Kings County Lakeshore Capacity Model
A Review

Final Report

Prepared for

Municipality of the County of Kings

By

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EXECUTIVE SUMMARY

The Kings County Lakeshore Capacity Model

In 1995, Horner and Associates Limited in collaboration with Michael Michalski Associates and Raymond, Walton, Hunter developed the Kings County Lakeshore Capacity Model based on formulations and assumptions of Ontario's Lakeshore Capacity Model. The model, hereafter known as the Kings County Lakeshore Capacity Model (KCLCM), was applied to a chain of lakes in the Gaspereau River drainage basin with the expectation of it being used as a planning tool with the capability of reliably predicting the amount of sustainable development around individual lakes without exceeding target water quality objectives.

Model predictions for springtime total phosphorus and ice-free season $chlorophyll_a$ mean concentration contributed to the establishment of target objectives based on $chlorophyll_a$ to reflect an estimate of dwelling carrying capacity by lake. The KCLCM is a mass balance model which combines various catchment and lake characteristics to estimate or predict in-lake values for phosphorus and chlorophyll a concentration and Secchi depth.

In 1997, water quality objectives based on $chlorophyll_a$ were established for the 18 lakes and ponds in the chain of lakes and the model used to estimate the carry-capacity of each lake using these objectives.

Volunteer Water Quality Monitoring Program

The water quality monitoring program established for Kings County is designed to gather empirical data which can be used to check the accuracy of the Kings County Lakeshore Capacity model predictions. The program is also used to track levels of other constituents such as pH, alkalinity, conductivity and turbidity which can be used to assess the effects of anthropogenic influences (acid precipitation, road de-icing, construction) and colour and dissolved organic carbon which play a role in the biological response of a water body to nutrient loading. The program was initiated in 1997.

Current Water Quality Protection Framework

The current policy framework combines a number of watershed management tools to assist in the management of water quality. These tools range in nature, from site specific tools such as management of vegetation and watercourse setbacks, to broader land management tools such as identifying a maximum number of units in close proximity to the shore and managing the number of subdivisions occurring on a yearly basis. To support the application of these land management tools, the Kings County Lakeshore Capacity Model was also developed to assist in understanding the capacity of key receiving waters to assimilate future and existing development.

Through the review of the policies, meeting minutes, discussions with municipal staff, stakeholders and review of the KCLCM, a number of issues in the relationship between the current framework, model and water quality management best practices have been identified. A summary of the identified issues and concerns is as follows:

- The relationship between policy framework, model, monitoring results and water quality objectives is unclear;
- The technical accuracy of the KCLCM and the Water Quality Monitoring Program results is being questioned;
- The relationship between existing land uses and inputs to the model is unclear;
- The relationship between future lakeshore development capacity and overall watershed management is unclear;
- Staff resources are constrained and the water quality protection framework is putting unnecessary strain on these limited resources ; and,
- There is a lack of in-house scientific expertise required to evaluate model results or provide ongoing analysis.

Recommendations
The study develops recommendations resulting from a review of the current water quality protection framework; this review included the land use policy framework, KCLCM and volunteer monitoring program. This analysis is organized around the major issues identified in the Study Objectives (Appendix A), and other key issues identified over the course of the study. A description of the key study recommendations for the future management of the watershed study area can be found in Section 6.0 of the main report. A summary is provided as follows:

- Replace water quality indicator chlorophyll$_a$ with total phosphorus.
- Up-grade the KCLCM, or adopt the Nova Scotia Phosphorus Model.
- Analytical services at the Environmental Services laboratory should be retained for pH, alkalinity, total nitrogen, color, conductivity, turbidity, dissolved organic carbon.
- Resume chlorophyll$_a$ analysis at the Environmental Services laboratory.
- Secure analytical services for total phosphorus analysis offering a Reportable Detection Limit of 2 ug L^{-1}.
- Provide greater protection of the lands surrounding Hardwood Lake through regulatory controls.
- Change the 350 ft impact/management zone to a 300 m impact/management zone.
- Consider using all existing lots on a lake as the baseline input to the model, as opposed to existing dwellings.
- Eliminate the 'back-lot' LUB requirements and apply the waterfront lot maximum lot coverage requirements and 65 foot waterfront setback to all development within the S1 and S2 Zones.

- Require Site Plan Approval for all development occurring within the S1 and S2 Zones
- Environment Canada’s (2004) tiered approach to the management of phosphorus in freshwater systems should be used as a guidance framework for watershed management.
- Environment Canada’s (2004) 50% above baseline total phosphorus rule should apply.
- Clearly establish the policy procedures to be undertaken once a lake achieves its maximum shoreline development threshold.

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1.0 BACKGROUND

The Municipality of the County of Kings (Kings County) Lakeshore Capacity Model (KCLCM) and County of Kings Municipal Planning Strategy (MPS) Shoreland District (SD) land use policies are focused on the protection of water quality through ongoing sustainable management of land use activities. These policies combine a number of watershed management tools, including the best practices in site design, management of activities in close proximity to the shoreline, and management of activities through planning approval processes. In addition to these tools, the Kings County Lakeshore Capacity Model was also developed to assist in understanding the capacity of key receiving waters to assimilate future and existing development.

In 1997, the Kings County Lakeshore Capacity Model was incorporated by the Municipality of the County of Kings in the Municipal Planning Strategy Policies and Land Use Bylaws to assist in managing development in this area. These MPS policies were the first of their kind to be developed in Nova Scotia and represent a major policy achievement in the protection of water quality and watershed management. The Water Quality Monitoring Program (WQMP) Steering Committee (SC) brings together varied technical and community-based expertise in the management of the program, including Acadia University and the Province of Nova Scotia. This framework represents a substantial accomplishment and useful example of citizen engagement in the maintenance and development of a watershed management policy framework.

While the program ran for the first 10 years with little change to the modelling and policy framework, as the KCLCM and WQMP entered into the 2007 monitoring season, the WQM SC were noting some unusual trends in monitoring results, and were beginning to debate the causes of this discrepancy. The validity of the model was questioned by members of the public in-light of significant differences between predicted and measured total phosphorus and chlorophyll$_a$ concentrations. Concern was also expressed regarding the fact that the model had not been re-examined since its inception in 1997. There were also some concerns developing among Kings County Staff that the level of resources required to maintain the planning framework were unnecessarily onerous. It was determined in 2007 that the policy framework should be amended. The decision to amend these policies was in part a reaction to the ongoing volunteer water quality monitoring program results, and but primarily an attempt to streamline the planning approval process and delineate a clearer relationship between the KCLCM, monitoring results, and the policy framework.

In the 2008 season, the WQM SC met again, and noted continued discrepancy in the monitoring program results. Possible reasons for the discrepancy were noted, and there was continued debate regarding the relationship between the KCLCM, monitoring results, and the policy framework. It was determined at this time that the WQM SC was in favour of an external review of the lake monitoring initiative. The key aim of this external review was to evaluate the KCLCM, recommend changes to the model and monitoring framework, and subsequently improve the land use policy framework (as needed) to more accurately reflect the model and any newly determined changes or proposed water quality objectives.

This report is the result of the 2008 decision to evaluate the KCLCM and associated policy framework.

2.0 PROJECT APPROACH

The objectives of this report, as outlined in the proposal, are included in Appendix A. Reviews of the modelling and volunteer monitoring program are presented in Appendices B and C, respectively. Excerpts from latter two sections have been incorporated into the main body of the report to address several planning, modeling, and water quality monitoring issues that have been identified.

Based on a review of the current planning framework, recommendations for further changes to the Municipal Plan and Land Use Bylaws are proposed. These recommendations are based on the team's current knowledge of best practices for land use and water quality management and the review of the KCLCM.

The existing Municipal Plan, Land Use Bylaws and relevant documents (Meeting Minutes, Staff Reports and Consultant Reports) have been examined in an effort to depict the current relationship between water quality and the planning framework. The 1995 Horner report, the Nova Scotia Phosphorus Model User's Manual, the CCME Guidance Framework for Management of Phosphorus document, and volunteer input assisted in model and WQMP reviews.

The recommendations outlined have resulted from a review of the study team's proposed changes to the model and monitoring framework. They are suggestions that build on the current land use policy framework, strengthening the policies to more accurately reflect the model and proposed water quality objectives. They stem from the team's current knowledge of water quality and watershed management practices, and respond to the issues as noted in the following section.

3.0 CURRENT WATERSHED MANAGEMENT FRAMEWORK

3.1 Key Identified Policy Issues

Through the initial review of the policies, meeting minutes, discussions with municipal staff, stakeholders and review of the KCLCM, a number of issues in the relationship between the current framework and water quality management best practices have been identified. A summary of the identified issues and concerns is as follows:

- The relationship between policy framework, model, monitoring results and water quality objectives is unclear;
- The relationship between existing land uses and inputs to the model is unclear;
- The relationship between future lakeshore development capacity and overall watershed management is unclear;
- Staff resources are constrained and the land use and water quality protection framework is putting unnecessary strain on these limited resources ; and,
- There is a lack of in-house scientific expertise required to evaluate model results or provide ongoing analysis.

3.2 Current Policy Framework

The policy framework combines a number of watershed management tools to assist in the management of water quality. These tools range in nature, from site specific tools such as management of vegetation and watercourse setbacks, to broader land management tools such as identifying a maximum number of units in close proximity to the shore and managing the number of subdivisions occurring on a yearly basis. To support the application of these land management tools, the Kings County Lakeshore Capacity Model was also developed to assist in understanding the capacity of key receiving waters to assimilate future and existing development.

For each of the identified 45 lakes the planning framework sets out a 1000 ft. deep (as setback from the lake shoreline) land use Shoreline Designation. The aim of this designation is to both to enable recreational and cottage oriented development, while at the same time managing this development so that it recognizes the ‘sustainable limits to use’ and protects ‘the integrity of the natural features, process, and wildlife habitats’ (MPS, Section 3.5, page 3.5-1).

The Land Use Bylaw (LUB) also uses regulatory provisions to enforce watershed management, and a wide range of site management tools are enabled. In both the S1 and the S2 Zones the land use bylaw identifies maximum building lot coverage, as well as maximum land disturbance requirements (maximum lot clearance). Lot densities are controlled, with no more than one dwelling on a lot, and a minimum lot size of 50,000 sq ft (slightly larger than 1 acre). A 65 ft shoreline setback requiring minimal vegetation and clearance is also established.

While the 1000 ft Shoreline Designation applies to all 45 lakes, the policy framework differentiates between lakes that have been modeled and those that have not. Approximately 27 lakes have not been modelled, while the remaining 18 lakes have been modelled using the KCLCM. For those lakes that have been modelled, the lands within the 1000 ft Shoreline Designation are zoned primarily Seasonal Residential (S1), with some exceptions where land is zoned Future Shoreline (S2). Lakes that have not been modelled are generally zoned S2. Wetlands within the 1000 ft buffer are zoned Environmental Open Space.

The KCLCM is used in the development of policy aimed at protecting significant water bodies on the South Mountain. Although there are land use policies in place for approximately 45 lakes (MPS, Shoreland District Zoning Schedules 1S-32S), the water quality monitoring program is focused on 18 of these lakes.

The water quality objectives are focused on the 18 lakes that have been modelled. These 18 lakes represent key receiving waters in one watershed, which begins at Lake George and ends at Lumsden Pond. Water quality management objectives have been established for each of the 18 lakes. The key indicator used for the water quality monitoring program is $chlorophyll_a$. In most instances the water quality objective is a $chlorophyll_a$ concentration of 2.5ug/L. However, in some instances the water quality objective is lower than the 2.5 ug/L, particularly for lakes experiencing less development pressure. In other instances, modelling shows that water quality objectives have already been surpassed (Lake Murphy and Lake George). In these cases the stated 2.5 ug/L water quality objective is still maintained, and it is noted that Council will work with residents around these lakes to undertake measures to improve water quality. For the 18 identified lakes, the KCLCM has established maximum residential densities for waterfront development. These are based on the predicted capacity of each receiving water body to maintain the proposed water quality objective.

To apply the water quality objectives to the modelled lakes, the policy framework establishes a 350 ft impact zone (as setback from the shoreline) within those areas zoned S1. Maximum residential densities, as established using the KCLCM, are applied within this 350 ft impact zone. These residential densities represent the number of residential units that can be built along the shoreline before a given lake reaches its carrying capacity, as based on the stated water quality management objectives. These developments are allowed to proceed ‘as-of-right’. Once the development surrounding a lake reaches this maximum density, development may still proceed, but only through site plan approval. Any development outside of the 350 ft setback may proceed as-of-right. In contrast, in the S2 Zone, development adjacent to receiving waters may only proceed by site plan approval, whereas development on a lot without water frontage may proceed ‘as-of-right’. Finally, in all zones, subdivision is managed and only one lot is permitted to be subdivided per area of land, per calendar year.

4.0 KINGS COUNTY LAKESHORE CAPACITY MODEL

The KCLCM was employed in Kings County to assist in developing a better understanding of the potential impacts of human activity (mainly land development) on receiving water quality in key water bodies. The model uses information that describes watershed characteristics, selected hydrologic and morphometric features, and existing and future development to generate predictions of lake total phosphorus and chlorophyll$_a$, an indicator employed to reflect the size of algal populations. Hence, nuisance situations associated with a change in trophic status due to an increase in phosphorus loading can be avoided through the establishment of indicator thresholds for development.

Phosphorus affects aquatic ecosystems by promoting increased growth of algae. As the amount of phosphorus available to the system increases, so does the size of algal populations. The result can be a change in the apparent colour of a lake or stream, resulting in a green or blue-green colour. If the populations of algae become too large, they may cause taste and odour problems for individual or municipal water supplies and can produce toxins that cause gastro-intestinal problems for people and animals. Large algal populations can also clog water intakes, become a nuisance around docks or be a safety hazard for swimmers or boaters, and through the process of decomposition, have the potential to negatively impact fish and fish habitat.

Phosphorus loading models have become an important component of environmental management and land use planning during the past thirty years. Much of the work related to these models is based on the groundbreaking work of Richard Vollenweider Vollenweider 1968, 1976), and others, who analyzed data from around the world to determine relationships among physical, biological and limnological parameters that have led to our present ability to predict the effects of human activities on lake water quality. Based on Vollenweider's work, researchers in Ontario developed the first reliable and easily applicable phosphorus loading model in the early 1970's (Dillon and Rigler 1975). The Dillon and Rigler model gives the researcher or decision maker the ability to easily change a variety of parameters related to actual or possible human activities in a watershed and predict the eventual effect on water quality, specifically total phosphorus and chlorophyll$_a$. Early research by Sakamoto (1966) and others (Dillon and Rigler 1974; Vollenweider and Kerekes 1981), found a relationship between phosphorus and chlorophyll in lakes. Chlorophyll is the primary photosynthetic pigment of photosynthetic organisms and is an indicator of algal biomass and lake productivity. We know that increased phosphorus loading results in an increased phytoplankton standing crop.

In 1995, Horner and Associates Limited in collaboration with Michael Michalski Associates and Raymond, Walton, Hunter adapted Ontario's Lakeshore Capacity Model (LCM) to a chain of lakes in the Gaspereau River drainage basin to be used as a planning tool with the capability of reliably predicting the amount of sustainable development around individual lakes without exceeding target water quality objectives. Model predictions for springtime total phosphorus and ice-free season chlorophyll$_a$ mean concentration contributed to the establishment of target objectives based on chlorophyll$_a$ to reflect an estimate of dwelling carrying capacity by lake. Originally developed and calibrated for Precambrian Shield lakes in Southern Ontario, the LCM was refined in its application to the Kings County lakes. Both the LCM and KCLCM versions are mass balance models which combine various catchment and lake characteristics to estimate or predict in-lake values for phosphorus and chlorophyll a concentration and Secchi depth. The model enables a user to assess the effects of existing land uses as well as the potential water quality impacts of future watershed development. The KCLCM can be used to establish lake capacities for development in order to maintain objective water quality levels and avoid nuisance situations which can be associated with changes in trophic status.

4.1 Kings County Lakeshore Capacity Model Framework Review

This section provides an overview the key recommendations resulting from the review of the current water quality protection framework, which consists primarily of the policy framework, model and volunteer monitoring program. Analysis is organized around the major issues identified in the Study Objectives (Appendix A), and other key issues identified over the course of the study.

4.1.1 Issue 1 – Technical Accuracy: Total Phosphorus/Chlorophyll$_a$ Relationship

One of the primary objectives of this study is to better understand the relationship between the use of cholorphyll$_a$ as an indicator, the model, and the policy framework. Specifically, the Municipality would like to know whether lake water quality should be linked to municipal land use planning by using the lakeshore capacity model as a decision making tool to predict lake carrying capacities based on chlorophyll$_a$ as the main water quality indicator. At the present time, the KCLCM generates predicted values for chlorophyll$_a$ using model predicted springtime total phosphorus concentrations. The accuracy of the estimated chlorophyll$_a$ concentration will, of course, depend on whether the typical trophic relationship between the two variables exists for lakes modeled in the Gaspereau River system. Empirical data collected to date through the volunteer monitoring program indicates that the traditional relationship between the two variables does not exist.

There was no documented methodology found that described the process used to establish water quality objectives for chlorophyll$_a$ in Municipal Planning Strategy and Land Use Bylaw, nor were there records describing the relationship between chlorophyll$_a$ concentrations and total phosphorus concentrations. What is known is that the threshold chlorophyll$_a$ objective was set at 2.5 ug L^{-1}. The threshold, however, was reduced to between 1.7 and 2.4 ug L^{-1} for a number of lakes (Gaspereau, Salmontail, Trout River, Little River, Methals, Dean Chapter, Black River, and Lumsden) to presumably account for the projected distribution of development opportunities mainly due to access. In other words, it is assumed that lake capacity was shifted from one lake to another to provide a more equitable distribution of development opportunities for the more accessible lakes in the drainage system.

The equation used in the KCLCM converting ice-free total phosphorus to chlorophyll$_a$ is based on the premise that a relationship between the two variables exists. For clear water lakes it has been demonstrated that it does (Dillon and Rigler 1975; Kerekes 1980;

Kerekes 1981). The existence of a similar relationship for the Gaspereau River lakes was examined using total phosphorus and chlorophyll$_a$ data contained in the water quality database (1993-2008). Lakes in the dataset include Aylesford, Black River, Gaspereau, George, Hardwood, Little River, Loon, Lumsden, Murphy, Sunken, Trout River, and Tupper. Whereas Sunken Lake was added to the monitoring program in 2007, only eleven lakes were considered in figures illustrating 1993 – 2003 data.

Figures 1 and 2 are log-log plots of maximum ice-free chlorophyll$_a$ concentrations in relation to mean ice-free season total phosphorus concentration. Figure 3 is a log-log plot of mean ice-free season chlorophyll$_a$ and mean ice-free total phosphorus concentrations. Figure 1 considers all empirical data collected from 1993 – 2008, while Figures 2 and 3 use only that data gathered from 1993 - 2003. The 1993 – 2003 dataset covers a period of uniform analytical methodology (i.e., fluorometric chlorophyll$_a$ data only) and during which no suspicious data were reported (i.e., 2004 total phosphorus were excluded from annual reporting because they were considered suspicious). For reference, both figures contain the regression line for the relationship developed for these variables in a group of Organization for Economic Co-operation and Development (OECD) study lakes (Vollenweider and Kerekes 1981a,b).

Based on the plotted data, it appears that the Gaspereau River lakes do not follow the typical trophic response to nutrient loading. Slightly less scatter of the data occurs in Figures 2 and 3, which can be explained by the exclusion of the spectrophotometrically produced chlorophyll$_a$ which were found to be over-estimates relative to that produced by the fluorometric method. Elimination of these data from Figures 2 and 3 place all of the lakes below the OECD regression line. Water color, macrophyte abundance, and zooplankton over-grazing are all known to influence chlorophyll$_a$ production. A direct relationship between the two variables for these lakes cannot be supported by the data available. Kerekes (1990), however, suggested that a quantitative trophic response to total phosphorus may exist for dystrophic water bodies, with the average concentration of chlorophyll$_a$ per unit total phosphorus being less than that observed in clear water systems (Schwinghamer 1975; Kerekes 1981). This association is due in large part to the reduced bio-availability of phosphorus in colored-water (Vollenweider and Kerekes 1981). Until such time that a TP:Chla relationship can be demonstrated for the modeled lakes in Kings County, the use of chlorophyll$_a$ as a trophic indicator in the planning strategy is without empirical validation and should be replaced. Chlorophyll$_a$, however, continues to provide a valuable measure of biological productivity in lakes and should be retained by the volunteer monitoring program as a water quality indicator.

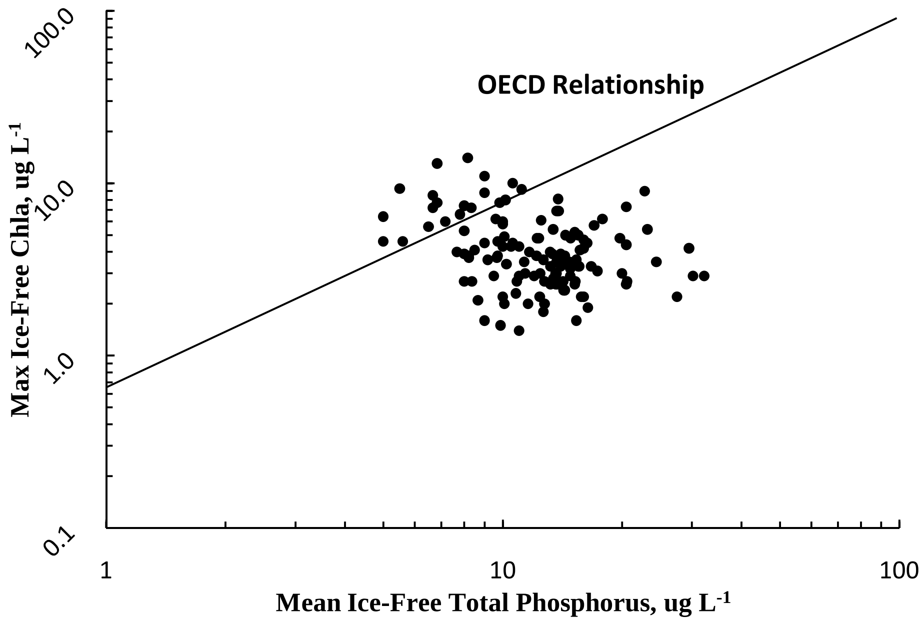


Figure 1. Maximum ice-free chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2008 (12 lakes; n = 126). The OECD regression line for the same relationship is indicated.

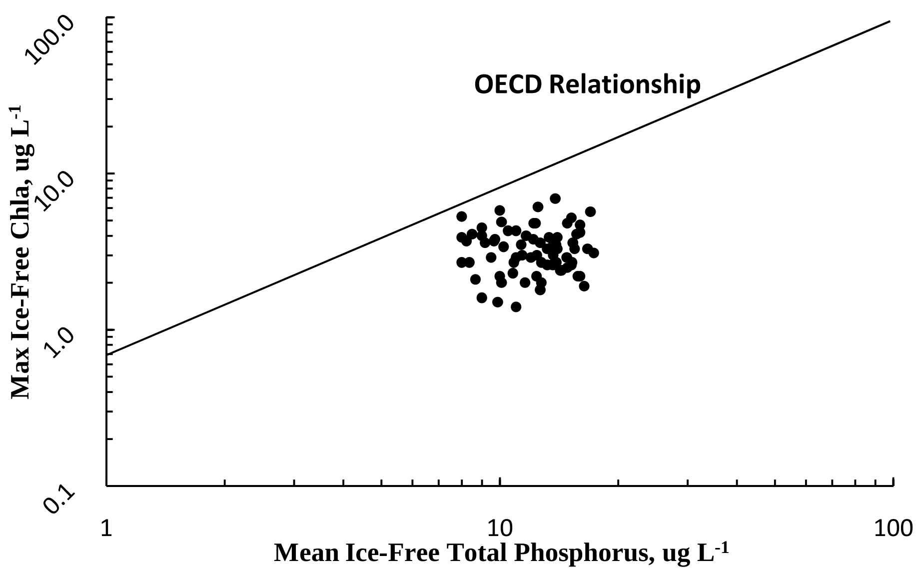


Figure 2. Maximum ice-free chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2003 (11 lakes; n = 72). The OECD regression line for the same relationship is indicated.

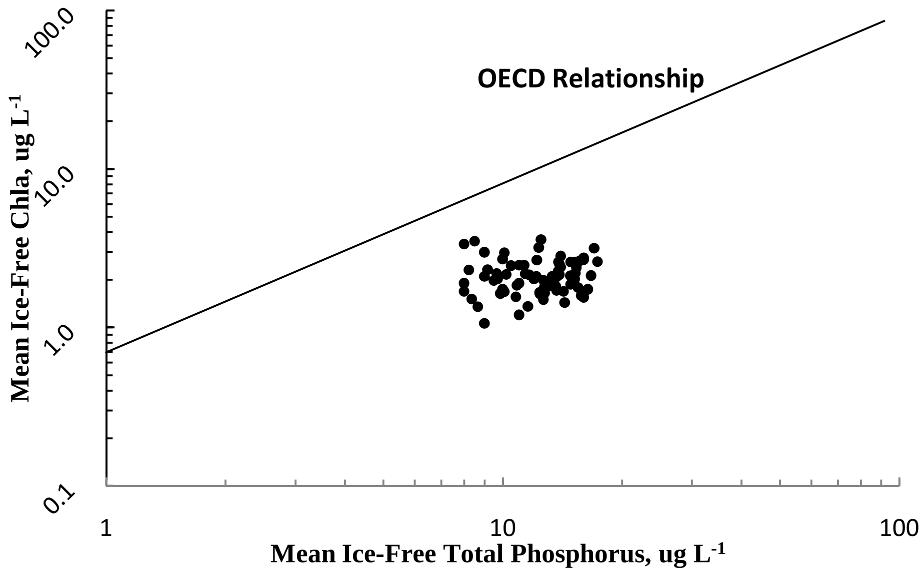


Figure 3. Mean ice-free chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2003 (11 lakes; n = 72).

Similar to the relationship between chlorophyll$_a$ and phosphorus, the nature of the response between phosphorus and overall algae growth is different in dystrophic lakes (coloured) as opposed to clear water lakes. Dystrophic lakes contain high concentrations of dissolved humic substances originating from terrestrial sources i.e. sphagnum bogs. These substances chemically bind phosphates into colloidal complexes which reduces the bioavailability of the phosphorus for algal production. Humic content in clear water lakes, on the other hand, is much lower and the impact on nutrient availability significantly less. The most recent scientific research studying this relationship suggests that dystrophic lakes are able to absorb more phosphorus than clear water lakes, before changes in water quality are detected.

4.1.1.1 Recommendations

The use of chlorophyll$_a$ as a trophic indicator in the planning strategy is without empirical justification and should be replaced. Chlorophyll$_a$ is a response indicator; it typically correlates to phosphorus and phytoplankton growth. However, the typical relationship between phosphorus and chlorophyll does not present itself in the dystrophic lakes. The current KCLCM and Land use framework both rely on the existence of the typical relationship and predicted values of chlorophyll$_a$ from model predicted total phosphorus values. By reverting to phosphorus we will eliminate some of the uncertainty associated with the modelling process. At the same time, although phosphorus is a more accessible indicator, it still does not provide a clear relationship with dystrophic water quality. The relationship between phosphorus and dystrophic water quality is still not clearly understood within the scientific community. Generally, more of the phosphorus present in dystrophic lakes is tied up with dissolved humic substances and unavailable for algal growth. Using baseline trophic indicators as would be found in a clear water lake represents a conservative approach to reconciling this issue. (More discussion about this relationship can be found in Section 4.1.2 and Section 5.0). If Kings County proceeds to use total phosphorus as an indicator, the water quality objectives included in the Municipal Plan and Land Use Bylaw will need to be adjusted to reflect this change. As in the original policy framework, once water quality objectives for phosphorus are set, the model can be run to determine the maximum residential development density for each lake based on phosphorus.

4.1.2 Issse 2 – Technical Accuracy: Continued Use of the KCLCM

The other key objective of this study is to review the KCLCM and determine if the Municipality should continue using the KCLCM or to implement an alternative decision making tool in order to link lake water quality to municipal land use planning. A detailed review of the KCLCM model components is provided in Appendix B. In reviewing the KCLCM a major short-coming of the model is its inability to consider more than one landscape category. It is critical that a variety of landscapes be available in the phosphorus model so that changing and more diverse watersheds can be accommodated.

It has been shown that lakes and streams respond to phosphorus inputs based on the total amount they receive each year (annual loading) which can be predicted by mathematical modeling. The various sources of phosphorus within a watershed can be determined, some of which are natural (precipitation, soils, geology) and some of which are the result of human activities (forest harvesting, agriculture, fertilizer use, wastewater treatment outputs, industries, etc.). The long term condition of a water body or group of interconnected water bodies can thus be predicted. Some of the sources of phosphorus such as on-site wastewater treatment systems can take many years to come into equilibrium with the soil and water system being considered, which is why phosphorus loading models are used to illustrate the eventual potential state of a water body.

An alternative to the KCLCM is the Nova Scotia Phosphorus Model (NSPM), a more recent mass-balance model which is based on formulations and assumptions common to the KCLCM. This model has been developed for use in Nova Scotia and allows a researcher or decision maker greater flexibility (Brylinsky 2004). A common feature of both models is that predictions for total phosphorus represent a whole-lake average concentration, be it springtime or ice-free season (KCLCM) or annual (NSPM).

At the present time, the KCLCM does not allow for more than one landscape type, whereas a newer generation model, the Nova Scotia Phosphorus Model (NSPM), considers several and gives a researcher or decision maker the ability to easily consider different scenarios based on a variety of input parameters related to actual or possible human activities in a watershed and predict the eventual effect on water quality. Land use categories of the NSPM currently include:

- Forested,
- Forested in combination with a minimum of 15% cleared land,
- Residential,

- Commercial,
- Institutional,
- Industrial, and
- Agriculture.

This list can easily be expanded to accommodate other land types.

The Municipality has two model options: continue the use of the KCLCM and make adjustments to allow for a wider variety of landscape inputs, or, change over to the NSPM. Both models are useful management tools that provide valuable guidance to controlling nutrient enrichment from watershed development and ultimately maintaining a desired level of water quality of lakes.

Tasks required before either model can be re-applied or applied for the first time include:

For the KCLCM –
- Revise model format to include a variety of landuse categories,
- Determine area of each existing landuse, and
- Up-date the number of lots within the 300 metre zone with seasonal or permanent dwellings

For the NSPM –
- Determine area of each existing landuse, and
- Determine the number of lots within the 300 metre zone with seasonal or permanent dwellings

Values for many of the NSP model inputs (lake area, precipitation, evaporation, runoff, total phosphorus loading from precipitation) can be taken directly from the KCLCM. The number used in for both models that represents residential lot development should be a combination of the numbers of existing and approved lots. For model calibration, only existing lots should be considered. Contrary to that currently applied in the current model, a settling velocity figure of 12.4 m yr^{-1} should be used (Dillon 2009, pers. com.).

We are assuming that the Municipality has internal GIS expertise as well as access to appropriate landuse mapping. If this is true, under minimal external supervision, it is our opinion that neither model option would require a significant amount of effort or cost.

With this being said, the Municipality may still wish to consider whether or not lakeshore capacity modeling is an appropriate tool for this particular watershed. While the value of the NSPM as a tool in assessing development capacity and protecting water quality in clear water lakes is scientifically evident, it is less clear in the case of dystrophic lakes, because the relationship between phosphorus and water quality is still not fully understood scientifically.

Generally, the most recent scientific research studying this relationship suggests that dystrophic lakes are able to absorb more phosphorus than clear water lakes, before changes in water quality are detected. Therefore, by using standard phosphorus water quality objectives that would be applied in clear water quality lakes in these dystrophic lakes, the municipality is applying a more stringent or conservative water quality objective (since it would typically take more phosphorus to produce the same change in water quality in a dystrophic lake). Using phosphorus as an indicator therefore would likely still positively contribute to the protection of water quality in this watershed.

Volunteer monitoring programs like that currently in operation, are intended to gather information that is used to track temporal changes in water quality, information which is extremely valuable and can help the municipality to track water quality over time. However, these programs are not capable of predicting the effects of anthropogenic activity on water quality, knowledge that is essential to avoid adverse aquatic effects. Once a monitoring program detects significant change in water quality, the full effects of this change may not be felt until fifteen or twenty years down the road, since the impacts are cumulative over time. The Municipality's goal of sustaining a desired level of water quality in its lakes requires a means of establishing individual lake capacities to which levels of development can be measured. Once validated, either of the phosphorus loading models mentioned is able to predict a reasonably accurate estimate of lake phosphorus concentration given a change is phosphorus loading.

Although the dystrophic lakes of the Gaspereau River drainage system appear to deviate from the phosphorus:chlorophyll$_a$ relationship upon which the trophic classification of lakes is based, it is our opinion that abandoning the use of either of these models because of this would eliminate the only means of gauging the potential effects on water quality due to shoreline development over the long term. This being said, more consideration needs to be given to how the land use planning framework relates to the model predictions, including how water quality objectives are set , and subsequently what actions are taken once a given lake reaches a water quality objective. This is discussed in greater detail in Section 5.0.

4.1.2.1 Recommendations

The Municipality should either make landuse formatting revisions to the KCLCM or consider adopting the NSPM.

4.1.3 Issue 3 – Technical Accuracy: Reliability of Total Phosphorus Empirical Data

Another concern resulting from the variations in the results from the water quality monitoring program is that the data wasn't accurate. In his interpretation of observed data, Brylinsky (2004, 2008) noted that anomalies existed with the total phosphorus data which were not explainable. In particular, information generated in 2004 was abnormally high relative to other years and differences between concentrations for some duplicate samples were large. With the change in labs at the end of 2004 the levels of phosphorus and month to month variability in the data were reduced. It is inevitable that these anomalies will cast uncertainty on the reliability of the total phosphorus database as a whole. For example, in other studies involving similar sized lakes exposed to similar levels of development pressure, mean total phosphorus concentrations for ice-free period over a nine-year period for one Ontario lake ranged from 6.05 to 7.21 ug L^{-1}, a fluctuation of slightly more than 1 ug L^{-1} (Hutchinson et al., 1991). Locally, the difference between minimum and maximum mean annual total phosphorus concentrations recorded for four lakes in the Halifax area over a ten-year period was < 3 ug L^{-1} (CWRS 2009b). The variation observed in the Kings County lakes over its eleven-year monitoring period, excluding 2004 data, was much higher at between 8 and 12 ug L^{-1}.

Water sample collection and handling and laboratory techniques are two major factors which can affect a true measure of a water quality parameter. Field blank measurements taken during the monitoring efforts indicate that the integrity of the water samples submitted for testing is not being compromised by sample collection and handling procedures employed by the volunteer program. With the exception of a few occasions, results for duplicate water samples do not indicate any influence attributable from lab handling or processing. However, the extreme fluctuation in month-to-month phosphorus concentrations, coupled with the findings of the Ontario and Halifax studies referenced previously, suggests that the QEII lab results may not be entirely accurate. Although more realistic trends in phosphorus levels are now being reflected in data produced by the Fredericton lab, the level of detection at this lab is not considered to be adequate.

4.1.3.1 Recommendations

At the start of the monitoring program in 1997, analytical services employed were expected to provide a reliable set of data which could be used to validate the KCLCM. Over time, irregularities in the dataset reduced confidence levels to a point where the reliability of the data was questioned. Reporting differences were discovered between analytical methods that explained the observed shift in $chlorophyll_a$ concentrations. The variability in monthly and annual mean total phosphorus concentrations recorded for the Kings County lakes was assumed to be normal, but appeared to be somewhat abnormal when compared with other similar lakes. Several potential reasons contributing to the anomalies were suggested, including analytical error, analytical methodology, and method reporting detection limits.

In an effort to eliminate the sort of irregularities experienced in the Kings County dataset for total phosphorus and to enhance reporting limits, it is recommended that analytical services for total phosphorus analysis be moved from the current lab in Fredericton to one which offers a lower reportable detection limit. The purpose of the move is to secure the analytical service best suited for the needs of the monitoring program.

The analytical methods recommended by this review and the labs involved are, when in combination, believed capable of generating a more consistent and reliable data record for total phosphorus and $chlorophyll_a$ over the long term.

It is also recommended that water quality data for these two variables recorded during the 2009 water sampling season be reviewed as part of the annual reporting process, specifically as they relate to historical measurements.

Further recommendations for procedures of the volunteer water quality monitoring program are included in Appendix C.

4.1.4 Issue 4 – Relationship between land use policy and the model – Control Lake

Over the course of the review, the study team noted that Hardwood Lake has been identified as the original study ‘control lake’ and serves as a baseline for model calibration. However, lands surrounding Hardwood Lake have been zoned S2, which still allows for significant development within close proximity to the lake that may impact future water quality.

This is of concern, since control lakes are usually lakes void of human influence. Because human activity is limited around a control lake, they can then be used for model calibration because phosphorus inputs are limited to natural sources. Inputs such as typically associated with development, such as contributions from urban drainage, point sources, or from on-site septic systems are therefore excluded. When considering only the natural phosphorus supply, it is possible to quantify basic lake processes and to estimate an ‘undeveloped’ phosphorus concentration for a lake. This is an important management benchmark for evaluating the potential impact of development on lake water quality (Hutchinson et al. 1991; Hutchinson 2002).

4.1.4.1 Recommendations

The Municipality should consider protecting portions of the shoreline around Hardwood Lake through more restrictive regulatory controls. The Open Space Designation has already been identified as a key zone that may be used in managing land use within this watershed, and this zone can been employed to provide more protective controls around this particular lake.

4.1.5 Issue 5 - Relationship between land use policy and the model: 300m Impact/Management Zone

Over the course of the review, the study team noted some discrepancies between the assumptions built into the model and the land use management framework. To apply the water quality objectives to the modelled lakes, the policy framework establishes a 350 ft impact zone (as setback from the shoreline) within those areas zoned S1. Maximum residential densities, as established using the KCLCM, are applied within this 350 ft impact zone. These residential densities represent the number of residential units that can be built along the shoreline before a given lake reaches its carrying capacity, as based on the stated water quality management objectives. A significant land use factor contributing to increased phosphorus loading is the number of septic systems within close proximity to a receiving water body. Once a lake achieves a maximum residential density, all subsequent development is required to proceed via the site plan approval process.

There has been significant discussion regarding the amount of septic system phosphorus which ultimately reaches a water body. The KCLCM takes a conservative approach and assumes that 100 percent of the phosphorus in septic systems situated within 300 metres of a lake or tributary receiving water will eventually contribute to the phosphorus load for that lake. Research suggests that between 26 and in excess of 90 percent of the septic phosphorus load may be immobilized (Robertson et al. 1998; Dillon et al. 1994; Wood 1993; Hart et al. 1978).

The 300 m impact zone was first introduced by Dillon and Rigler (1975) and Dillon et al. (1986), a modelling feature carried forward by many modelers ever since. Although this figure is convenient for modelling purposes, it is technically indefensible given our current knowledge. A more realistic tiered approach proposed by France (2002), itself arbitrary, attempts to incorporate the effects of soil attenuation into the modelling process. We are not aware of any location within Canada that has tested this approach, but the Kings County situation offers a unique opportunity to do so. Instead of assuming that all septic systems within the 300 m zone at some point in time contribute 100 percent of its total phosphorus load to a lake or tributary stream, the France approach would assume that septic systems within 100 metres of a lake or tributary receiving water would contribute 100 percent; between 100 and 200 metres 67 percent; and between 200 and 300 metres 33 percent. Those systems beyond 300 metres would contribute 0 percent. Ranking phosphorus loading in this manner would replace the current approach where systems located 300 metres away from a lake would contribute 100 percent of its phosphorus while a system situated 1 metre further away would have zero impact. After reviewing the modelling work conducted by the County using the KCLCM, it is unclear, but assumed, that the maximum distance used to delineate the septic tank impact zone was 300m. Up until now, 300 m has been used for modelling in Nova Scotia. Maximum carrying capacities in Section 3.5 of the Municipal Planning Strategy are based on a distance of 107 m (350 feet) from a lake. Whatever the distance, it should be the same for both the model and management applications to remain consistent.

Upon review of the KCLCM background material provided to the consulting team, there is no clear link between the model and this 350 ft shoreline setback. As discussed above, typically, a model would reflect a zone of impact as large as 300m and a 300 m impact zone is a standard feature of most models. In order to clearly link the influences of existing land use and model predictions it is suggested that the 350 ft setback be changed to show a setback of 300 m. Creating this clear link between the regulation of land use policy and the model will help Kings County in understanding the accuracy of the model predictions, and further refining land use inputs over the long-term.

Following from this, one of the key issues highlighted as part of the 2007 amendments to the water quality protection policy framework identified that the Shoreline District policies did not ‘explain how to count the number of dwellings around a lake to determine if lakes that are assigned a carrying capacity have reached their maximum limit’. Therefore, it was impossible to understand what counted as ‘existing development’ contributing towards carrying capacity and what could be considered new development. The amendments suggested that all dwellings within the S1, S2 and O1 Zones be counted towards that lake’s assigned maximum limit. While this does more clearly delineate what is considered existing development, this definition should also be more clearly linked back to the model. Again, the model input variable that is linked existing dwellings in the number of on-site disposal systems within 300m of a lake or tributary stream.

4.1.5.1 Recommendations

It is recommended that if the Municipality adopts the NSPM, that the policy framework be changed to reflect that all existing lots within 300 m of the receiving waters are key 'inputs' and potential impacts to receiving water quality (existing lots will either house an on-site septic system at the present time, or have this development right afforded to them under the land use bylaw/provincial regulations).

Therefore, the existing residential land input to the model would include all existing lots within 300 m of the lake. Lots that cross the S1/S2 boundary would also be counted. If the Municipality uses this as the model 'input' then it becomes easier to count the contribution of new development; any new lot created would count towards the maximum density. While this is a more conservative approach than the current approach, it does more accurately reflect the development rights that are currently afforded to individuals under the MPS and LUB, and demonstrates the current potential impact to water quality. Given that some lakes have already reached their maximum densities, this may mean that more lakes will have reached their predicted threshold.

In addition to this, the project team would recommend that the Municipality eliminate the 'back-lot' LUB requirements and apply the waterfront lot maximum lot coverage requirements and 65 foot waterfront setback to all development within the S1 and S2 Zones. While the S1 and S2 Zones both differentiate between Waterfront Lots and Back-Lots, there is no definition in the MPS Policy or LUB for 'Back-Lots', and it is assumed this means lots that do not have waterfront access. Upon review of the S1 and S2 requirements, there is little difference between the lot requirements for back-lots and waterfront lots. Key differences are the maximum lot coverage, and the rear yard and boathouse setback from the shoreline.

The noted differentiation between back-lots and waterfront lots is unnecessary from a watershed management perspective. If a lot is located within 300m of the shoreline or tributary stream, (essentially the full extent of the S1 and S2 zones) it is viewed as a lot contributing to water quality. Therefore, it is advantageous to apply the more stringent waterfront lot coverage requirements to all lots falling in the S1 or S2 zone, regardless of whether or not they access the shoreline. Further, it is possible to have a lot pattern where a lot may not have direct water frontage, but it may still be within 65 feet of the waterfront. Therefore, it is also advantageous to apply the 65 foot setback to all buildings falling in the S1 or S2 Zone. These changes will also simplify the regulatory management of these zones, and contribute to streamlining the staff review process. It will also more accurately reflect current best management practices and the relationship between development and receiving water quality.

Finally, the 2007 amendments to the policy framework incorporated the use of the site plan approval process. This was introduced in an effort to streamline the process, and to eliminate the need for development agreements, which were viewed as time-consuming and expensive. While the study team believes that this was a reasonable step in creating a more manageable policy framework, the current framework only requires site plan approval when a lake has reached the maximum residential density requirements.

It is proposed that all development in the watershed needs to be managed, and in particular development occurring within 300 m of a receiving water's edge. The site plan approval process is a valuable tool that can assist the municipality in influencing environmental site design, and educate residents about watershed and water quality protection and lot level controls. Regardless of whether or not the municipality proceeds with the KCLCM, NSPM or no model at all, it is suggested that the site plan approval process be extended to any new development occurring within the S1 and S2 zones (which represent all lands within 300m of the water's edge). This will assist in streamlining the approval process, as there is no further need to distinguish between which lots are already counted or not counted; all new development occurring in the S1 or S2 zones would require the Site Plan Approval process. It is not expected that this will place undue strain on the development/site plan approval and permitting process; in the S1 and S2 zones during the years 1998-2007, there were on average approximately 20 development permits per year (13 new development and 7 additions to existing residences).

4.1.6 Issue 6 - Relationship between the land use policy framework and overall watershed management: Watershed Landscape

Developing a greater understanding of the relationship between the receiving waters and watershed landscape may help to remedy potential future water quality issues. This being said, the project team would encourage the Municipality to develop a stronger link between the overall watershed and the management of land use. The KCLCM and NSPM consider all lands in the watershed as contributors to watershed and receiving water health, however in the current policy framework the link between the policies and overall watershed management is not clear. At the present time the Land Use Bylaw breaks out Schedules that depict individual lakes or groups of lakes. The relationship between the watersheds and the lakes included in the policy framework is not mapped or discussed. While development within the 300m zone is managed, the remaining lands in the watershed are permitted to continue to develop, as-of-right. These land are primarily zoned Forestry, although a significant portion of land around Gaspereau Lake, Trout River Pond and Murphy Lake is zoned Country Residential. There are a few other areas covered by Isolated Zones, and McGee Lake is protected with water supply zoning.

Once the Municipality refines the model and existing framework, it should become a future policy objective to further enhance the relationship between the model, water quality management and overall watershed health.

4.1.6.1 Recommendations

We recommend that the municipality include mapping delineating the Lake George to Lumsden Pond Watershed. At minimum, a map showing the full extent of the watersheds and the receiving waters involved should be provided. This could be as simple as delineating the watershed boundaries on the overall Kings County Zoning map and referencing it in the Shoreland District policies. This will help in strengthening the policy to reflect the relationship between receiving water quality and the overall health of the watershed. The mapping can also be used to educate individuals regarding the cumulative effects of water quality and the extent of the receiving waters modelled in the KCLCM (or NSPM).

Within the watershed, the municipality may wish to consider the application of watershed management controls in these all of the watershed, not just the 300m impact zone. For example, if large-scale residential development were to occur in the lands surrounding and draining to Murphy Lake, this could result in changes to water quality not considered by the modelling predictions. Lot level controls may help to minimize those impacts, or if it is required the water quality impacts be considered as part of the development process, the Municipality may be able to work with the developer to mitigate potential impacts.

4.1.7 Issue 7 - Relationship between the land use policy framework and overall watershed management: Ongoing Monitoring of Water Quality Protection Framework

While the model was developed over 10 years ago, loss of technical knowledge resulting from staff changes and a lack of in-house expertise are contributing to frustration with the current policy framework. The KCLCM, or NSPM if adopted, should not be viewed as a static land use management tool. Models are continually being refined, and as the municipality continues to gather water quality data, there may be further changes to the model required. As the relationship between dystrophic lakes and traditional water quality indicators such as phosphorus and $chlorophyll_a$ is better understood, it may be that more accuracy can be models to produce more relevant water quality objectives and land use management framework.

4.1.7.1 Recommendations

At a minimum, Kings County should be reviewing the existing policy framework and KCLCM (or NSPM) every five years, at which time any concerns or discrepancies in the modelling and land use framework can be assessed. The model can also be a valuable tool in assessing land use patterns and potential future development, and if large-scale development is proposed within the Lake George to Lumsden Pond watershed, the municipality may wish to consider using a receiving water capacity model to assess receiving water capacity to assimilate this new development.

5.0 NEXT STEPS

Phosphorus export coefficient modelling in Nova Scotia has evolved considerably since it was first introduced in the mid-1970's. Even though this approach has some limitations with respect to some lakes in Nova Scotia, such as the dystrophic lakes in Kings County, this strategy to watershed management is popular among planners. Improvements to the application of such models have resulted from export coefficient research based on Nova Scotia climatological and geological regimes and land use types. Further enhancements to the model's spreadsheet format have led to the development of the Nova Scotia Phosphorus Model (Brylinsky 2004).

The Nova Scotia Phosphorus Model is supported by a users' manual that provides a step-by-step procedure for model application. The manual also contains information on basic limnological concepts and model formulations to enhance a readers' appreciation of the modelling technique. Briefly, application of this model requires the following information:

- lake surface area,
- watershed area (land only),
- number of lots, both existing and approved serviced by on-site septic systems within 300m of the water body or tributary stream,
- breakdown of watershed into various landuse categories,
- lake volume,
- precipitation, lake evaporation, and runoff amounts,
- rate of atmospheric phosphorus deposition,
- rate of overland phosphorus export, and
- number of persons per household serviced by septic systems.

Application of any model to a lake or lake system must be supported by a monitoring program in order to assess the accuracy of its predictions and to track changes in water quality. The design of the program must strike a balance between sampling logistics, accuracy, and cost. The Kings County volunteer water quality monitoring program contains the basic elements of what is required. The selection of monitoring sites and water sampling depths, however, may not be sufficient for the deeper lakes and those with irregular basin shapes in the study group. For these and similar lakes, composite water samples should be made up of water collected from several depths through the entire water column.

Water quality thresholds are typically set according to what is considered "acceptable". Depending on the end-use of a water body, the definition of "acceptable" may vary. For example, phosphorus limits associated with a recreational water use classification are mainly related to aesthetics, and would likely differ than those necessary to sustain a cold-water fishery. Also, the public's perception of acceptable water quality for various recreational activities is subjective and can translate into varying degrees of tolerable degradation in water quality. Adoption of Environment Canada's (2004) tiered approach to the management of phosphorus in lakes would eliminate this subjectivity and provide managers and planners a mechanism by which to achieve established goals and objectives.

5.1 Water Quality Objectives

The CCME Water Quality Index (WQI) is an approach that considers a number of environmental parameters (mostly chemical), to derive a relative index of water quality on a scale of values ranging typically from 0-100, but could be considered on a scale that was from "good" to "bad". The WQI has been used in British Columbia and Alberta to provide an overview of water quality in a number of river basins.

While the WQI is a valuable tool for giving decision makers or the public an easy to understand overview of environmental conditions in a number of similar environments (i.e. the major river basins in a province, or the lakes in a region) that might be quite valuable in a state of the environment report, for instance, it is not a predictive tool. The value of the modelling approach represented by the KCLCM is that it should help resource managers avoid problems by limiting the inputs of phosphorus from human activities and natural processes (i.e. by limiting the number of households in a watershed). To date the WQI has been used to report on present or past conditions, not to predict future consequences.

As presently applied, the WQI depends on a much larger number of parameters than those reported by researchers in Kings County. Alberta, for instance, calculates a WQI based on four sub indices: metal ions (major ions, heavy metals); eutrophication indicators (Total P, NO_2-N, NH_4-N, TN, pH, Dissolved Oxygen); pesticides; and bacterial indicators. All of these data are used to calculate a single index that can then be used to compare different locations or environmental systems.

In the context of King's County, the data to compute a WQI similar to that used in Alberta do not appear to exist, and one must question what value such an index would bring to the planning process, except to show how well, or how poorly, environmental resources are being managed over time.

In the absence of an empirically defensible means of associating deterioration in water quality based on concentrations of $chlorophyll_a$, an alternative management tool for the protection of lake water quality in Kings County is needed. Environment Canada's (2004) tiered approach to the management of phosphorus in freshwater systems offers a guidance framework for watershed managers and planners to achieve goals and objectives established for specific surface water resources. In Kings County, for example, protection of water quality is seen as paramount, as reflected in steps taken by the Municipality to this point in the management of surface water resources. Depending on the goal, a trigger range associated with a trophic level (Table 4), or a reference value which is 50% above the natural or baseline phosphorus concentration of a lake is established. The purpose of these triggers is to indicate when there is risk of an impact to water quality. In Kings County, $chlorophyll_a$ presently serves as its water quality indicator and an oligotrophic "trigger limit" has been set at 2.5 ug L^{-1}. Classic OECD trophic levels and corresponding indicator concentrations and transparency for total phosphorus, $chlorophyll_a$ and Secchi depth are provided in Table 3 (Vollenweider and Kerekes 1982).

Depending on which empirical total phosphorus data set is considered (1993-2003 QEII data, 2005-08 Fredericton data, or 1993-2008 all data), the majority of monitored Gaspereau River lakes are currently at or above the OECD oligotrophic threshold of 10 ug L^{-1} and would be mesotrophic, a trophic classification which should be supported by $chlorophyll_a$ data. Given the inconsistency of the lab methodologies use to generate these data, a similar comparison based on the OECD oligotrophic threshold of 2.5 ug L^{-1} for $chlorophyll_a$ would be less meaningful. However, for the sake of argument, if only the favoured fluorometric $chlorophyll_a$ data is examined, the results indicate that the majority of monitored lakes are below the 2.5 ug L^{-1} threshold placing them in the oligotrophic category. If the main objective of the Municipality in setting its limit was to maintain an oligotrophic trophic status, and if for example its lakes were clear water lakes, then the same intended goal could be achieved if a 10 ug L^{-1} limit for total phosphorus was adopted.

Table 3. Trophic classification of lakes and corresponding indicator concentrations and transparency (from Environment Canada 2004).

Trophic Level	**Total Phosphorus ug L^{-1}**	**Chlorophylla ug L^{-1}**		**Secchi Depth m**	
		Mean	**Max**	**Mean**	**Max**
Ultra-oligotrophic	<4	<1	<2.5	>12	>6
Oligo-Mesotrophic	4 – 10	<2.5	<8	>6	>3
Meso-eutrophic	10 –35	2.5 – 8	8 – 25	6 – 3	3 – 1.5
Eutrophic	35 – 100	8 - 25	27 – 75	3 – 1.5	1.5 – 0.7
Hypereutrophic	>100	>25	>75	<1.5	<0.7

Table 4. Total phosphorus trigger ranges for various trophic categories of lakes (Environment Canada 2004).

Trophic Level	**Trigger Ranges for TP, ug L^{-1}**
Ultra-oligotrophic	<4
Oligotrophic	4 – 10
Mesotrophic	10 – 20
Meso-eutrophic	20 – 35
Eutrophic	35 – 100
Hypereutrophic	>100

From Table 4, the OECD "trigger range" for oligotrophic lakes would be 4-10 ug L^{-1}. For mesotrophic lakes the range would be 10-20 ug L^{-1}, and so on. In the event that a trigger is exceeded, further assessment is undertaken, including steps such as defining the problem, identifying causes, and identifying and implementing corrective measures.

The following example of what to do when a trigger is exceeded is offered for demonstration purposes only and in no way should be universally applied. Each exceedence should be treated on a case by case basis.

"Sunset Lake in central Nova Scotia is a popular cold-water fish destination for many avid anglers. The local environmental association has endeavoured to maintain this resource for years to come through the education of its membership in proper aquatic etiquette for the protection of the lake's water quality. Scientific experts have advised them that one of the most significant means of protecting the fishery is to maintain a mean annual total phosphorus lake concentration at or below 10 ug L^{-1}, which equals the trigger for the OCED 4-10 ug L^{-1} oligotrophic trigger range. They were informed that at these concentrations, the risk of dissolved oxygen depletion in the colder bottom layer of the lake would be low. Maintaining sufficient oxygen levels in this zone are important because this zone provides refuge for cold-water fish species during the warmer periods of the year. At the start of the Association's involvement, it initiated a water quality monitoring program which included the analysis of total phosphorus and dissolved oxygen. The first two years of the program produced total phosphorus annual mean concentrations of 9.5 and 8.7 ug L^{-1}, respectively. In the third year, the mean was 11.3 ug L^{-1}, a value which exceeded the trigger range. Dissolved oxygen levels were above 6 mg L^{-1}.

The Association proceeded to investigate possible reasons for the increase and the potential implications if the rise in lake concentration was in fact prelude to an on-going upward trend. Several steps were taken. The risks associated with total phosphorus levels and tolerance levels of cold-water fish species were investigated. A lot survey was conducted to examine potential new sources of phosphorus. The monitoring program's design was reviewed to consider whether or not it was necessary to make changes in order to generate more accurate estimates of annual mean total phosphorus. The program was also assessed regarding the value of wintertime monitoring. The Association examined the benefits of expanding their education program to include lake residents. A management decision was made to conduct one additional year of testing at an increased sampling frequency and further assess the situation at its conclusion. In the meantime, efforts would be undertaken to deliver educational materials to all residents in the lake's watershed."

This approach is likely to be challenged for the dystrophic lakes in Kings County given the fact that a relationship between total phosphorus and $chlorophyll_a$ has not been demonstrated. Considering the example above, in absence of similar algal production levels per unit total phosphorus for dystrophic lakes, the stress on dissolved oxygen levels would likely not produce the same affects as those anticipated for clear-water lakes, resulting in the 10 ug L^{-1} trigger being somewhat on the conservative side. Evidence from research conducted by Kerekes (1981), and to some extent that gathered from the Kings County lakes (see Figures 3 and 4), suggests that even though a strong relationship between these two variables has not been established for dystrophic water bodies, the level of a biological response (as reflected in $chlorophyll_a$ concentrations) is less than what is found in clear water systems. The dystrophic lakes investigated covered a rather narrow range of total phosphorus and $chlorophyll_a$ values. A more thorough review of the relationship would require expansion of the data set through the addition of a wider variety of lakes.

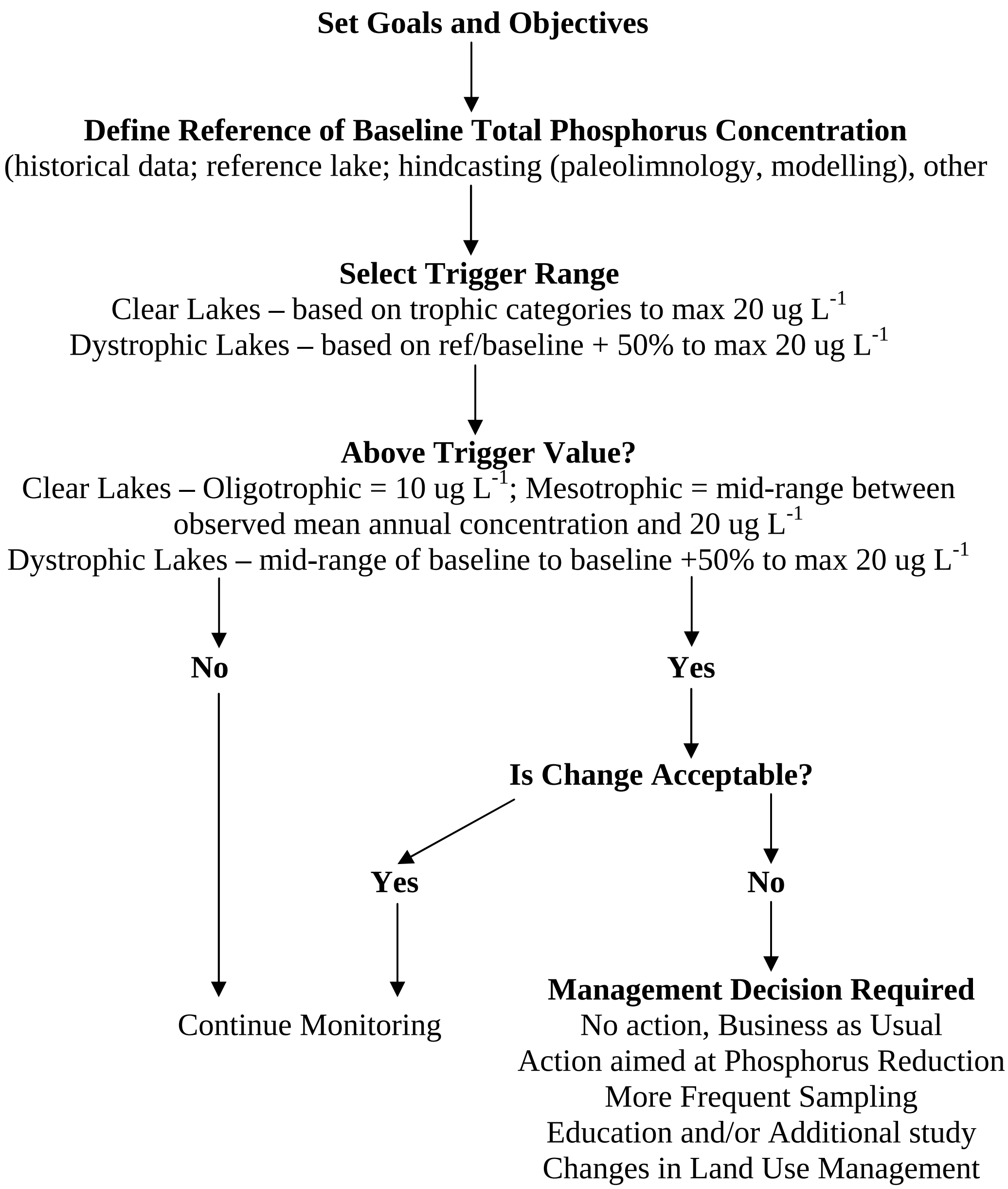
For lakes in the Gaspereau River drainage area, many of which currently exhibiting ice-free mean total phosphorus concentrations above 10 ug L^{-1}, special attention is required. Until such time that the question concerning the relationship between total phosphorus and $chlorophyll_a$ in dystrophic lakes is addressed, it is impossible to speculate with any certainty on dystrophic counterparts for the trigger ranges of various trophic categories. An alternative management approach for dystrophic lakes, with slight modifications to that recommended by Environment Canada (2004), is illustrated in Figure 4.

The difference between the two approaches is that while the trigger value for clear water lakes is set at the upper limit of the baseline concentration trophic category, for dystrophic lakes, the trigger value would set at mid-range of the reference/baseline total phosphorus concentration and it plus 50%. A maximum limit of 20 ug L^{-1} total phosphorus is recommended for all lake types. An increase of 50% above baseline total phosphorus levels, up to a maximum of 20 ug L^{-1}, is considered to minimize the risk of the deterioration of water quality. For example, a dystrophic lake with a baseline total phosphorus concentration of 8 ug L^{-1} could increase by 50%, or 4 ug L^{-1}, to 12 ug L^{-1} while still maintaining a low risk of an impact. The same baseline for a clear water lake would have a trigger value of 10 ug L^{-1}, the upper limit of the oligotrophic category. The Ontario Environment promotes an upper limit of 20 ug L^{-1} in order to avoid nuisance algae. Special consideration should be given to lakes anticipating increases in total phosphorus concentrations above 12 ug L^{-1} due to anthropogenic activities. This note of caution relates to the fact that impairment of fish and fish habitat has been documented at these levels, due mainly to its affect on dissolved oxygen levels (Molot et al. 1992; Clark and Hutchinson 1992). These findings are reflected in CCME (1999) minimum dissolved oxygen guidelines for the protection of aquatic life – minimum of 5.5 mg L^{-1} for warm-water ecosystems and 6.5 mg L^{-1} in cold-water ecosystems. It is imperative that water quality monitoring programs of this nature include dissolved oxygen testing.

5.2 Water Quality Protection

At the present time, water quality objectives are established using $chlorophyll_a$ as the primary indicator. For each lake a water quality objective has been established. The KCLCM is subsequently used to predict the number of additional residential units that can be supported by the receiving waters without resulting in a change in water quality from the stated objectives. The policy framework establishes a 350 ft impact zone (as setback from the shoreline) within those areas zoned S1. Maximum residential densities, as established using the KCLCM, are applied within this 350 ft impact zone. These residential densities represent the number of residential units that can be built along the shoreline before a given lake reaches its carrying capacity, as based on the stated water quality management objectives. These developments are allowed to proceed 'as-of-right'. Once the development surrounding a lake reaches this maximum density, development may still proceed, but only through site plan approval.

Figure 4. Guidance framework for the management of total phosphorus in clear and dystrophic lakes (adapted from Environment Canada 2004).



This study recommends that chlorophyll_a be replaced with phosphorous, and that the current model is replaced with the NSPM. If Kings County proceeds with this change, new residential development density limits will need to be set, not only because the model and the primary indicator has changed, but also because it is recommended that all existing lots be counted as potential inputs/contributors to water quality within 300m of the lake. It is also recommended that Kings County change the current planning approval processes to require site plan approval process for all future development within 300m of a lake. In the future, this process might be extended to all development within the limits of the watershed. This is a preliminary step in managing water quality early on the process at the site level.

Under the current framework the maximum residential density limits represent the number of units that can be accommodated before the stated water quality objective is surpassed. However, once a maximum residential density limit is reached, there is no resulting change in land management. Development is allowed to proceed, although it requires a more involved planning application process (site plan approval). Even if the proposed amendments of this report are accepted and site plan approval is required for all development within 300 m of a lake, there would still be no policy in place which considers how development will be managed once a water quality objective is surpassed. Under the current and proposed scenarios, development density will continue to increase despite the predicted change in water quality and contravention of water quality objectives.

As discussed in the previous section, the first step in setting water quality objectives for each lake is to establish a baseline condition. This baseline condition should be established using all existing lots as contributors (regardless of the presence of existing septic systems. The water quality objective, as suggested by Environment Canada and recommended by this study is that mean annual total phosphorus concentration not exceed 50% of this established baseline up to 20 ug L^{-1}.

Once the newly established water quality objectives are set, the NSPM (or KCLCM) can be run to determine how much additional receiving water capacity there is to assimilate new development before the water quality objectives would be surpassed. Development would continue according to the S1 and S2 Zones, through site plan approval. Once a lake reaches its development capacity, it should act as an automatic trigger which causes a review of the land use and water quality protection framework. Municipal Plan policy should mandate that Kings County Staff, the WQM SC and Council review the conditions of the particular lake and determine if the land use framework is still adequate or if new land use policies need to be put in place to more adequately protect water quality in the lake.

Another automatic trigger for a review of the land use framework should be if it is determined through routine water quality monitoring that total phosphorus concentrations are nearing or have exceeded a total phosphorus trigger value. In cases where long term phosphorus levels exhibit an up-ward trend, is it more likely that an exceedence is real and expected to continue into the future. Whereas, if the occurrence of an exceedence is observed to be anomalous, one additional year of data should be gathered and the roles of climatologic/hydrologic influences more thoroughly examined.

In both cases, once it is determined that predicted future development or current development is going to negatively impact water quality, there are many potential responses that could be considered by the Municipality. A list of potential options is considered below. This list is not meant to be exhaustive and is only intended to represent a range of options available to the municipality.

Business as Usual
In this case the Municipality (Staff, WQMSC, Staff) may determine that although the development has exceeded the water quality objective (based on 50% change over baseline), that they are comfortable with allowing development to continue until such time as the development capacity reaches the 20 ug L^{-1} water quality limit. This would be dependent on the particular lake, and the overall expectations for water quality for that lake.

Further Study
The Municipality may determine that further study is needed in order develop a stronger and better understanding of water quality in a given lake. The Municipality may choose to study the particular impacts to water quality in greater detail, or to undertake a higher level of water quality monitoring to gain a better understanding of the physical and chemical parameters impacting water quality in said lake. During this period of study development might be continued business as usual or a moratorium may be temporarily placed on new subdivisions while the study is being completed.

Discontinue the Activity
The Municipality may determine that no additional development can be supported by the receiving waters and may choose to change the current land use regulations so that no new subdivision is permitted in the S1 and S2 Zones of the lake in question that would further negatively impact water quality.

Improve the resiliency of the system
The Municipality may determine that they want to work with current landowners to improve water quality by improving the overall watershed resiliency. In this case, once a given lake reaches a water quality objective it may represent a trigger for the Municipality to establish stronger regulations in the management of land development in the overall watershed to assist in the protection of water quality. Or, a particular lake may have known problems, which if addressed, might improve the overall potential water quality in said lake. For example, if it is known that particular lake has a number of old, technically out-dated septic systems which could be contributing significantly to a deterioration in lake water quality, then the municipality could determine that this particular issue must be addressed in order to improve the overall resiliency of that particular water body. A municipality could create a wastewater management district, or develop a centralized on-site wastewater treatment which would help to provide the regulatory framework through which these problems could be remediated. Which type of action was chosen to improve overall resiliency of the system would be dependent on the particular lake and the nature of surrounding development.

It is important to note that these potential actions could be combined to respond to predicted or monitored water quality deterioration. Similarly, the policy framework need not be so rigid that it is only when a water quality objective is surpassed that these types of measures are employed. For example, a municipality may wish to improve the resiliency of a water body or initiate further study of the watershed independently of any water quality objective being surpassed.

Finally, it is important that the municipality create an upper limit for water quality that represents a cut-off to receiving water capacity. The suggested upset water quality objective for phosphorous in the lakes in this study is 20 ug L^{-1}. If water quality in a given lake is expected to surpass this water quality objective based on model prediction or as a result of the monitored impacts of existing development, at such time the municipality should no longer permit any new subdivisions to occur within the S1 and S2 Zones around that particular lake. It may be that this halt to development is temporary until the Municipality can improve the resiliency of that particular water body (ie: through establishment of wastewater management districts or stormwater management master plans which are in place to remediate existing problems). The ultimate approach is to halt all development until such time that the lake has reached equilibrium, a period of time which could extend for more than 20 years. Or it may be that no new development is permitted unless it is negotiated through a Development Agreement and the development meets a certain standard of site design and wastewater management and treatment, and proves this with a study of receiving water capacity. In all instances any new development should be treated as having a strong potential to impact water quality in such a manner that would negatively impact the continued use and health of said water body, and should be view with extreme caution. The regulatory environment should respond accordingly.

6.0 FUTURE STUDY

The following areas were identified for future study.

6.1 Strengthen stormwater management controls through the site plan approval process.

There are no policy requirements for stormwater management controls in the current water quality protection framework. Since stormwater is one of the key contributing elements to water quality resulting from development, it is suggested that Kings County consider strengthening the stormwater management controls. Under the Municipal Government Act, the site plan approval process can be used to regulate stormwater management (Municipal Government Act, Part 8, Section 231, 4, j). It is recommended that the Municipality explore this option.

Stormwater Beneficial Management Practices (BMPs) can be used for managing stormwater quality and quantity to minimize the effects of development on downstream environments. The various BMPs may be implemented to control the source of water quality or quantity effects, or reduce the impact by mitigating quality and quantity during stormwater conveyance or at the 'end-of-pipe'. The selection of the appropriate BMPs is guided by the type of downstream environment or receiving water body. In ideal circumstances, source control, conveyance controls and end-of-pipe controls are used in synergy and succession, and selection is based on an understanding of the watershed as a whole.

Stormwater BMPs can be implemented in both existing developments and new developments to improve water quality. The selection of suitable BMPs must be site specific, considering the watershed sensitivities, site features, space requirements, cost, BMP performance estimates, cumulative effects and acceptability by the public. Kings County may also want to consider developing an overarching Stormwater Management Plan specific to receiving waters that have currently surpassed their water quality objective, or are close to surpassing objectives based on predicted water quality. Current federal and provincial monies allocated to infrastructure funding could be targeted for particular projects.

Whenever feasible, post-development water quality should equal or exceed that of a pre-development scenario. The selection of water quality criteria for a new development depends on the assimilative capacity of the receiving water body. Areas of particular sensitivity are those where stormwater discharges directly to a lake or watercourse. Without proper treatment, the episodic increase in phosphorus and total suspended solids during storm events may result in localized algae blooms or fecal indicator bacteria, even though the entire lake health may be satisfactory.

6.2 Lake Bathymetry

Bathymetric mapping exists for all but two of the study lakes. Although not an integral component of the modelling or monitoring efforts, it would be useful to have maps for Little River and Tupper lakes. Several physical characteristics of a lake are calculated based on bathymetric information (surface area, maximum length, mean width, maximum width, mean depth, maximum depth, shoreline length, shoreline development, and volume). The maps are also useful when examining the sustainability of aquatic life in that they identify, for example, areas within a lake which would serve as refuge areas for cold water fish species during warmer periods of the year. It is recommended that an effort be made to ensure that lake bathymetry is available for any modelled lake.

6.3 Designate Portions of the Lakeshore as No-Go or Conservation Areas

Much of the undeveloped land along lakeshores provides important habitat and valuable natural water frontage. By applying a conservation or open space designation to a percentage of land around each lake, Kings County could take valuable steps in protecting this land, and also assist in preserving existing water quality. It is recommended that the County work with land owners and lake/residents groups in the Gasperau watershed to determine if there are opportunities for increased protection of lakeshore lands. There may be opportunities for this level of protection surrounding lakes where there are limited development pressures and a smaller group of landowners.

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8.0 GLOSSARY OF TERMS

Algae – primitive photosynthetic plants that occur as microscopic forms suspended in water (phytoplankton), and as unicellular and filamentous forms attached to rocks and other substrates. About 15,000 species of freshwater algae are known.

Alkalinity – acid neutralizing capacity of water. It is the sum of all the titrable bases.

Annoxic – absence of dissolved oxygen gas.

Anthropogenic – derived from human activity.

Biomass – mass units of organic matter per unit surface area or per unit volume; mass of living material of an organism.

Chlorophyll$_a$ – pigment common to all major groups of plants but not present in bacteria. It is one of the pigments necessary for photosynthesis to take place. Chlorophyll$_a$ is used as an algal biomass indicator.

Colour – with reference to water, colour refers to the intensity of yellowish-reddish-brown hue caused by dissolved humic substances in the water.

Dissolved Oxygen – solubility of oxygen in fresh water is affected by temperature and increases considerably in cold water. Solubility is also affected by pressure and salinity. Sources of dissolved oxygen include the atmosphere and photosynthetic activity by algal populations. Oxygen is consumed by animals, plants, chemical oxidation, and especially by bacterial respiration in decomposition of sedimenting organic matter.

Drainage basin – area from which precipitation drains to a given lake or river.

Epilimnion – the uniformly warm upper layer of a lake when it is thermally stratified in summer. The layer above the metalimnion.

Euphotic zone – the stratum of a lake which receives at least 1% of the amount of light striking the surface. This stratum includes the limnetic and littoral zones.

Eutrophic – lakes richly supplied with plant nutrients supporting heavy plant growths. As a result, biological productivity is generally high, the waters are turbid because of dense growths of phytoplankton, or contain an abundance of rooted aquatic plants; deepest waters exhibit reduced concentrations of dissolved oxygen during periods of restricted circulation. Eutrophic lakes tend to be shallow, with average depths less than 10 metres (33 feet) and maximum depths less than 15 metres (50 feet).

Eutrophication – the complex sequence of changes initiated by the enrichment of natural waters with plant nutrients. The first event in the sequence is an increased production and abundance of photosynthetic plants. This is followed by other changes that increase biological production at all levels of the food chain, including fish. Successional changes in species populations occur in the process. The original meaning of eutrophication was simply nutrient enrichment. In recent years it has become more common to use the term in connection with the results rather than the cause (that is, an increase in trophic state caused by nutrient enrichment).

Export coefficient – a measure of the amount of a substance exported from a system, usually expressed as mass per area per time.

Hypolimnion – the uniformly cool and deep layer of a lake when it is thermally stratified in the summer. The layer is below the metalimnion.

Metalimnion – the zone in which temperature decreases rapidly with depth in a lake when it is thermally stratified in summer. The metalimnion lies between the epilimnion and hypolimnion. The term is roughly equivalent to thermocline in ordinary usage.

Total nitrogen – forms of greatest interest are nitrate, nitrite, ammonia, and organic nitrogen. Although phosphorus and nitrogen are the most important nutrient factors causing shifts from oligotrophy to more productive trophic levels, it is phosphorus which is often the limiting factor.

Nutrient – element or compound necessary for life, derived primarily from inorganic sources but may be ingested by some organisms in a “recycled” organic form.

Oligotrophic – lakes poorly supplied with plant nutrients and supporting little plant growth. As a result, biological productivity is generally low, the waters are clear, and the deepest layers are well oxygenated throughout the year.

Oxic – having oxygen.

Oxygen depletion – state of reduced dissolved oxygen concentration in an aquatic system usually as a result of an excess respiration over photosynthesis.

pH – the negative logarithm of the hydrogen activity in a solution. A pH value of 7.0 indicates a neutral solution, values of 0 to 7.0 indicate acid conditions, 7.0 – 14.0 indicate alkaline conditions.

Photosynthesis – the process by which green plants convert the sun’s energy into chemical energy in the form of carbohydrates, fats, and proteins.

Phytoplankton – plant plankton; see plankton.

Plankton – community of microorganisms, consisting of plants (phytoplankton) and animals (zooplankton), inhabiting open-water regions of lakes and rivers.

Precipitation – water and water-borne substances falling from the atmosphere in liquid (rain, dew, etc.) and solid (snow, hail) form.

Respiration – the process of enzymatic breakdown of organic substances in living cells that release energy for various biological activities.

Secchi disk – a 20 cm diameter weighted disk with black and white quadrants on the upper surface which is attached to a metered line and lowered in the water until it just disappears and then is raised until it can be seen again. The average of the two depths is called the Secchi disk transparency or Secchi depth.

Specific conductance or conductivity – the reciprocal of electrical resistance of a solution containing ions, such as neutral waters, measured at a specific temperature (25C). It is measured using a probe with two electrodes across which a constant potential difference. The ratio of the current passing between the electrodes to the potential difference is read on a meter calibrated in umho or umho/cm and can be used to estimate the salinity of waters.

Suspended matter – substances which can be separated out of a fluid medium by mechanical means such as filtration or centrifugation.

Stratification – formation of separate and distinct layers of strata due to physical and/or chemical differences. (i.e. thermal stratification of a lake).

Total phosphorus – sum of all the states of phosphorus in a sample including dissolved, suspended organic, and inorganic fractions. Phosphorus is often considered a limiting factor in lake eutrophication.

Trophic state – characterization of a body of water in terms of position in a scale ranging from oligotrophy to eutrophy.

Turbidity – scatter of light caused by suspended and colloidal substances in a fluid medium.

Volume-weighted sample – a water sample made up of subsamples taken at various depths through the water column and mixed in ratios equivalent to those of the lake strata-volumes at the sampling depths.

APPENDIX A. PROJECT OBJECTIVES

The overall objective of the project is to conduct a review of the Kings County Lakeshore Capacity model and its link to municipal land use planning. The review is to provide recommendations concerning:

- Revisions to the lake capacity model or the implementation of a replacement decision making tool,
- Appropriate water quality objectives,
- The volunteer lake monitoring program,
- Municipal Planning Strategy and Land Use Bylaws, and
- The method of applying the recommended decision making tool to additional lakes in Kings County and Nova Scotia

Specific tasks associated with the review include addressing the following questions:

A. Should the Municipality link lake water quality to municipal land use planning by continuing to use the lakeshore capacity model as a decision making tool to predict lake carrying capacities based on $Chlorophyll_a$ as the main water quality indicator?

-Or-
Should the Municipality implement an alternative decision making tool to link lake water quality to municipal land use planning? Such an alternative tool may be based on, but is not limited to, utilizing phosphorus as the main water quality indicator and /or expanding the water quality monitoring efforts to include a basket of indicators similar to the Canadian Council of Ministers of the Environment (CCME) water quality index. Any alternate tool would have to be scientifically defensible and practical to apply in Kings County using existing water quality data.

B. If recommending the continued use of the lakeshore capacity model based on $Chlorophyll_a$, or other variables, as the main indicator(s), recommend changes to the model, water quality objectives, predicted carrying capacities, monitoring program and associated land use policies and bylaws that improve the initiatives effectiveness for municipal land use planning, water resource management decision-making, and lake protection.

If recommending an alternative decision making tool that is scientifically defensible and practical to apply in Kings County using existing water quality data, apply the new approach to Kings County lakes and recommend changes to land use policies and bylaws and the lake monitoring program that improve the initiatives effectiveness for municipal land use planning, water resource management decision-making, and lake protection.

C. Make recommendations outlining the step-by-step actions needed to effectively apply the recommended decision making tool to additional lakes in Kings County, or elsewhere in Nova Scotia. The recommendations should clearly describe the method for determining lake water quality objective(s), or indicator threshold(s), both on a broad provincial basis and an individual lake basis, as well as the method for determining any associated land use controls. The recommendations should be written so a municipal planner with a novice understanding of lake water science could effectively implement and use the decision making tool.

APPENDIX B. KINGS COUNTY LAKESHORE CAPACITY MODEL

The phosphorus loading model developed for application to lakes in Kings County, known as the Kings County Lakeshore Capacity Model (KCLCM) was the product of work undertaken in 1995 (Horner and Associates 1995).

Originally developed and calibrated for Precambrian Shield lakes in Southern Ontario, the Lakeshore Capacity Model (LCM) was refined in its application to the Kings County lakes. Both versions are mass balance models which combine various catchment and lake characteristics to estimate or predict in-lake values for phosphorus and chlorophyll$_a$ concentration and Secchi depth. The model enables a user to assess the effects of existing land uses as well as the potential water quality impacts of future watershed development. As in the Kings County situation, the model can also be used to establish indicator thresholds for development in order to maintain water quality levels and avoid nuisance situations which can be associated with changes in trophic status.

In order to provide the reader with a basic understanding of the input and output variables represented in the KCLCM, a flow chart is presented in Figure B-1.

B.1 Model Assumptions

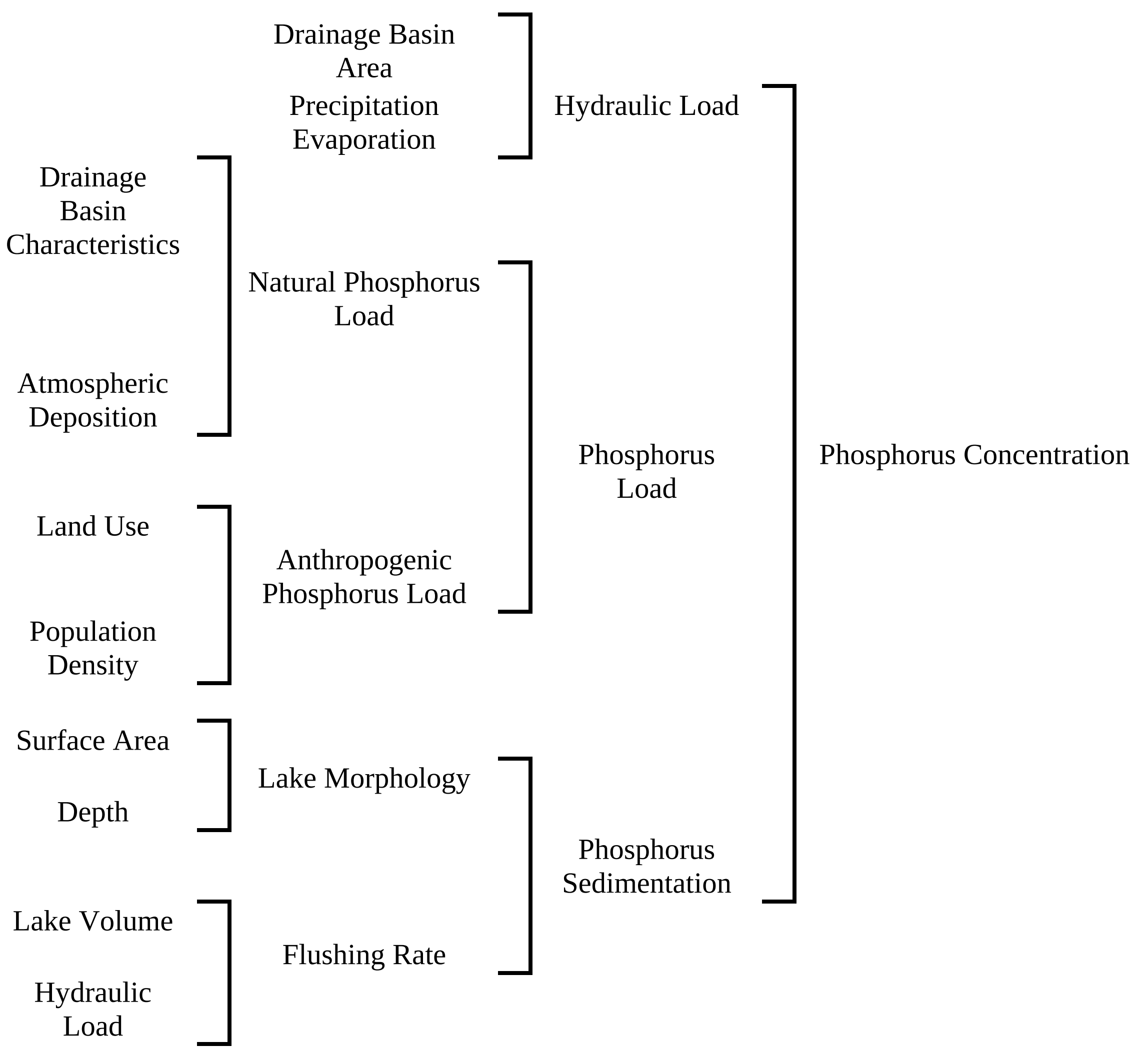
The KCLCM makes several assumptions. These include:

- 100 percent of the phosphorus entering an on-site wastewater disposal system will eventually make its way to a lake.
- Phosphorus contributed per capita per year is 0.8 kg.
- Overland export load of phosphorus for the Kings County lakes is twice that for lakes in Ontario found on similar geologic settings due to the fact that this area of Nova Scotia receive approximately twice the amount of precipitation received in Ontario.
- A single phosphorus export coefficient is representative of entire drainage area.
- A single phosphorus retention coefficient is representative for all water bodies.
- Shoreline, island, and back lots with septic systems are sources of total phosphorus. (The Horner Report did not specify the distance from a lake or tributary watercourse used to define the impact zone limits, but is was assumed to be 300 metres (1,000 feet).
- One-third of waterfront properties will eventually be occupied or used on a full-time basis.
- A relationship between chlorophyll$_a$ and total phosphorus exists.

There has been significant discussion regarding the amount of septic system phosphorus which ultimately reaches a water body. The KCLCM takes a conservative approach and assumes that 100 percent of the phosphorus in septic systems situated within 300 metres of a lake or tributary receiving water will eventually contribute to the phosphorus load for that lake. Research suggests that between 26 and in excess of 90 percent of the septic phosphorus load may be immobilized (Robertson et al. 1998; Dillon et al. 1994; Wood 1993; Hart et al. 1978).

The KCLCM has adopted a per capita phosphorus load figure which originated with the Dillon-Rigler phosphorus loading model. The Dillon-Rigler figure of 0.8 mg $capita^{-1}$ $year^{-1}$ was based in part on septic tank total phosphorus prior to the introduction of low-phosphate detergents. Subsequent research suggests that this figure is an over-estimate of current conditions (Robertson et al. 1998; Dillon et al. 1994; Wood 1993). The pre-low-phosphate detergent septic tank average total phosphorus concentration was 13.2 mg L^{-1} (Dillon et al. 1986). Based on findings reported by Gartner Lee Ltd. (2002) following the introduction of low-phosphate detergents where an average septic tank total phosphorus concentration of 8.2 mg L^{-1} was observed, Hutchinson (2002) proposed the use of a more appropriate value of 0.6 mg $capita^{-1}$ $year^{-1}$. An average total phosphorus value of 7.6 mg L^{-1} has been observed in septic tank effluent at a research facility operated by the Centre for Water Resources Studies (CWRS 2009a).

Figure B-1. Flow chart of major factors controlling lake phosphorus concentration used by the KCLCM (from Brylinsky 2004).



In the absence of export data for landscapes in Nova Scotia, the KCLCM assumes a land export coefficient of 11.0 mg m^{-2} yr^{-1}, a figure extrapolated from empirical data collected in Ontario. The overland phosphorus export coefficient of 5.5 mg m^{-2} yr^{-1} reported in Dillon et al. (1986) for forested landscapes on igneous bedrock was doubled to 11 mg m^{-2} yr^{-1} given the fact that Ontario receives roughly half the amount of precipitation that Nova Scotia does. Application of a single export coefficient limits the model's ability to account for specific land use activities such as forest harvesting and agriculture. Research carried out in Nova Scotia after the Horner report by Scott et al. (2000) reported an average export coefficient of 6.9 mg m^{-2} yr^{-1} for similar landscapes based on measurements from four watersheds. One of the study's watersheds, Sharpe Brook, which drains an area of the South Mountain near Prospect, was characterized as forested with >15% of the area cleared and yielded a unit export value of 8.0 mg m^{-2} yr^{-1}. Lowe (2002) investigated phosphorus export from 10 sub-watersheds within the Gaspereau River system with mean water colour ranging from 12 to 110 colour units and reported export coefficients ranging from 19.1 to 63.4 mg m^{-2} yr^{-1}. These export values are considerably higher than the range of 8.9 – 15.3 mg m^{-2} yr^{-1} reported by Scott et al. (2000) for slightly higher coloured water ranging from 99 – 194 colour units.

The phosphorus retention coefficient is a measure of the amount of phosphorus lost from the water column through sedimentation. The coefficient is expressed by the relationship between the settling velocity of phosphorus and the areal water load (Patterson et al. 2006). For dimictic, oligotrophic lakes with oxic hypolimnia, a settling velocity of 12.4 m yr^{-1} is appropriate. For lakes experiencing periods of hypolimnetic anoxia, a reduced settling velocity of 7.2 m yr^{-1} is used. The latter value was applied to all of the Kings County lakes modelled. The higher flushing rates of the Gaspereau River lakes was considered as justification for using the lower value.

The 300 m impact zone was first introduced by Dillon and Rigler (1975) and Dillon et al. (1986), a modelling feature carried forward by many modelers ever since. Although this figure is convenient for modelling purposes, it is technically indefensible given our current knowledge. A more realistic tiered approach proposed by Hutchinson (2002), itself arbitrary, attempts to incorporate the effects of soil attenuation into the modelling process. We are not aware of any location within Canada that has tested this approach, but the Kings County situation offers a unique opportunity to do so. Instead of assuming that all septic systems within the 300 m zone at some point in time contribute 100 percent of its total phosphorus load to a lake or tributary stream, the Hutchinson approach would assume that septic systems within 100 metres of a lake or tributary receiving water would contribute 100 percent; between 100 and 200 metres 67 percent; and between 200 and 300 metres 33 percent. Those systems beyond 300 metres would contribute 0 percent. Ranking phosphorus loading in this manner would replace the current approach where systems located 300 metres away from a lake would contribute 100 percent of its phosphorus while a system situated 1 metre further away would have zero impact. After reviewing the modelling work conducted by the County using the KCLCM, it is unclear, but assumed, that the maximum distance used to delineate the septic tank impact zone was 300m. Up until now, 300 m has been used for modelling in Nova Scotia. Maximum carrying capacities in Section 3.5 of the Municipal Planning Strategy are based on a distance of 107 m (350 feet) from a lake. This issue needs clarification.

The assumption that one-third of waterfront properties will at some point in time be permanent full-time residences is in keeping with Municipal background reports (County of Kings 2009).

B.2 Model Predictions

The KCLCM output variables of interest to this review are springtime- and ice-free total phosphorus and ice-free chlorophyll$_a$. The predicted value for chlorophyll$_a$ is generated using the model predicted springtime total phosphorus concentration. The accuracy of the estimated chlorophyll$_a$ concentration will, of course, depend on whether the typical trophic relationship between the two variables exists for lakes modeled in the Gaspereau River system.

There was no documented methodology found that described the process used to establish water quality objectives for chlorophyll$_a$ in Municipal ByLaw #56. What is known is that the threshold chlorophyll$_a$ objective was 2.5 ug L^{-1}. For some lakes in the system, the value was presumably lowered to accommodate a greater potential development demand for downstream lakes. Lakes like Salmontail and Dean Chapter, for example. The following few sections attempt to create a clearer understanding of how individual lake chlorophyll$_a$ objective concentrations contained in the municipal bylaw relate to total phosphorus. Results of the exercise are presented in Table B-1.

Municipal staff (B. Sivak) supplied an Excel file entitled "July97" that was assumed to be a working version of the KCLCM used in the original water quality objective setting process.

B.2.1 Prediction of Ice-Free Total Phosphorus

The KCLCM predicts springtime total phosphorus (Equation B-1) which is subsequently converted to ice-free total phosphorus (Equation B-2) and ice-free chlorophyll$_a$ (Equation B-3).

Springtime total phosphorus is calculated using Equation B-1:

$$TP_{SP} = J_T\,(1-R)/0.956qs \qquad \text{Equation B-1}$$

where:
J_T = total phosphorus load (kg yr^{-1})
R = lake phosphorus retention coefficient
qs = areal water load (m yr^{-1}), or annual hydraulic load ($10^6 m^3\ yr^{-1}$)/lake area ($10^6\ m^2$)

In its current form, the KCLCM output variable list does not include mean ice-free total phosphorus. By not providing this information, a comparison with observed total phosphorus data gathered through the volunteer monitoring program is not possible. In order to be able to compare field data with model predictions, Equation B-2 is needed to convert model predictions for springtime total phosphorus to ice-free total phosphorus. At the present time, this conversion step is imbedded in the model calculation for chlorophyll$_a$ (see below). The relationship between springtime and ice-free season total phosphorus, based on information from 21 lakes over a 2-7 year period from the Muskoka region of Ontario, and is expressed in the following equation:

$TP_{IF} = (0.8 \times TP_{SP}) + 2.04$ Equation B-2

where:
TP_{IF} = mean ice-free total phosphorus (ug L^{-1}), and
TP_{SP} = springtime total phosphorus (ug L^{-1}).

Table B-1. KCLCM predictions for springtime and ice-free season total phosphorus.

		Total Phosphorus			
	Chla Objective	Springtime	Ice-Free	Springtime	Ice-Free
	(taken from Municipal ByLaw #56)	Values based on Chla Objective		1997 Model Predictions	
	ug L^{-1}				
George	2.5	11.6	11.3	10.3	10.3
Loon	2.5	11.7	11.4	8.0	8.4
Aylesford	2.5	11.6	11.3	8.5	8.8
Crooked	2.5	11.7	11.4	8.8	9.1
Four Mile	2.5	11.6	11.3	10.0	10.0
Two Mile	2.5	11.7	11.4	9.2	9.4
Blue Mountain	2.5	11.7	11.4	7.0	7.6
Gaspereau	2.0	9.6	9.7	7.1	7.7
Salmontail	1.7	8.3	8.7	6.2	7.0
Murphy	2.5	13.5	12.8	12.6	12.1
Trout River	2.2	10.4	10.4	8.4	8.8
Moosehorn	2.5	11.7	11.4	8.3	8.7
Little River	2.1	10.1	10.1	8.5	8.8
Methals	2.1	10.0	10.0	8.4	8.8
Dean Chapter	1.8	8.8	9.1	7.6	8.1
Black River	2.1	10.0	10.0	8.4	8.8
Lumsden	2.4	11.2	11.0	9.4	9.6

B.2.2 Prediction of Ice-Free Chlorophyll$_a$

KCLCM predictions for ice-free chlorophyll$_a$ are generated using model predicted concentrations of ice-free total phosphorus. This is achieved using the following equation:

$$\log_{10}(\text{Chla}) = 1.45(\log_{10}[TP_{IF}]) - 1.14 \qquad \text{Equation B-3}$$

Example: Using an ice-free total phosphorus (TP_{IF}) of 10.0 ug L^{-1}, the predicted chlorophyll$_a$ (Chla) is:

$$\begin{aligned}\log_{10}(\text{Chla}) &= 1.45(\log_{10}[10.0]) - 1.14\\ &= 1.45(1.0) - 1.14\\ &= 0.31\\ \text{Chla} &= 10^{0.31}\\ &= 2.0 \text{ ug L}^{-1}\end{aligned}$$

Where:
Chl_a = mean ice-free chlorophyll$_a$ (ug L^{-1}),
TP_{IF} = mean ice-free total phosphorus (ug L^{-1}).

It should be noted that the regression equation B-3 is based on a combination of *ice-free means of total phosphorus and chlorophyll$_a$* from 30 Japanese lakes, 19 lakes in southern Ontario, and miscellaneous lakes in North America and Europe and carries with it broad confidence limits (i.e. at 10 ug L^{-1} TP_{IF}, Chla 95% limits range from 0.75-5.65 ug L^{-1}; 50%: 1.47-2.90 ug L^{-1}). The *mean annual chlorophyll$_a$* upper limit concentration of 2.5 ug L^{-1} for the oligotrophic trophic category suggested by Vollenweider and Kerekes (1982), a value adopted in the Kings County Planning Strategy, was based *mean annual total phosphorus* concentrations from a different set of lakes. The use of a different data set, mean annual versus ice-free mean total phosphorus and chlorophyll$_a$, and the confidence limits associated with Equation B-3 all contribute to explain the difference between the equation generated value of 2.0 ug L^{-1} and the Vollenweider and Kerekes value of 2.5 ug L^{-1}.

B.3 Model Accuracy

This evaluation of the accuracy of model predictions is based on total phosphorus concentrations generated in 1997 that reflect the potential change in total phosphorus concentrations given land use and level of residential development at that time. It is obvious that in the 11 years since changes have occurred which will be contributing additional phosphorus which is not being reflected by the 1997 predictions. If the phosphorus data displayed an upward trend over the period of record, the influence of post-1997 changes in the comparison may be of concern. However, the data suggests that, if anything, there is a downward trend in phosphorus concentrations which suggests that post-1997 anthropogenic phosphorus sources are not showing up in the lakes at this time. The validity of this latter trend is discussed further in Section B.5.

Ice-free predicted and observed total phosphorus measurements have been compiled and are presented in Table B-2. The data offers three field data scenarios for comparison with predicted values. The first considered only phosphorus data produced by the ES lab at the QEII between 1993 and 2003. The second considered only that data produced at the AS lab in Fredericton between 2005 and 08. With the exception of phosphorus data from the 2004 sampling season, a third scenario considered all data from both labs.

Assuming that all observed total phosphorus data are reliable, the mean difference between observed and predicted ice-free total phosphorus concentration was 22 percent with the majority of predictions under-estimates of observed values. In most situations, especially those involving on-site wastewater disposal systems, model predictions are expected to be greater than observed measurements because of the time-lag between when phosphorus enters a disposal system and when it actually contributes to the phosphorus load of a surface water body. A comparison of observed data versus model prediction using the Fredericton lab data produced a marginally better overall fit at 21 percent when compared with 26 percent when using the QEII lab results.

Table B-2. Predicted versus observed ice-free (IF) season total phosphorus concentrations for data representing three monitoring periods (1993-2003, 2005-08, 1993-2008*).

Period	1997	1993-2003		2005-08		1993-2008*	
	Model Predicted IF Total P	Observed IF Mean Total P	% Diff.	Observed IF Mean Total P	% Diff.	Observed IF Mean Total P	% Diff.
	ug L^{-1}	ug L^{-1}	%	ug L^{-1}	%	ug L^{-1}	%
Hardwood	8.9	12.0	-25.8	13.0	-31.5	13.0	-31.5
George	10.3	11.0	-6.4	7.0	+47.1	10.0	3.0
Loon	8.4	13.0	-35.4	10.0	-16.0	12.0	-30.0
Aylesford	8.8	11.0	-20.0	8.0	+10.0	10.0	-12.0
Crooked	9.1						
Four Mile	10.0						
Two Mile	9.4						
Blue Mountain	7.6						
Gaspereau	7.7	14.0	-45.0	10.0	-23.0	12.0	-35.8
Salmontail	7.0						
Murphy	12.1	13.0	-6.9	11.0	+10.0	12.0	0.8
Trout River	8.8						
Moosehorn	8.7						
Little River	8.8	13.0	-32.3	14.0	-37.1	14.0	-37.1
Methals	8.8						
Dean Chapter	8.1						
Black River	8.8	13.0	-32.3	9.0	-2.2	11.0	-26.7
Lumsden	9.6	14.0	-31.4	11.0	-12.7	13.0	-20.0

* data from 2004 were not included in the calculations

All of the issues related to model design, the validity of input information, and the reliability of lab generated total phosphorus data need to be addressed to obtain a more accurate assessment of the model's predictive ability for these lakes.

B.4 Total Phosphorus/Chlorophyll$_a$ Relationship

The validity of applying Equation B-3 to predict a chlorophyll$_a$ concentration from a total phosphorus concentration is based on the premise that a relationship between the two variables exists. For clear water lakes it has been demonstrated that it does (Dillon and Rigler 1975; Kerekes 1980; Kerekes 1981).

The existence of a similar relationship for the Gaspereau River lakes was examined using total phosphorus and chlorophyll$_a$ data contained in the water quality database (1993-2008). Lakes in the dataset include Aylesford, Black River, Gaspereau, George, Hardwood, Little River, Loon, Lumsden, Murphy, Sunken, Trout River, and Tupper. Whereas Sunken Lake was added to the monitoring program in 2007, only eleven lakes were considered in figures illustrating 1993 – 2003 data. This information was provided by municipal staff. Figures B-2 and B-3 are log-log plots of maximum chlorophyll$_a$ concentrations in relation to mean ice-free season total phosphorus concentration. Figure B-4 is a log-log plot of mean ice-free season chlorophyll$_a$ and mean ice-free total phosphorus concentrations. Figure B-2 considers all empirical data collected from 1993 – 2008, while Figures B-3 and B-4 use only that data gathered from 1993 - 2003.

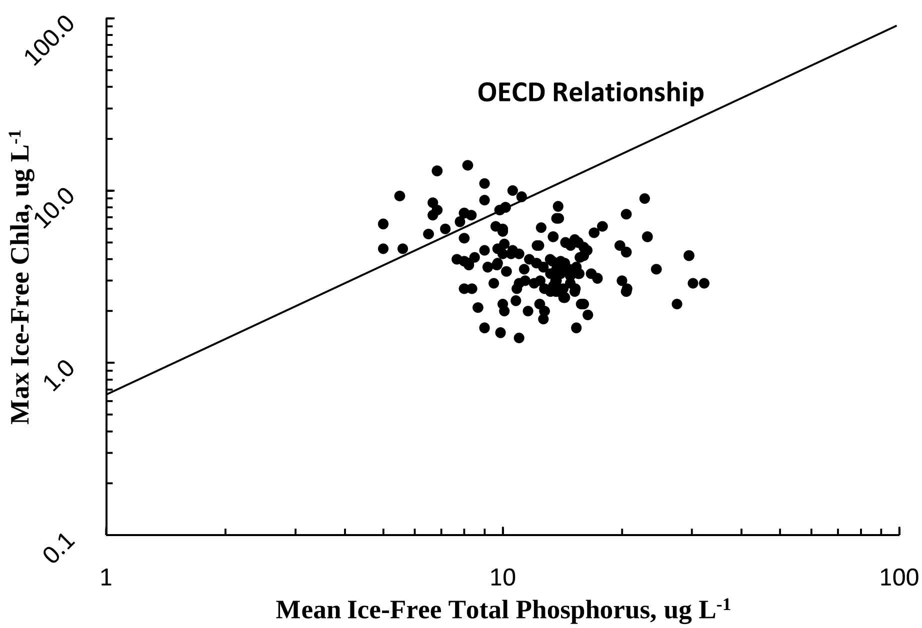


Figure B-2. Maximum chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2008 (12 lakes; n = 126). The OECD regression line for the same relationship is indicated.

The 1993 – 2003 dataset covers a period of uniform analytical methodology (i.e., fluorometric chlorophyll$_a$ data only) and during which no suspicious data were reported (i.e., 2004 total phosphorus were excluded from annual reporting because they were considered suspicious). For reference, both figures contain the regression line for the relationship developed for these variables in a group of Organization for Economic Co-operation and Development (OECD) study lakes (Vollenweider and Kerekes 1981a,b).

It appears that the Gaspereau River lakes do not follow the typical trophic response to nutrient loading. Slightly less scatter of the data occurs in Figures B-3 and B-4, which can be explained by the exclusion of the spectrophotometrically produced chlorophyll$_a$ which were found to be over-estimates relative to that produced by the fluorometric method. Elimination of these data from Figures B-3 and B-4 place all of the lakes below the OECD regression line. Water color, macrophyte abundance, and zooplankton over-grazing are all known to influence chlorophyll$_a$ production. A direct relationship between the two variables for these lakes cannot be supported by the data available. Contrary to the Kings County situation, Kerekes (1990) suggested that a quantitative trophic response to total phosphorus may exist for dystrophic water bodies, with the average concentration of chlorophyll$_a$ per unit total phosphorus being less than that observed in clear water systems (Schwinghamer 1975; Kerekes 1981). This association is due in large part to the reduced bio-availability of phosphorus in colored-water (Vollenweider and Kerekes 1981). Until such time that a TP:Chla relationship can be demonstrated for the modeled lakes in Kings County, the use of chlorophyll$_a$ as a trophic indicator in the planning strategy is without empirical validation and should be replaced.

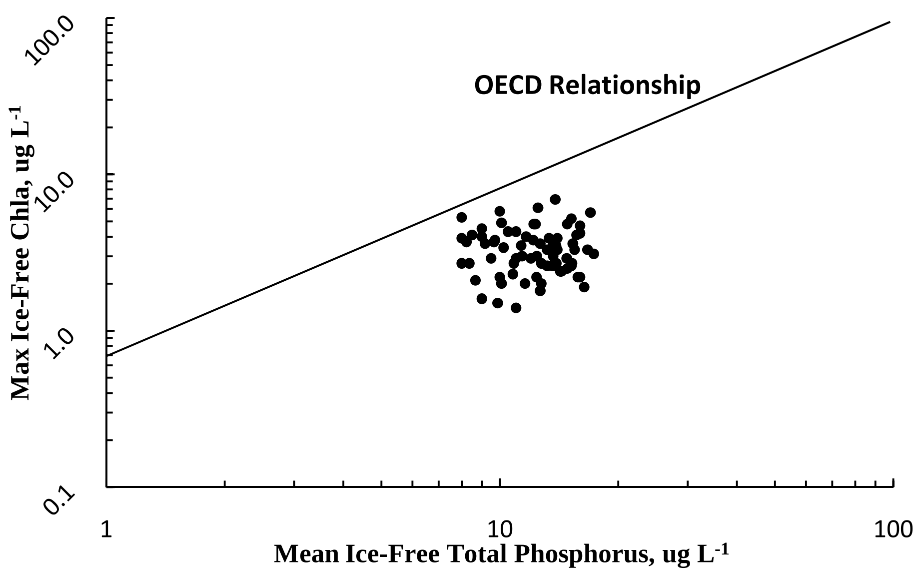


Figure B-3. Maximum ice-free chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2003 (11 lakes; n = 72). The OECD regression line for the same relationship is indicated.

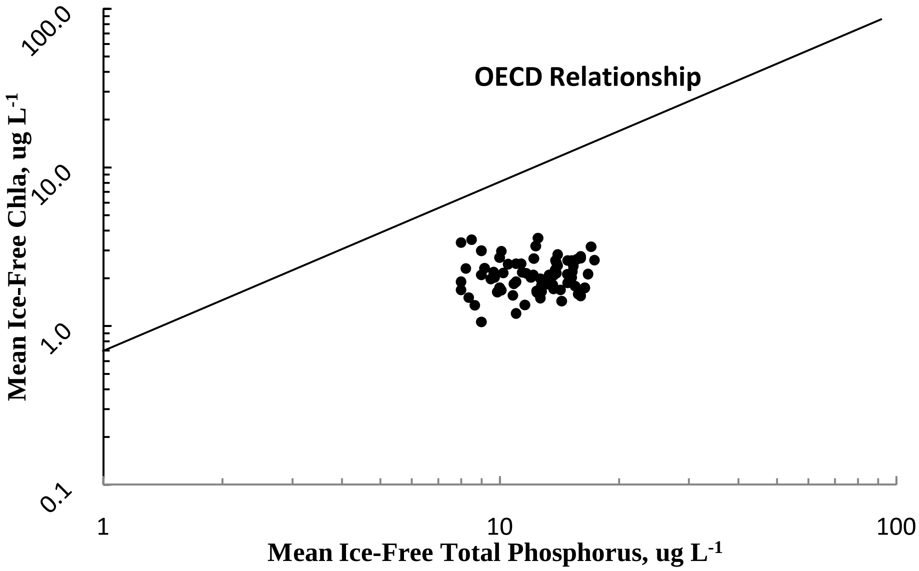


Figure B-4. Mean ice-free chlorophyll$_a$ concentration in relation to mean ice-free season total phosphorus concentration, 1993 – 2003 (11 lakes; n = 72). The OECD regression line for the same relationship is indicated.

B.5 Reliability of Total Phosphorus Empirical Data

In his interpretation of observed data, Brylinsky (2004, 2008) noted that anomalies existed with the total phosphorus data which were not explainable. In particular, information generated in 2004 was abnormally high relative to other years and differences between concentrations for some duplicate samples were large. With the change in labs at the end of 2004 the levels of phosphorus and month to month variability in the data were reduced. It is inevitable that these anomalies will cast uncertainty on the reliability of the total phosphorus database as a whole. For example, in other studies involving similar sized lakes exposed to similar levels of development pressure, mean total phosphorus concentrations for ice-free period over a nine-year period for one Ontario lake ranged from 6.05 to 7.21 ug L^{-1}, a fluctuation of slightly more than 1 ug L^{-1} (Hutchinson et al., 1991). Locally, the difference between minimum and maximum mean annual total phosphorus concentrations recorded for four lakes in the Halifax area over a ten-year period was < 3 ug L^{-1} (CWRS 2009b). The variation observed in the Kings County lakes over its eleven-year monitoring period, excluding 2004 data, was much higher at between 8 and 12 ug L^{-1}. The range for Fredericton lab data was significantly improved at between 0.6 and 16.4 ug L^{-1}, averaging 4.7 ug L^{-1}.

Water sample collection and handling and laboratory techniques are two major factors which can affect a true measure of a water quality parameter. Field blank measurements taken during the monitoring efforts indicate that the integrity of the water samples submitted for testing is not being compromised by sample collection and handling procedures employed by the volunteer program. With the exception of a few occasions, results for duplicate water samples do not indicate any influence attributable from lab handling or processing. However, the extreme fluctuation in month-to-month phosphorus concentrations, coupled with the findings of the Ontario and Halifax studies referenced previously, suggests that the QEII lab results may not be entirely accurate. Although more realistic trends in phosphorus levels are now being reflected in data produced by the Fredericton lab, the level of detection at this lab is not considered to be adequate.

In an effort to eliminate the sort of irregularities experienced in the Kings County dataset for total phosphorus and to enhance reporting limits, it is recommended that analytical services for total phosphorus analysis be moved from the current lab in Fredericton to one which offers the same colorimetric method but with a lower reportable detection limit. The purpose of the move is to secure the analytical service best suited for the needs of the monitoring program.

APPENDIX C. VOLUNTEER WATER QUALITY MONITORING PROGRAM

The water quality monitoring program established for Kings County is designed to gather empirical data which can be used to check the accuracy of the Kings County Lakeshore Capacity model predictions. It is also used to track levels of other constituents such as pH, alkalinity, conductivity and turbidity which can be used to assess the effects of anthropogenic influences (acid precipitation, road de-icing, construction) and colour and dissolved organic carbon which play a role in the biological response of a water body to nutrient loading.

The program design incorporates the ability to:
1. Gather data which is representative of ambient conditions,
2. Operate over the long term to determine existence of trends,
3. Gather information which can be used to calibrate the model on the undeveloped or control lake (Hardwood Lake),
4. Gather information which can be used to calibrate the model on the developed lakes,
5. Provide information to improve the accuracy of model predictions,
6. Assess the status of lake water quality in reference to water quality objectives, and
7. Support stewardship initiatives of the public.

The process of designing a water quality monitoring program to satisfy the conditions listed above involves the consideration of logistics, accuracy, and cost. A critical component of any water quality monitoring program is consistency - consistency in sample collection and handling techniques; consistency in laboratory methods. As previously discussed, for one reason or another, the latter has proven problematic.

Volunteers have been extremely diligent in administering the water sample collection and handling protocols established for the monitoring program as described in the Kings County Volunteer Lake Water Quality Monitoring Program Reference Manual. This manual was produced in 1998 by the Implementation Committee for the monitoring program.

There are, however, a few minor refinements to the protocol that are recommended. They are:

1. Because the Secchi depth is used to determine the depth at which water samples are collected, it is important to perform the measurement and the rinsing of water sample bottles from positions in the boat so that any disturbance to the water column resulting from these activities does not affect the quality of water sample being collected. This simply means using both the front and rear or opposite sides of the boat to perform these individual tasks.

2. When ever possible, a flat-bottomed boat should be used. This style of boat offers greater stability that that of a canoe, for example. It also allows a volunteer to get closer to the water surface when taking Secchi depth measurements.

3. To reflect current efforts, the list of lakes being monitored in Table 4 in the manual should be up-dated.

4. In reference to the “analysed within 24 hours of collection” statement under “Lab Analysis” on page 2-14, it is important that samples reach a lab as soon as possible after collection. The 24 hour timeframe is important for a few parameters like pH and alkalinity. For the remainder, samples are stable under proper preservation and storage conditions for several days or weeks. The word “analysed” should be changed to “delivered” in this sentence.

C.1 Sampling Station Locations and Sampling Frequency

C.1.1 Lake Monitoring Stations

The traditional approach to selection of sampling locations in lakes is to position monitoring sites at the deepest point of a lake. Depending on lake morphology, it is possible that more than one deep-lake station is necessary in order to avoid the possibility of documenting localized water quality instead of a lake average.

For all lakes in the Kings program, a single monitoring station in each lake has been identified. The stations are positioned at the deepest points of each lake. Several of the lakes, however, have large irregular basin shapes which may result in spatial differences in water quality. Black River Lake, in particular, is a long narrow water body with at least three distinctive lake basins. It is recommended that spatial variability be investigated in Black River Lake through the collection of water samples from the deep station in all three lake basins during Spring turnover.

For logistical and safety reasons, water samples have been retrieved from locations other than the designated deep-lake station. Granted, some information is better than no information. However, to be consistent, it is essential that water collection for individual lakes be conducted at the same lake station.

The practice of marking sampling stations each monitoring season with a buoy attached to a secured line is excellent. Fixed positioning guarantees seasonal consistency for water sample collection and it also saves the volunteer time. In order to reduce potential year to year variability in the positioning of the marker buoy, positioning with the assistance of GPS is recommended.

C.1.2 Sampling Frequency

At the present time, lakes are sampled on a monthly basis during the ice-free season (May-October). This sampling regime should continue. Data records indicate that there are periodic gaps for some lakes. It is important that all of the lakes being monitored receive the same sampling effort. Doing so ensures continuity between lake-datasets which is crucial to the interpretative process. Gaspereau and Tupper lakes are the two water bodies with incomplete data records.

C.1.3 Water Sample Depths

Water samples representing the euphotic zone are made up of a 1:1 mixture of two water column depths - 0.25 m and 2 times the Secchi depth (or 1 metre above bottom, whichever is closer to surface). For the majority of lakes currently being monitored this sampling approach using a single lake station provides a close representation of average whole-lake water quality. However, for the deeper water bodies (Aylesford Lake, Gaspereau Lake, Black River Lake, and Lumsden Pond) this may not be the case. For these lakes, up to 75 percent of the water column is not being considered. In the absence of a stratum-volume breakdown, it is not possible to comment on what this translates into in terms of a percentage of total lake volume. If none of these lakes thermally stratify, sampling in this manner may not be an issue. However, for those that do stratify, and depending on the volume of the lake below the maximum sampling depth, it may.

The following procedure is recommended to quantify the potential implications. Prepare a volume-weighted sample made up of water from at least 3 depths at least once during the thermally stratified period of the sampling season (July to September) for the deeper lakes for comparison with the normal two-depth sampling method. It will be necessary to calculate stratum volumes for volume-weighting of water samples. The stratum interval for this exercise will typically depend on the contour interval used to generate the bathymetric map. For the lakes in question, the necessary lake bathymetry is available. This procedure should be carried out for at least the 2009 monitoring season. Results of this investigation will indicate whether or not changes to the current 2-depth sampling method for these deeper lakes are necessary for subsequent monitoring seasons.

C.2 Laboratory Services

All water samples collected from the study lakes have been processed through the Environmental Services lab (ES) at the QEII Health Services Centre since the program start-up in 1997.

Laboratory analyses being performed for the monitoring program include:

pH, alkalinity, total nitrogen, color, conductivity, turbidity, dissolved organic carbon, total phosphorus, ortho-phosphorus, chlorophyll$_a$ and phaeophytin.

With the exception of phosphorus and chlorophyll$_a$/phaeophytin analyses, which have been split between the ES lab and the Analytical Services (AS) lab of the New Brunswick Department of Environment in Fredericton, all of the remaining analytical data were generated at the QEII facility and under the scope of its accreditation.

C.2.1 Total Phosphorus

Contrary to the understanding expressed in the 1997-2006 water quality summary report (Brylinksy 2007), total phosphorus analyses for the project were performed by the NB Environment lab from 2005 onward and not only for the 2005 monitoring season. The ES lab performed the test from 1997 through 2004. The decision by the Steering Committee to change labs was based in part on a decision by the ES lab to switch analytical methods from an automated ascorbic acid method (RDL of 2 ug L^{-1}) to an ICP-

MS method (RDL of 5 ug L^{-1}). For data continuity, the correct decision was made to switch to a lab which performed the test using similar chemistry and detection method.

The total phosphorus method at the AS lab is an automated ascorbic method (Standard Methods, 4500-PI - UV Irradiation; with modifications). This is a lab accredited method with a limit of quantification or reportable detection limit ("the lowest quantity of a substance that can be identified and quantitatively measured using an analytical method that has been validated with specified accuracy and precision"(NFRD, 2005)) of 5 ug L^{-1}. It is interesting to note that the ES lab utilized the same method using similar equipment but with a RDL of 2 ug L^{-1}. The difference in RDL's can be attributed to a number of reasons i.e., signal:noise ratio of the analytical instruments, cell path length.

C.2.2 Chlorophyll$_a$

Chlorophyll$_a$ analyses were performed by the ES lab until November 2005 after which the task was transferred to the AS lab. The main reason prompting the ES lab to drop the test from its parameter list was its inability to achieve accreditation. One of the hurdles encountered was the fact that there are a limited number of labs offering the test that are also willing to participate in proficiency testing required by the accrediting agency. The AS lab's accreditation issued by Canadian Association for Laboratory Accreditation Inc. (CALA, formerly the Canadian Associated of Environmental Analytical Laboratories, CAEAL) for its chlorophyll$_a$ method does not include proficiency testing for the same reason.

Samples submitted between 1997 and 2005 were analysed at the ES lab using a fluorometric method (10200H.3) as described in Standard Methods (1998), and in 2006, 2007, and 2008 at the AS lab using a spectrophotometric method (Standard Methods 10200H.2 1998). Both labs followed the same basic pigment extraction technique with a few minor modification differences. For example, instead of using a tissue grinder for the disruption of chlorophyll$_a$ from phytoplankton cells retained on the glass fiber filter, the ES lab uses an ultrasonic bath whereas the AS lab uses a shaker.

A noticeable shift in chlorophyll a results was observed in the year following the move from the ES lab to the AS lab. This occurrence was noted in the 2008 "draft" monitoring program annual report (Brylinsky 2008). In an effort to address the concerns subsequently raised by members of the Steering Committee and volunteer group regarding the validity of the data, an inter-lab investigation was conducted during the 2008 monitoring season. Preliminary findings of that investigation are presented in the following section.

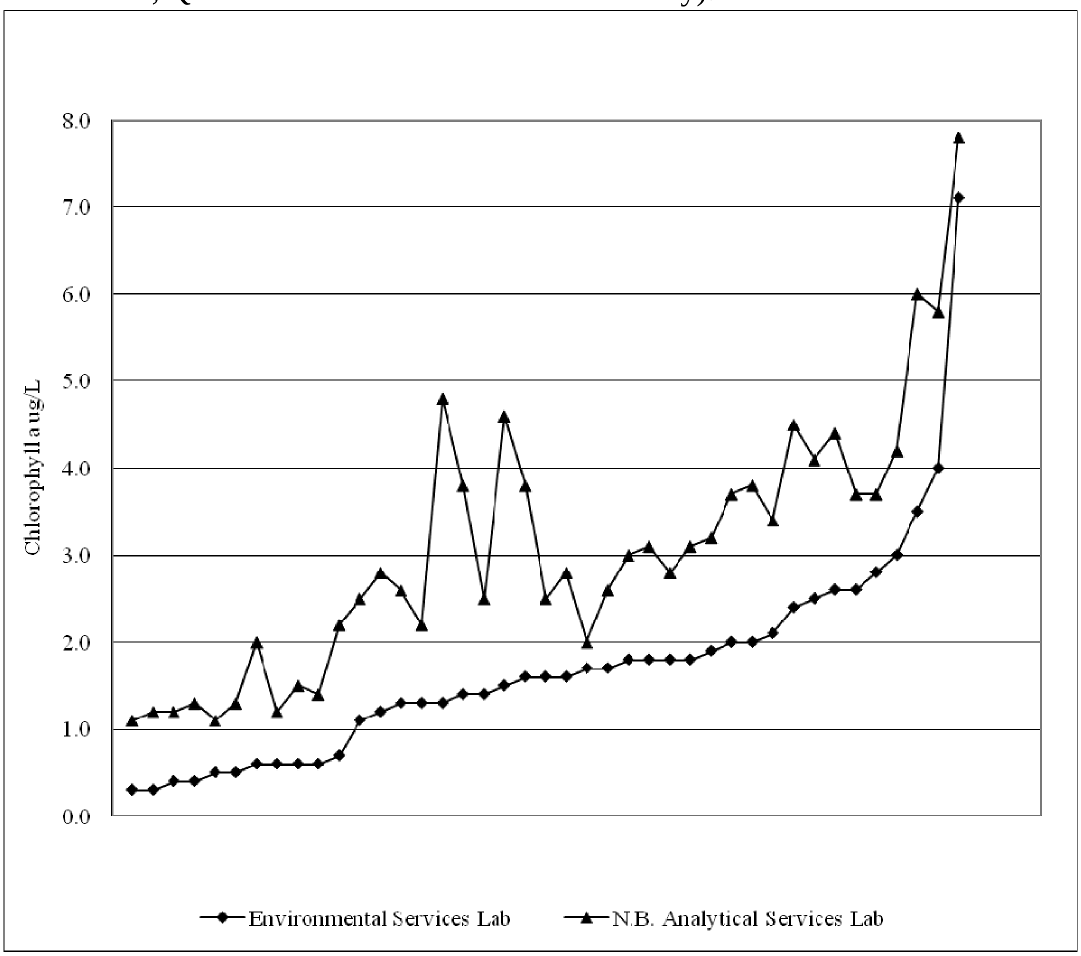
C.3 Inter-Laboratory Chlorophyll$_a$ Paired-Testing Study

Water samples for the inter-lab study were comprised mainly of field duplicates gathered by the Kings County volunteers as part of routine lake monitoring. Although not substantiated by the authors of this report, duplicate water samples from other lake monitoring programs operated by the Nova Scotia Department of Fisheries and Aquaculture and the Nova Scotia Department of Environment may have been included in the testing. The AS lab received its samples through the ES lab and results were compiled by ES staff. Standard sampling and handling protocols were applied. A total of 41 lake samples and 2 field blanks were submitted for testing.

Paired-results are illustrated in Figure C-1. Data are ordered from lowest to highest concentration.

It is obvious from Figure C-1 that there is a definite bias in the data with the spectrophotometric method producing consistently higher values. Neither method is accredited. This pattern is consistent with a review by Pinckney et al. (1994) in which the spectrophotometric method over-estimated actual values by 16%. Staff at the QEII lab continue to review the data.

Figure C-1. Inter-Laboratory Chlorophyll$_a$ Paired Testing Results (provided by H. MacDonald, QEII Environmental Services Laboratory).



Whereas the relationship between the two datasets is definitely not linear, it will be impossible to achieve absolute continuity between the two datasets through the application of a conversion factor(s). A further complication on the issue of deciding whether or not to retain chlorophyll$_a$ as a planning indicator is the fact that the equation used in the KCLCM describing the relationship between phosphorus and $chlorophyll_a$ is based on $chlorophyll_a$ data generated using a spectrophotometric technique (Dillon and Rigler 1974). This is not to say that the regression equation isn't appropriate in the Kings County case simply because of the preliminary findings of inter-lab study which indicate that the Fredericton lab's spectrophotometric technique produces results which are consistently higher than the QEII's fluorometric method. It is also not to say that all spectrophotometric methods are the same and that the method used to generate the data upon which the Dillon and Rigler equation is based would result in duplication of the Fredericton/QEII lab comparative plot (Figure C-1). Until such time that this matter is resolved, it is recommended that the spectohotometric method for $chlorophyll_a$ analysis be abandoned. To maintain consistency between the data produced during the first seven years of the monitoring program, any future $chlorophyll_a$ tests on the Kings County lakes should be done by fluorometry. The issue of consistency extends to the bulk of chlorophylla data in Nova Scotia. It is presumed that the majority of available information in the province originates with Canadian Wildlife Service National Park surveys, investigations of the Centre for Water Resources Studies, laboratory services provided by CWRS to Environment Canada and Parks Canada, Soil and Water Conservation Society of Metro Halifax studies, and QEII Environmental Services lab. A fluorometric technique common to all of these data was employed.

C.4 Laboratory Service Recommendations

C.4.1 General Water Chemistry (pH, alkalinity, total nitrogen, color, conductivity, turbidity, dissolved organic carbon)
Services provided by the ES lab at the QEII Health Services Centre appear satisfactory and should be continued.

C.4.2 Total Phosphorus

The foundation of the Kings County Lakeshore Capacity Model is total phosphorus (TP) and at the present time estimates of $chlorophyll_a$, which are based on phosphorus predictions, are instrumental in the municipal planning strategy. For these reasons it is imperative that the analytical method used is capable of generating results that are reliable. Phosphorus concentrations in the majority of the Kings County lakes under review, and elsewhere in Nova Scotia, are less than 10 ug L^{-1}. Because of this, it is essential that a low-range analytical method with a RDL in the order of 2 ug L^{-1} be used. The method currently employed by the lab performing the test has an RDL of 5 ug L^{-1}.

Only one lab was identified that was presently able to satisfy essential elements of the monitoring program. That is, this lab is accredited for the total phosphorus test, the test is a colorimetric method with similar chemistry with an acceptable RDL, and the location of the lab in regard to the QEII lab for the delivery of water samples is convenient. The lab in question is:

Maxxam Analytics
200 Bluewater Road, Bedford, NS Phone: (902) 420-0203.

Maxxam Analytics' Campobello, Ontario affiliate lab offers a TP method with a RDL of 2 ug L^{-1}. The method is described as APHA Method 4500 P-B (digestion method)/ 4500F (ascorbic acid colorimetric method) and uses the same chemistry and detection method currently in use by the Kings monitoring program.

In order to satisfy the RDL requirement, water samples would otherwise have to be shipped outside of the province. This responsibility would fall on the volunteer program. Because of sample holding times, water samples would have to be preserved prior to shipping. If for whatever reason the local option is not desirable, the alternative lab is:

ALS Canada
The ALS Canada Winnipeg, Manitoba affiliate lab (Phone: 204-255-9720) performs the TP test using a 1 ug L^{-1} RDL. Samples are digested using a sulphuric acid-persulphate mixture to convert organic phosphorus to orthophosphate. The samples are analyzed by either the Flow Injection Analysis (FIA) or the Segmented Flow Analysis (SFA) method. The absorbance measured by the instrument is proportional to the concentration of orthophosphate in the sample and is reported as phosphorus. Samples are analyzed for total or total dissolved phosphorus depending on the sample pretreatment (APHA, 1998). Ascorbic acid (RDL 5 ug L^{-1}) and stannous chloride (RDL 1 ug L^{-1}) are the particular chemistries on which the tests are based.

The ALS Dartmouth laboratory outlet is scheduled for closure and will no longer provide drop-off services. The specific date of the closure is not available, but was hinted to be within months. Without a local drop-off point, water samples will need to be preserved and shipped to Winnipeg by the volunteer monitoring program.

C.4.3 Chlorophyll$_a$

Fluorometry continues to be the most popular analytical technique for chlorophyll$_a$ analysis. It has been used to generate the majority of data in Nova Scotia as well as data used to establish trophic status categories. As of June 8, 2009, the fluorometric method used by the QEII lab to produce the first seven years of chlorophylla data for the Kings County Volunteer Monitoring Program is again being offered at the QEII lab. As a result, it is recommended that services for this test be transferred from the Fredericton lab to the QEII lab immediately.

C.5 Client-Laboratory Relationship

It is very important that an open line of communication between a client and laboratory personnel exists and remains active to ensure the consistency of a dataset is maintained. Laboratories are continuously taking steps to ensure its operations are providing the best service for their clients and to improve lab efficiency. Technological advances in the field of laboratory equipment plays a major role in this evolution. Changes to analytical methods typically follow refinements to "Standard Methods".

It is incumbent upon a lab to inform its clients of any alteration to lab procedure which has the potential to affect the consistency of data. Given that this client expectation is not normally adhered to, it is important that the client ask questions. It was clearly demonstrated by the Kings County data record that all tests are not the same. We suggest that the onus is on the lab to guarantee continuity between analytical methods. However, it is critical that the client ask questions of the lab in the event of data irregularities.

As part of the volunteer water quality monitoring program's standard operating procedures it is recommended that the lab(s) is contacted prior to each monitoring season to review analytical procedures for each of the tests being performed for the program.

C.6 Immediate Changes to Volunteer Monitoring Program

As a consequence of the QEII re-offering fluorometric testing for $chlorophyll_a$, it is recommended that analysis be resumed at the QEII lab immediately.

It is also recommended that total phosphorus analyses be carried out using a similar method to that currently employed but one with a lower Reportable Detection Limit. Maxxam Analytics, located in Bedford, Nova Scotia, is one such lab. If analyses for total phosphorus are transferred to the Bedford lab, it is also recommended that a duplicate sample set be submitted to the Fredericton lab on two occasions (spring, late-summer) for inter-lab comparison. The purpose of doing this is to establish a level of confidence in previous data generated at this lab. Duplicate water samples constitute aliquots from the same 2-depth lake composite. They are not two separate 2-depth composite samples which have been collected by repeating the routine sampling procedure a second time.

It is suggested that a comparative study be conducted that examines the potential implication of using a composite euphotic zone water sample to represent whole-lake water quality for Aylesford Lake, Gaspereau Lake, Black River Lake, and Lumsden Pond. Retrieval of two types of composite water samples from all study lakes on at least one occasion between July and September from the deep-station will be necessary. One of the samples is the current two-depth euphotic zone composite, while the second is a volume-weighted composite representing the entire water column and is made up of lake water collected from a minimum of three depths (top, middle, and bottom).