipalities in Ontario which are proactive and take an environment first type of approach to protecting water quality. Mitigation measures were also presented and discussed in terms of site-specific criteria in hopes that they are incorporated in planning policies as needed.

The results of our water quality evaluation, review of the Rideau Lakes Study, and literature review of site evaluation guidelines and associated BMPs were all considered during the production of updated site evaluation guidelines. The background to the guidelines is presented above and the guidelines themselves are presented below as a checklist for individuals who are completing a waterfront site evaluation. The checklist includes evaluation criteria and BMPs which should be used in all cases to ensure that development has minimal impacts on water quality. Additional criteria are also presented for sites which are deemed to be highly sensitive. Site sensitivity is assessed through the same approach as reported in the Rideau Lakes Study with slight modifications made to the slope categories to best reflect the findings of our literature review. Lastly, biophysical site scores are used to indicate recommend “shoreline buffer widths” instead of “horizontal setback distances” as reported by Michalski and Usher but it should be noted that the scoring ranges have not been changed. The practical guides are meant to bridge the information gathered through this study with field application and could be altered by planning authorities as they see fit to best protect water quality in individual planning areas and reflect planning priorities in such areas.

5.1 Evaluation Criteria Checklist

The following section presents a checklist of evaluation criteria that should be addressed when evaluating development on existing lots of record or when considering severance proposals. Similar criteria are found in the Official Plan of the District Municipality of Muskoka as “Appendix J - Lake System Health Terms of Reference – Water Quality Impact Assessments”. The Muskoka criteria were developed with the intent that they would be included by the proponent in an application for a lot severance and that planning staff could review the criteria as part of the approvals process. In practice, the applicant retains an environmental consultant to conduct the assessment and pays for an independent review of the application against the criteria by a consultant working for the District of Muskoka or one of the lower tier municipalities. Staff at RVCA currently completes site assessments which negates the requirement of an independent review. Criteria need to be either assessed and described as marked by a "✓", or evaluated per the biophysical scoring system presented in Table 5.

The evaluation of other environmental features and functions, such as natural heritage features and more detailed natural hazards, is often required through other municipal, provincial or federal legislation and Table 4 only represents criteria related to a site evaluation focused on water quality impacts.

Table 4. Evaluation Checklist

a. Site Description	
- Topographic features	✓
- Natural hazards such as areas prone to flood or erosion	✓
- Watercourses, ponds, wetlands	✓
- Lot size, frontage, depth, area, shape	✓
- Permanent and intermittent streams	✓
-expected path of surface runoff	✓
- Aquatic vegetation & ecological description	✓
- Terrestrial vegetation community	See Table 5 for scoring
b. Soil Characteristics	
- Document and map soil conditions	✓
- Characterize soils used for leaching beds	✓
- Characterize native soils in mantle	✓
- Location of leaching bed	✓
- Pathway of subsurface flow relative to lake	✓
- Manual auguring to determine soil depth	See Table 5 for scoring
- Sources of suitable soil for raised fields	✓
- Soil Character - type, texture, colour	See Table 5 for scoring
***c.* Slopes**	
- Site contours	✓
- Slope areas (0-10, 10-15, 15-20, 20-25, >25%)	See Table 5 for scoring
- Depressions and gullies that channel water	✓
d. Vegetation cover	
- Map location and character of shoreline & upland vegetation	See Table 5 for scoring
- Photographic documentation	✓
-property shoreline (from lake)	✓
-tile field along direction of flow	✓

-building envelope shortest dist to lake	✓

e. Description of how development will occur

- Building location	✓
- Septic system location	✓
- Parking and other hard surfaces	✓
- Proximity to significant features	✓
- geological	✓
- man-made	✓
- wetlands, streams, other water	✓

f. Standard mitigation measures to eliminate impacts of nutrient and sediment loading

- Detailed construction mitigation plan	✓
- Stormwater management plan including control of runoff and other BMPs	✓
- Incorporation of "b" horizon soils	✓
- Minimum 30 m shoreline setbacks and buffer areas	✓
- Delineate building envelopes	✓
- showing setbacks from shore	✓
- showing yard setbacks	✓
- showing septics location	✓
- Show protection for natural vegetation	✓
- slopes and soil mantle for areas outside of building envelope	✓

5.2 Biophysical Site Scoring

The biophysical criteria presented below are unchanged from the scores produced by Michalski and Usher (1992) in the Rideau Lakes Study except for the addition of additional slope classes based on literature findings and 10 bonus points for a soil analysis indicating substantial phosphorus reduction potential.

Table 5. Updated Biophysical Criteria

Site Characteristic	Criteria			Score
Soil Depth	**Depth (cm)**			
	>150			0
	100-150			2
	75-100			4
	50-75			6
	25-50			8
	<25			10
Soil Texture	**Type**	**Percolation Rate**	**Phosphorus Retention Capability**	
	Coarse sand and gravel	Excessively rapid	Low	10
	Silty clay and clay	Low to impermeable	High	7
	Well-graded sands	Permeable to moderate	Low to medium	5
	Silty sand, clayey sand, silt and fine sand	Moderate to low	Medium to high	3
	Sandy loam	Moderate to low	Medium to high	3
	Loam	Permeable to moderate	Medium to high	0
Soil Analysis	If native soil between tile field and lake is > 1m deep, <1% $CaCO_3$ and >1% Iron/Aluminum			-10
Slope	**Slope Class**			
	0%-13%			0
	13%-20%			8
	20%-25%			10
	>25%			12
Vegetation	**Vegetation Cover Type**			
	Undisturbed woodlands, old fields, and meadows			0
	Disturbed woodlands, old fields, and meadows			3
	Close-seeded legumes (clover, alfalfa) and rotation meadows			5
	Row crops			7
	Fallow fields and base bedrock outcrops			10

Once criteria have been evaluated per the Assessment Criteria Checklist (Table 4) and scored per biophysical site scoring (Table 5), the results should be used to determine the shoreline buffer width as presented as “horizontal setback distance” by Michalski and Usher in the Rideau Lakes Study. Buffers refer to the vegetated portion of lands adjacent to waterbodies and when vegetation is retained they are by far the most effective mitigation tool and should remain as the primary mitigation factor under consideration. These buffers could allow for a maximum activity area of 25% of the shoreline with a maximum upset of 15m as discussed in Section 4.2.1.

Table 6. Biophysical site scores and recommended shoreline buffer.

Total Score	Recommended Depth of Shoreline Buffer (m)
36-40	90
31-35	80
26-30	70
21-25	60
16-20	50
11-15	40
≤10	30

Sites which score >20 or which are deemed to be sensitive by the reviewing authority should be subjected to additional evaluation criteria and if the recommended setback distance cannot be obtained, mitigation measures should be implemented. Additional evaluation criteria will be determined by the reviewing authority and could include:

- Soil chemistry analysis for phosphorus adsorption, $CaCO_3$ content extractable iron, extractable aluminum, and percolation rate estimated from particle size for the native soils and importation of soils, as required, to decrease the potential for phosphorus to move from septic systems to surface water.

- Lakeshore Capacity Assessment/Lakeshore Capacity sensitivity assessment in accordance with Province of Ontario (2010) guidance or any system adopted by the municipality and accepted by the Province.

- Recreational Capacity Assessment where developed and approved by the Province.

Additional mitigation measures which could be implemented at sensitive sites or to mitigate impacts at a site where the recommended horizontal setback distance cannot be obtained due to lot size or similar constraints include:

- Incorporation of a tertiary sewage treatment system such as non-calcareous, mineral rich soils
- An improved construction mitigation plan
- Improved stormwater management practices
- Planting of, or augmentation of native vegetation in shoreline buffer to improve shoreline buffer benefits
- Limiting site disturbance/regrading, especially within buffer

6. Summary

Waterfront development can have a variety of impacts and is often assessed in terms of recreational water quality, as defined by total phosphorus and its relationship to algal growth, water clarity and dissolved oxygen. Waterfront development can introduce phosphorus into surface water by migration from septic systems and stormwater runoff from cleared areas. Therefore, site specific factors such as slope, soil type and vegetation are very important in mitigating development impacts and are commonly studied as part of the development approval process. Other factors such as fish and wildlife habitat, hazardous lands, existing development, crowding, boat use and aesthetics should also be considered during waterfront development applications and can sometimes be addressed though the same factors that mitigate water quality impacts such as increased lot sizes or increased vegetation coverage. Through proper planning, policy development, lake stewardship and education the impacts of shoreline development can be greatly reduced. The site evaluation guidelines produced by Michalski and Usher (1992) were an excellent first step in minimizing impacts of shoreline development and through our assessment we have recommended modifications and additional considerations for adoption as planning tools.

Lakes are unique and it is difficult to properly develop policies on large spatial scales that address all aspects of lake characteristics. The approach of Michalski and Usher (1992) is a sound means to address site specific characteristics and we have recommended some additions that reflect recent understanding. In the future it would be beneficial to continue to refine waterfront planning tools on a lake-specific basis through improvements to monitoring programs, evaluation of lakeshore capacity assessments and questionnaires to solicit resident’s views on environmental and planning issues.

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Appendix A. Evaluation of Lake Characteristics

Water quality information was gathered from the Ministry of Environment's (MOE) Lake Partner Program and from the three Conservation Authorities' water quality monitoring programs in an attempt to characterize trends. Total phosphorus (TP) concentrations were evaluated because shoreline development can increase TP levels through sewage inputs and site clearing. Phosphorus also commonly limits biological productivity such as algae growth. The goal of the evaluation was to provide an indication of the impacts of development on water quality both temporally and spatially that could be used in combination with the literature review to infer the effectiveness of existing site evaluation guidelines in the Rideau Valley.

Each CA provided a list of representative lakes which are heavily developed and are sampled as part of their respective water quality monitoring programs. Specific challenges with MOE Lake Partner data also included changes which have been made to the sampling program which increased the reliability of data since 2000. In 2000 and thereafter, duplicates were collected which increased sample precision and since 2003 samples have been filtered, decreasing the artificial inflation of TP concentrations because of the inclusion of zooplankton in samples. Nonetheless, we focussed on Lake Partner data because the water quality data collected by the three CAs was collected using differing study designs and was not easily comparable. We focused on lakes where data was collected for at least ten consecutive years to ensure trends were based on dependable data. Trends were assessed through linear regression models such as Ordinary Least Squares, Generalized Least Squares or non-parametric trend analysis, depending on the status of statistical assumptions.

The lakes included:

- Mississippi Valley Conservation Authority: Kashawakamak, Mazinaw and Sharbot Lakes;
- Rideau Valley Conservation Authority: Otty and Upper Rideau Lakes; and,
- Cataraqui Region Conservation Authority: Buck, Charleston, Indian and Loughborough Lakes.

Mississippi Valley Conservation Authority

Kashawakamak Lake

Trends were analyzed at Sites 2 and 3 in Kashawakamak Lake. According to Lake Partner information, Site 2 is located in the northeast end of the lake in a deep spot while Site 3 is found in the main channel at the western end of the lake.

TP concentrations have been plotted in Figure A1. Generalized Least Squares (GLS) was used to assess the trend in phosphorus concentrations in Site 2 while Ordinary Least Squares (OLS) was used for Site 3 based on the degree of variance and autocorrelation amongst observations. Both sites display increasing trends in phosphorus as shown in Figure A1 and through slope values in Table A1, but the relatively low coefficients of determination (R^2) illustrate that the TP concentrations do not fit tightly around the trend line and p values greater than 0.05 demonstrate that neither trend is statistically significant.

Table A1. Trend analysis for Sites 2 and 3 in Kashawakamak Lake.

Site	n (years)	slope	R^2	p
2	14	0.1001	0.0346	0.2583
3	16	0.1596	0.1457	0.08

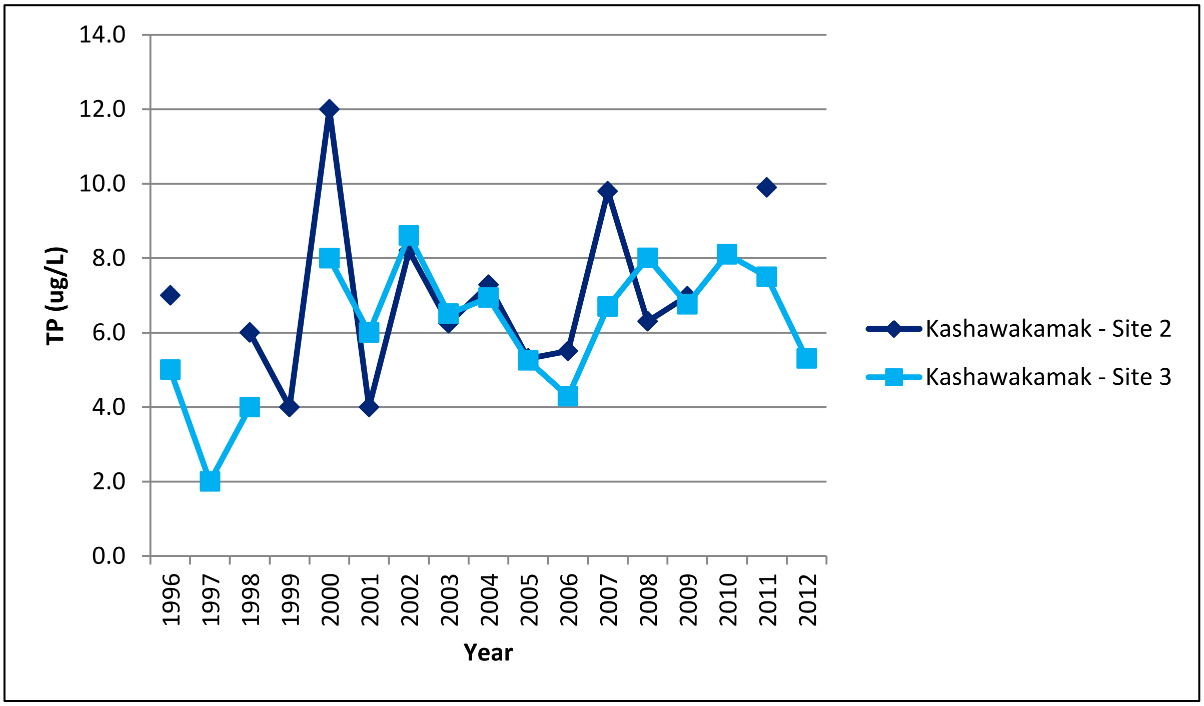

Figure A1. Phosphorus concentrations at Sites 2 and 3 in Kashawakamak Lake.

Mazinaw Lake

Trends were analyzed at Sites 2 and 3 in Mazinaw Lake. According to LPP information, Site 2 is located lower/mid-lake while Site 4 is located in the upper part of the lake in Campbell Bay.

The trends have been plotted in Figure A2. GLS and Mann-Kendall tests were used to assess the trends in phosphorus concentrations at Sites 2 and 3, respectively. Variability was high at both sites as displayed in Figure A2. Site A2 displays a slightly increasing trend that is spurred by the lowest TP concentration recorded in 1996 (2 µg/L) and is not statistically significant (p = 0.9). Site 4 exhibits a slightly declining trend on the other hand, but again, both R^2 and p values highlight the variability in the trend and lack of statistical significance (Table A2).

Table A2. Trend analysis for Sites 2 and 4 in Mazinaw Lake.

Site	n (years)	slope	R^2	p
2	12	0.0212	-0.0545	0.8972
Site	**n (years)**		**M-K tau**	**M-K p**
4	13		-0.079	0.7119

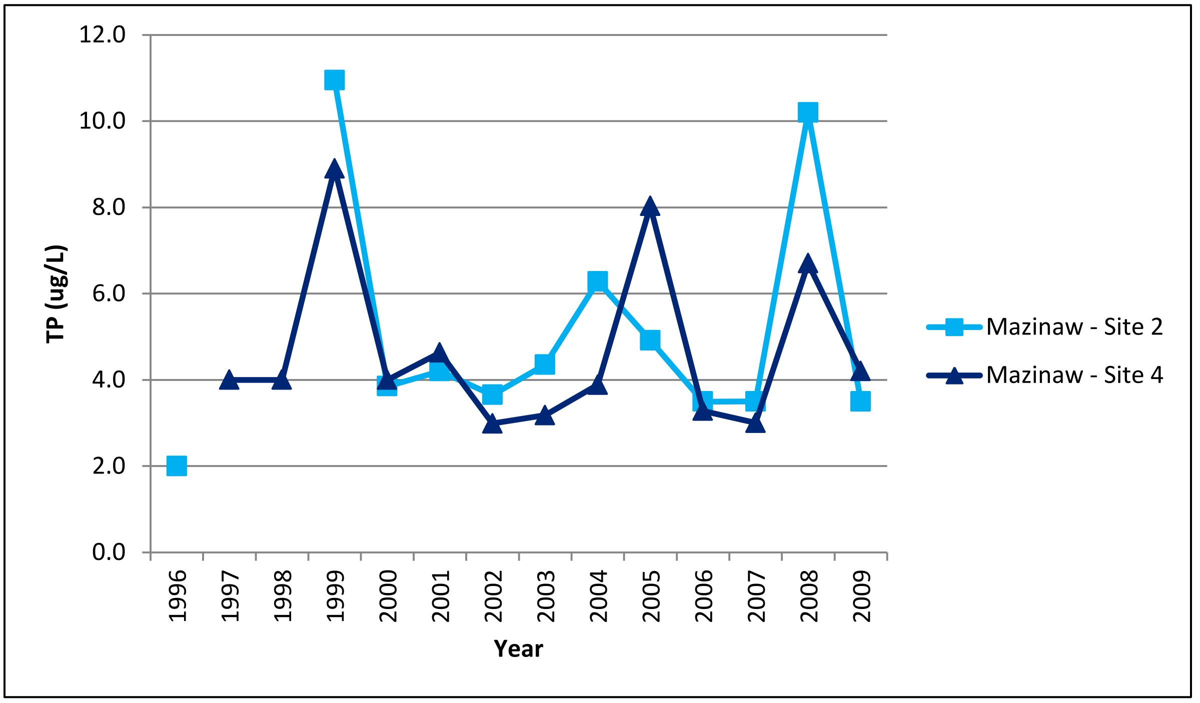

Figure A2. Phosphorus concentrations at Sites 2 and 3 in Mazinaw Lake.

Sharbot Lake

Trends were analyzed from two sites in the western basin of Sharbot Lake: Site 4 which is northeast of Breen Island and Site 5 near the Sharbot Lake Provincial Park. The trends have been plotted in Figure A3. OLS tests were used to assess the trends in phosphorus concentrations at both Sites and results are shown in Table 3.

Variability was high between years, especially at Site 5 where a low finding of TP (2.0 µg/L) in 1998 and high value in 2011 (19.8 µg/L) obscure any obvious trend (Table A3). Both sites display increasing trends in phosphorus but the R^2 values illustrate that the TP concentrations do not fit tightly around the trend line and high p values demonstrate that neither trend is statistically significant.

Table A3. Trend analysis for Sites 4 and 5 in Sharbot Lake.

Site	n (years)	slope	R^2	p
4	11	0.1030	-0.0753	0.5976
5	17	0.1824	0	0.3332

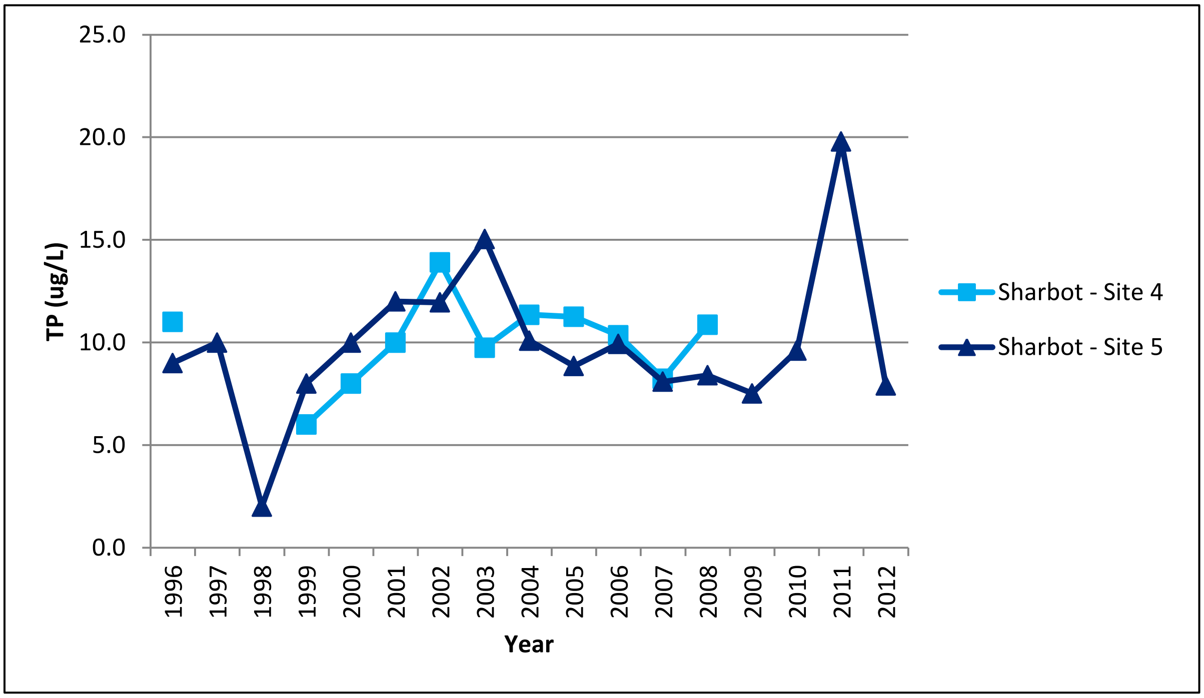

Figure A3. Phosphorus concentrations at Sites 4 and 5 in Sharbot Lake.

Summary

Phosphorus concentrations have increased at five out of the six sites analyzed. Only one site, Kashawakamak – Site 3, contained a p value (0.08) that was near statistical significance, and all sites displayed high variability between years. The trend analysis was not sufficiently thorough to determine that phosphorus concentrations are increasing in these lakes with confidence. In order to increase the confidence in any future assessments, changes should be made to the monitoring program as outlined in Section 2.2 and the trend analysis repeated at 5 year intervals.

Rideau Valley Conservation Authority

Otty Lake

Water samples were collected from Site 1 in the middle of Otty Lake, from 1996 - 2012. Results from the trend analysis are presented in Table A4 while TP concentrations are plotted in Figure A4. Results from the Mann-Kendall test highlight that TP concentrations are declining in Otty Lake, although M-K tau and

M-K p values indicate that the trend is not significant. Year to year variation has improved over the years, especially from 2002-2012 which is the around the time when the LPP introduced field filtering and duplicate sampling.

Table A4. Trend analysis for Site 1 in Otty Lake.

Site	n (years)	M-K tau	M-K p
1	17	-0.171	0.3419

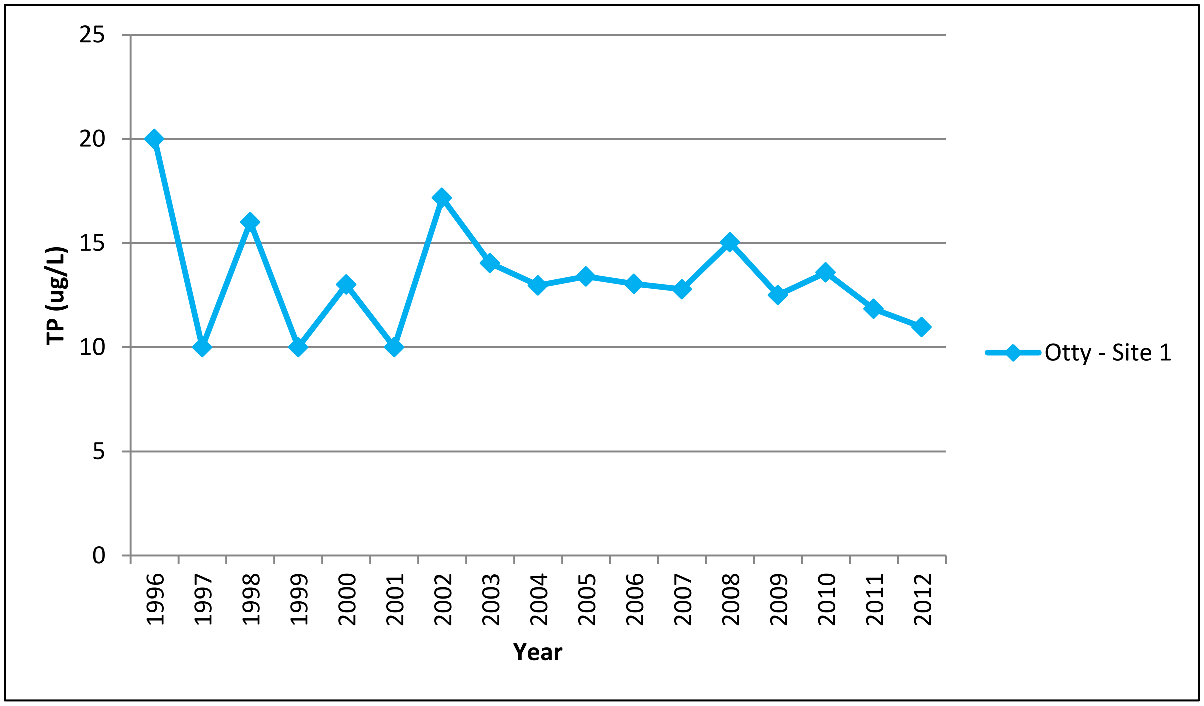

Figure A4. Phosphorus concentrations at Site 1 in Otty Lake.

Upper Rideau Lake

Samples were collected from Sites 1 and 2 in Upper Rideau Lake for greater than ten consecutive years. Site 1 is located in Kanes Bay while Site 2 is in McNally's Bay. Site 1 displayed declining trends with a low coefficient of determination (R^2) and measure of statistical significance (p) through OLS while Site 2 displayed an increasing trend with a higher, albeit still low R^2, and low p value (0.06). Variability between years declined sharply after Lake Partner methodologies improved. In this case it appears that these changes likely outweigh any natural or human-induced changes in TP levels and as a result, the trends should be examined with caution.

Table A5. Trend analysis for Sites 1 and 2 in Upper Rideau Lake.

Site	n (years)	slope	R^2	P
1	16	-0.0697	-0.0625	0.7372
2	15	0.5374	0.1567	0.0579

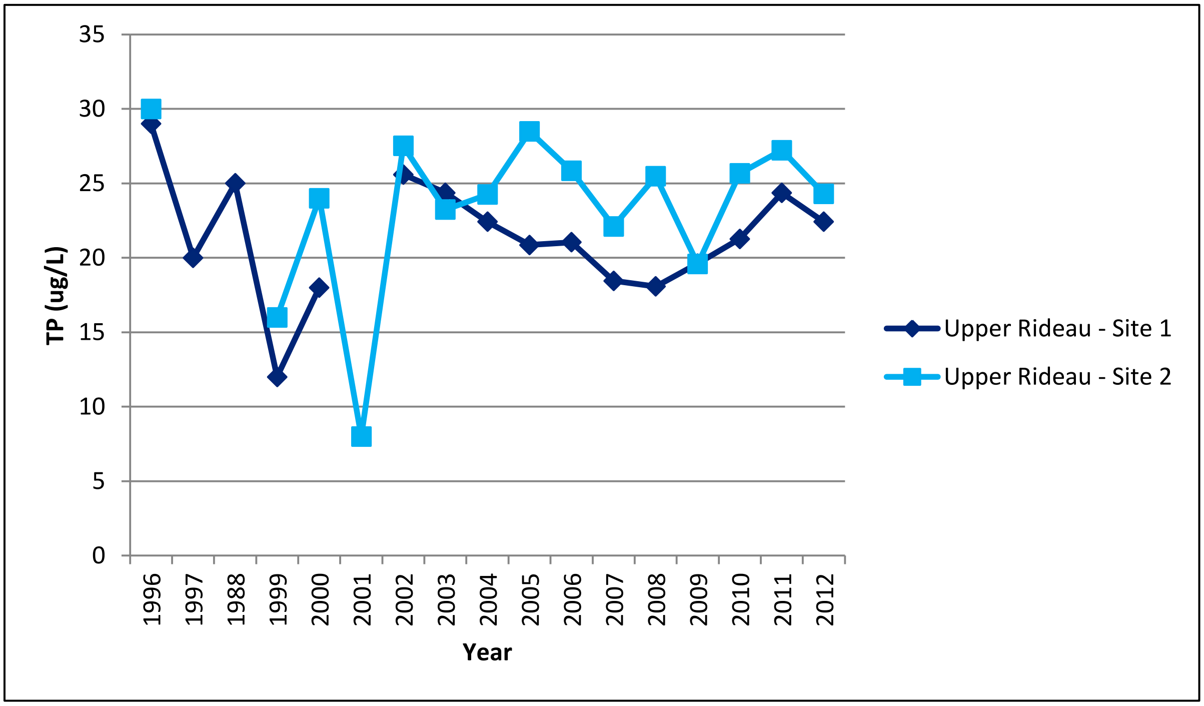

Figure A5. Phosphorus concentrations at Sites 1 and 2 in Upper Rideau Lake.

Summary

Phosphorus concentrations were only assessed at three sites so inferring larger scale trends may not be accurate and additional data is required to prove the trend. It appears that changes to sampling methodology however, have influenced phosphorus trends in these lakes more so than natural or human-induced factors. The trend analysis should be repeated at 5 year intervals.

Cataraqui Region Conservation Authority

Buck Lake

Water samples were collected and analyzed for TP from Site 1 (1996-2012) and Site 3 (1996-2005; Figure A6). Both Sites were assessed through Mann-Kendall trend tests with results presented in Table A6. Phosphorus concentrations are increasing but the coefficients of determination (M-K tau) are very low and p values are high indicating a lack of statistical significance. The increasing trend at Site 3 appears to be driven largely by a single elevated concentration of 19.1 µg/L in 2002.

Table A6. Trend analysis for Sites 1 and 3 in Buck Lake.

Site	n (years)	M-K tau	M-K p
1	17	0.0075	0.967
3	10	0.046	0.8559

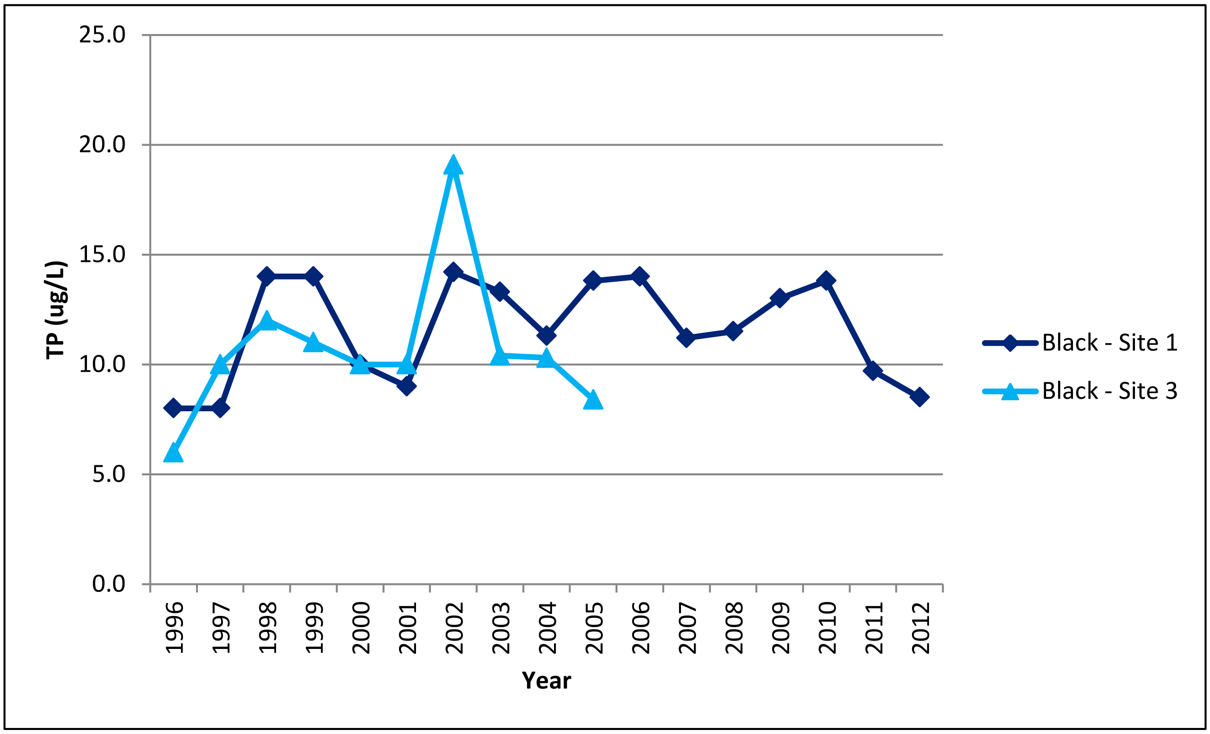

Figure A6. Phosphorus concentrations at Sites 1 and 3 in Buck Lake.

Charleston Lake

Seven sites in Charleston Lake contain TP data from >10 consecutive years. Variability was high between years until the early 2000s when the Lake Partner Program introduced new methodologies to improve the precision of results (Figure A7). Sites were assessed with differing statistical operations to define trends but all results as listed in Table A7, indicate declining TP values. The trends are statistically significant ($p < 0.05$) in six out of seven sites, Site 6 being the exception. R^2 values are also relatively high (close to 1) indicating that the data points fall close to the trend line.

Table A7. Trend analysis for Sites 1 to 7 in Charleston Lake.

Site	n (years)		M-K tau	M-K p
1	16		-0.7342	0.0001
2	13		-0.7949	0
5	17		-0.7602	0
7	13		-0.6929	0.011
	n (years)	**slope**	**R^2**	**p**
3	13	-0.6714	0.88	0
4	13	-0.6055	1	0
6	13	-0.1923	0.1343	0.1189

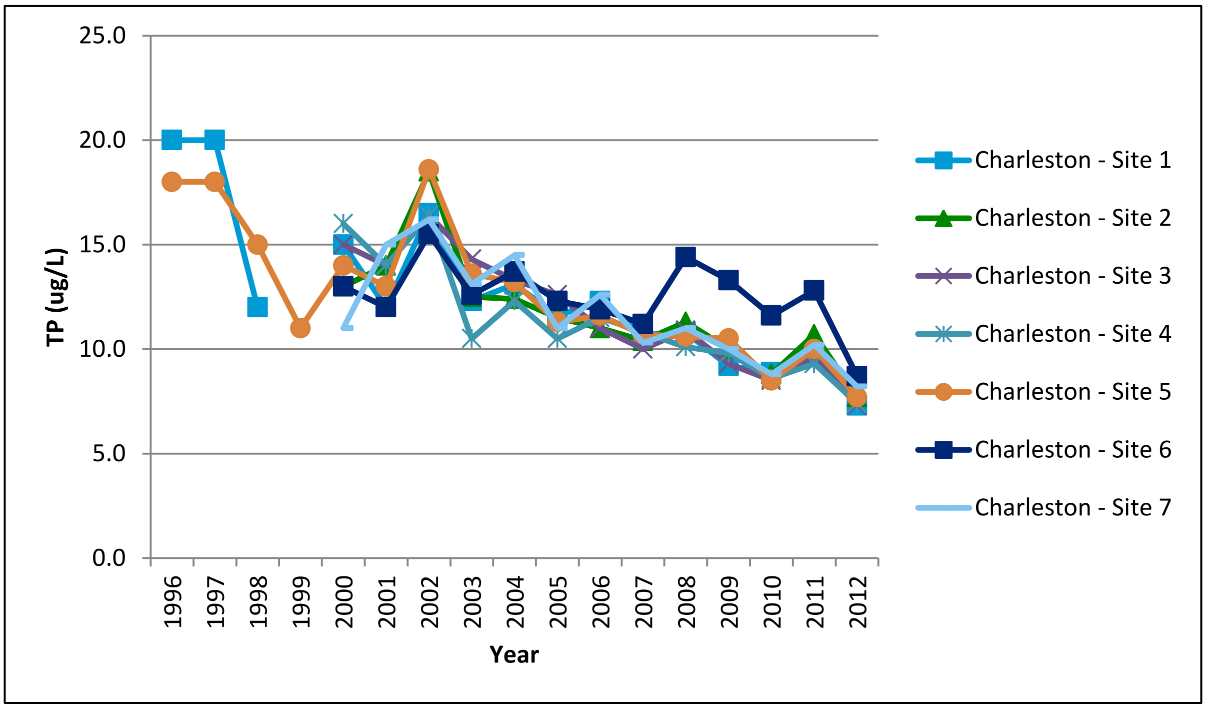

Figure A7. Phosphorus concentrations at Sites 1 through 7 in Charleston Lake.

Indian Lake

Only one site has been monitored in the middle of Indian Lake but it was sampled from 1996 - 2012. Data are plotted in Figure A8 and results from the trend analysis are presented in Table A8. A clear declining trend was produced from OLS which is statistically significant (p=0.01).

Table A8. Trend analysis for Site 1 in Indian Lake.

Site	n (years)	slope	R^2	p
1	17	-0.2007	0.3182	0.0108

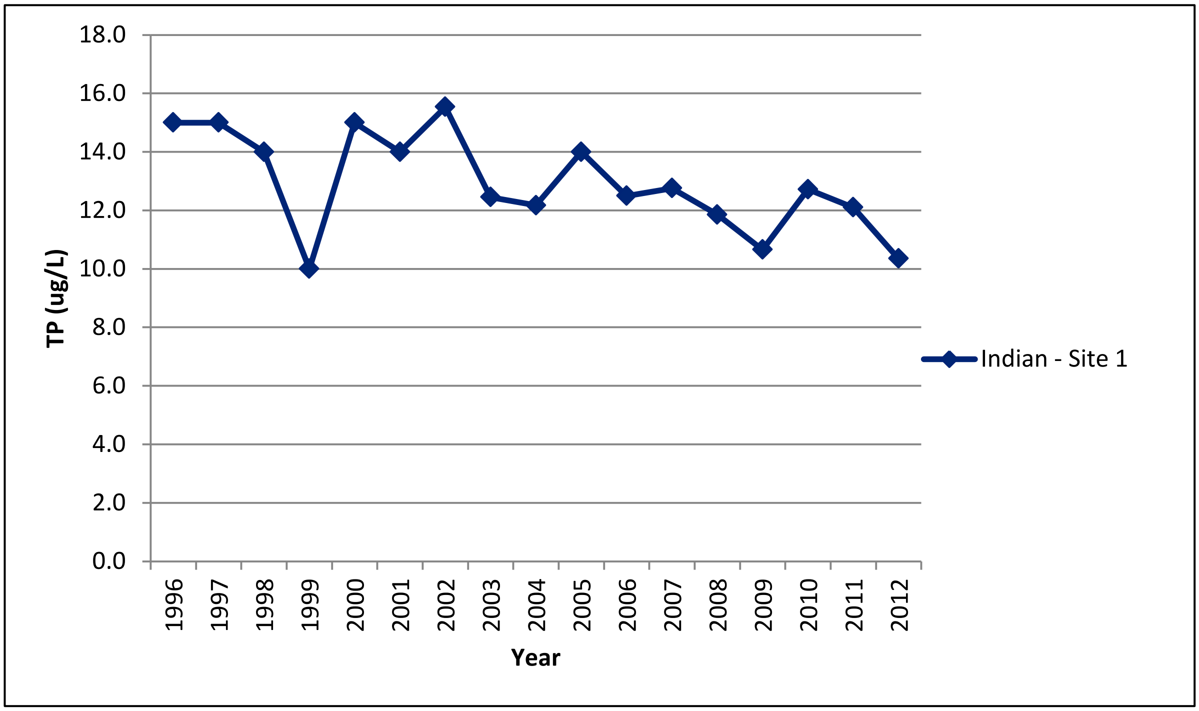

Figure A8. Phosphorus concentrations at Site 1 in Indian Lake.

Loughborough Lake

Water samples were collected at Site 2 in Loughborough Lake from 2000 - 2012. TP concentrations were elevated in 2000 and 2001 before variability decreased from 2002 to 2012 where values ranged between 12 and 24 µg/L. More consistent values from 2002 - 2012 were likely the result of improved sampling methodologies. Elevated values in 2000 and 2001 likely played a large part in fueling the declining trend shown by the results in Table 9 but the trend was not significant (p=0.16).

Table A9. Trend analysis for Site 2 in Loughborough Lake.

Site	n (years)	slope	R^2	p
2	13	-1.3791	0.35	0.1611

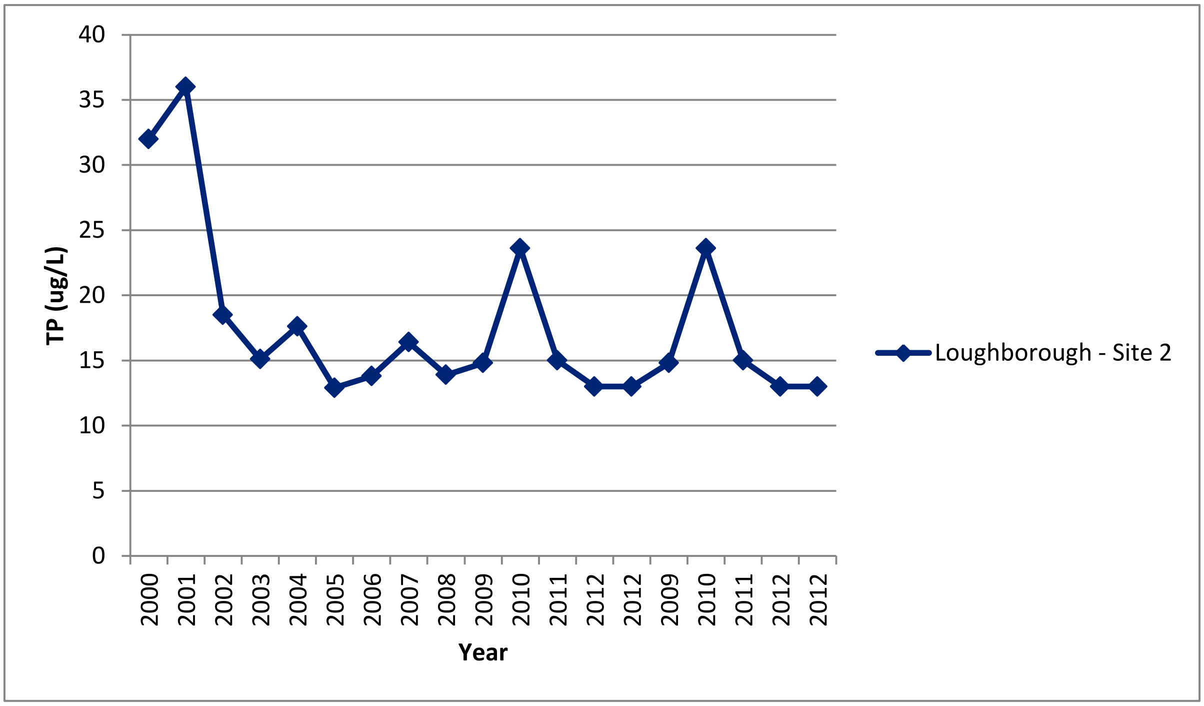

Figure A9. Phosphorus concentrations at Site 2 in Loughborough Lake.

Summary

Some of the CRCA lakes did not contain data from a large number of sites, but all of the lakes assessed contained datasets with reliable TP values measured in consecutive years. Indian, Loughborough and Charleston Lake exhibited declining trends in TP that were often statistically significant. The trends were sometimes exacerbated by elevated values before methodologies improved sampling precision, but after the early 2000s declining trends were still obvious, proving that a trend is occurring. The majority of the lakes and their respective watersheds under question are located on the Precambrian Shield and several lakes on the Canadian Shield in south central Ontario have displayed a decrease in TP concentration over the last decade in the absence of increased human activity in their watersheds, suggesting that this may be a regional scale process (Eimers, 2009; Quinlan et al., 2008; Yan et al., 2008).

Challenges and Limitations of Water Quality Data

Several challenges arose when evaluating water quality conditions in the nine lakes under investigation, namely the consistency in which samples were collected limited the ability to infer trends with confidence. It is important that sites were sampled in consecutive years and from roughly the same time of year so that trend calculations are accurate. Specific challenges with MOE Lake Partner data also included changes which have been made to the sampling program which increased the reliability of data since 2000. In 2000 and thereafter, duplicates were collected which increased sample precision and since 2003 samples have been filtered, decreasing the artificial inflation of TP concentrations because of the inclusion of zooplankton in samples. Nonetheless, we focussed on Lake Partner data and only on sites which contained at least ten years of data collected in consecutive years. Trends were assessed through linear regression models such as Ordinary Least Squares, Generalized Least Squares or non-parametric trend analysis, depending on the status of statistical assumptions. The adoption of consistent and improved methods in the Lake Partner Program means that future data should be increasingly reliable. We recommend that the trend analysis be repeated at 5 year intervals.

Recommended Improvements to Water Quality Monitoring Programs

Water quality monitoring programs can monitor a wide variety of stressors and results can be utilized to limit impacts through comparisons with guideline or background values, calculated lakeshore capacities, or trend analyses. We have suggested some general improvements to the three Conservation Authorities' water quality monitoring programs based on our preliminary review of their water quality data, with a focus on using the data to monitor the impacts of land development through assessment of TP and dissolved oxygen (D.O.). We recognize that these programs operate under tight financial restrictions and have attempted to propose changes that do not raise costs considerably but do provide more applicable information. Lake-specific monitoring should be conducted in addition to the following general improvements to the water quality monitoring programs:

- Collect TP samples at spring overturn. Previous studies conducted by the Dorset Environmental Science Centre have shown that a reliable long-term mean can be derived from 2 - 4 years of spring turnover data (MOE 1998). Spring turnover data also provides a better long-term trend than ice-free volume weighted means, with less effort and associated cost. Where concentrations are > ~12 ug/L then monthly sampling should be adopted as more productive lakes often show seasonality of TP concentrations;

- Coarse filter (80 µm) all TP samples to remove large zooplankton;

- Measure TP and D.O. during the window of 14 days either side of September 1st at the surface and 1 m off bottom to determine the presence of internal phosphorus loading in lakes where such processes could be occurring;

- Reduce the number of sample locations to deep bays where appropriate and increase the number of sites that are sampled in consecutive years; and

- Co-ordinate sampling efforts with the Lake Partner Program.