# 2009 WATER QUALITY INITIATIVE

## Prepared for: Muskoka Lakes Association

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**SUBJECT: Water Quality Initiative-Technical Report, Muskoka Lakes Association**

Dear Ms. Lewis:

RiverStone Environmental Solutions Inc. is pleased to provide you with the attached report.

Please contact us if there are any questions regarding the report, or if further information is required.

Best regards,

RiverStone Environmental Solutions Inc.

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## EXECUTIVE SUMMARY

The Water Quality Initiative (WQI) is a science-based monitoring program established by the Muskoka Lakes Association (MLA) that has just completed its ninth year of operation. The WQI program collects valuable data alongside local water quality programs run by other agencies. The scientific protocols for this program were initially developed by Dr. Neil Hutchinson of Gartner Lee Ltd. Beginning in 2009, MLA collaborated with RiverStone Environmental Solutions Inc. (hereafter RiverStone), a local environmental consulting company, for assistance with data analysis and the development of plans for Stewardship Initiative Groups based on local interests.

The results of the 2009 WQI monitoring program are presented in two reports. The 2009 Summary Report provides area specific information in a condensed format that includes the following components: area description, volunteer recognition, long term spring turnover and yearly mean phosphorus concentrations, long term total coliform and *E. coli* yearly means, 2009 data summary, trends and recommendations. This Technical Report provides a description of the program and scientific methods, and the detailed analysis and research conclusions for the past nine years of data collected by the MLA.

The Technical Report reviews the 2009 monitoring program data. Specifically, spring turnover phosphorus data indicates that only three of the areas sampled would be classified as mesotrophic or moderately enriched with nutrients, specifically phosphorus. The remainder of the areas can be classified as oligotrophic or nutrient poor, an indication of clean, clear water. Secchi disk data suggests that the water in most sampling areas has some degree of colouration resulting from dissolved organic carbon (DOC). The colouration of the water makes it difficult to use Secchi disk measurements as an indicator of nutrient level; however, the data can be used to look for long-term changes, as high nutrient concentrations are often related to reduced visibility.

The detailed analysis completed on the WQI monitoring data and described in this report was designed to answer a number of specific questions. First, can the data demonstrate a significant difference between nearshore and offshore phosphorus within lakes sampled (Lakes Muskoka, Rosseau, and Joseph)? Second, can the data demonstrate a significant difference between nearshore and offshore phosphorus within a specific lake (Lakes Muskoka, Rosseau, and Joseph)? Third, if any differences between nearshore phosphorus concentrations are detected, can they be attributed to a type of land use (urban, agricultural, etc.) or landform (wetland or creek)? In brief, the results of the analysis suggest the following. (1) Lakes Muskoka, Rosseau and Joseph all show the same long term trend for spring

turnover phosphorus concentrations indicating that these trends are highly influenced by global factors. With this much variability linked to broad-scale factors, it is a difficult task to identify more local impacts. The good news is that the long term trend in the MLA data is consistent with other long term data sets in Ontario indicating that for the most part phosphorus concentrations in our lakes is either decreasing or remaining stable. (2) In the areas sampled in the big three lakes at spring turnover, higher concentrations of phosphorus were found in the nearshore sites when compared to the deepwater sites. However, the movement of phosphorus from near the shore to deep water was potentially different for each area of the lakes: some areas had obvious differences between nearshore and deepwater phosphorus concentrations, whereas others exhibited minimal differences. (3) Overall, in the areas sampled in the big three lakes, higher concentrations of phosphorus were found at the nearshore sites when compared to the deepwater sites during the summer sampling period (Yearly Mean); however, even if the nearshore concentration was higher, it did not always affect the deepwater sites in the same way. (4) In terms of land use comparisons for the sites sampled in the big three lakes, higher concentrations of phosphorus were found in sampling areas containing creek outlets. However, interpretation of land use data should proceed cautiously as the findings may be biased by incorrect classification of land uses at some sites.

The long term *E. coli* data were also analyzed for trends. The results suggest that overall, the concentrations of *E. coli* for the sites sampled in the big three lakes are well below the MLA suggested limit of 10 cfu/100mL and lake water is safe for recreational purposes at these sites. There appears to be a direct relationship between the average concentration of *E. coli* found at the nearshore sites and that found at the offshore sites.

In summary, the WQI monitoring program data shows a general decreasing trend over the past nine years in phosphorus concentrations in the big three lakes. The data indicates that in general the lakes sampled as part of the MLA's WQI program have consistently good water quality suitable for recreational purposes. The WQI through its monitoring program and support has allowed members of the lake communities to take an active role in monitoring water quality in their neighbourhood(s). Stewardship Initiative Groups can and have used the monitoring data as the foundation for ongoing remedial action plans, and as a basis for discussions with local governments on how to best protect our lakes and recreational water quality for the future.

**Table of Contents**

**EXECUTIVE SUMMARY ........ 1**
**1. INTRODUCTION ........ 7**
1.1. Purpose of the Water Quality Initiative ........ 8
1.2. Water Quality-Phosphorus Thresholds ........ 9
**2. PROGRAM DELIVERY AND METHODS ........ 11**
2.1. Program Implementers ........ 11
2.1.1. Water Quality Portfolio ........ 11
2.1.2. Staff ........ 11
Scientific Advisor ........ 12
Partnerships ........ 12
2.2. Training and Volunteer Roles ........ 12
2.2.1. Program Evaluation Survey ........ 13
**3. SCIENTIFIC METHODS ........ 14**
3.1. Sampling Schedule ........ 14
3.2. Sites ........ 14
3.3. Monitoring Parameters ........ 15
3.3.1. Phosphorus ........ 20
3.3.2. Total Coliform ........ 20
*3.3.3. Escherichia coli (E. coli)* ........ 21
3.3.4. Secchi Depth ........ 22
3.3.5. Temperature ........ 22
3.4. Quality Assurance/Quality Control ........ 23
3.4.1. Quality Assurance ........ 23
3.4.2. Phosphorus Quality Control ........ 23
3.4.3. Bacteria Quality Control ........ 25
**4. MONITORING PROGRAM RESULTS ........ 25**
4.1. WQI Data 2009 and Phosphorus Thresholds ........ 25
4.2. WQI data 2009 and Secchi Disk ........ 31
**5. RESEARCH PROGRAM RESULTS ........ 32**
5.1. Review of Long-term WQI Data ........ 33
5.1.1. Analysis of long term Phosphorus trend during Spring Turnover at deepwater sites ........ 34

5.1.2. Analysis of the nearshore/offshore effect on Phosphorus during Spring Turnover ......... 36
5.1.3. Analysis of the nearshore/offshore effect on Phosphorus during the summer ................ 39
5.1.4. Analysis of Phosphorus by Land Use (summer data) 2002–2009................................... 43
5.1.5. Nearshore/offshore analysis of *E. coli* data 2002–2009 ................................................. 46
5.1.6. Statistical Methods......................................................................................................... 50
**6. RECOMMENDATIONS AND CONCLUSIONS ................................................................ 52**
6.1. Specific Program Recommendations for 2010.................................................................... 52
**7. Conclusions ........................................................................................................................ 53**
**8. DEFINITIONS..................................................................................................................... 54**
**9. REFERENCES .................................................................................................................... 57**

**<u>List of Tables</u>**

**Table 1**. Sampling Windows for 2009 ........................................................................................ 14

**Table 2**. A List of all the sampled sites in 2009 and the parameters monitored at each site. Numbers indicate the number of samples and * indicates spring turnover samples were taken. .......................... 16

**Table 3**. Phosphorus Duplicates for 2009 Quality Control.................................................................. 23

**Table 4**. 2009 Spring Turnover (µg/L) comparison to threshold concentrations identified in the Muskoka Official Plan.......................................................................................................... 29

**Table 5**. Results of a 3-level linear mixed model of year regressed on annual spring turnover phosphorus concentrations at deepwater sites on Lakes Joseph, Muskoka, and Rosseau between 2002 and 2009. Data was log-transformed prior to analysis, thus the coefficients are presented on the log-scale. Each of the three lakes had differing 2002 baseline phosphorus concentrations (see graph below), hence, an overall non-log-transformed coefficient cannot be presented. Yearly changes in phosphorus concentration did not vary by lake on the log-scale.......................................................... 35

**Table 6**. Number of observations per year included in a 3-level mixed linear model evaluating yearly changes in spring turnover phosphorus concentrations at deep-water sites on Lakes Joseph, Muskoka, and Rosseau. Years with low Total numbers of observations (i.e., 2002 and 2007) will produce less accurate results in the analysis than years with higher numbers of observations. Years in which the observations were not evenly distributed between the lakes would have results based mainly on the lake with the highest number of observations. (e.g., results derived from 2007 data would have been mainly based on Lake Joseph data). ................................................................................... 36

**Table 7**. List of sites used in analysis of the effect of nearshore/offshore sites on phosphorus concentrations. The findings of the analysis can only be interpreted to be valid for these particular sites. ........................................................................................................................ 43

**Table 8.** Differences in the natural log of phosphorus concentrations (ln[P]) by land use type for summer samples. Estimates of the change in ln[P] are presented with their associated p-values in brackets below. Values in bold text are significant at the 95% level (n = 2,496). ................................ 44

**Table 9.** Number of land use samples by lake (samples = individual data points, site = sampling site and group = bay or basin). This information will give you an idea of what lakes were included in the analysis of each land use effect in the table above (e.g., data from Wetland/river sites were only available for Lakes Muskoka and Rosseau and, therefore, the findings can only be attributed to those sites). )........ 45

**Table 10**. Statistical methods used for data analysis:........ 50

**List of Figures**

**Figure 1**. ColiPlate with 11 blue wells........ 21

**Figure 2**. Secchi disk demonstration........ 22

**Figure 3**. Spring-turnover phosphorus concentrations for all deepwater sampling sites in 2009........ 28

**Figure 4**. Mean Secchi disk reading at deepwater sites over the summer sampling period for 2009. *Note sites that are based on a single spring turnover sample. Muskoka River data is based on (n=25) pooled data from all sampling sites........ 32

**Figure 5**. Predicted annual spring turnover phosphorus concentrations (base-10 scale) at deepwater sites on Lakes Joseph, Muskoka, and Rosseau from 2002 to 2009........ 35

**Figure 6**. Effect of proximity to shore on spring-turnover phosphorus concentrations for basins in Lake Joseph. Note STI (single nearshore site) and STN (2 years of data) have high data variation........ 37

**Figure 7**. Effect of proximity to shore on spring turnover phosphorus concentrations for basins in Lake Muskoka. Note the BOY and ELG results are based on only one year of data (one offshore sample and three nearshore samples) and so may be inaccurate........ 38

**Figure 8**. Effect of proximity to shore on spring turnover phosphorus concentrations for basins in Lake Rosseau. Note the ART, MGN, and MLG results are based on only one year of data (one offshore sample and three nearshore samples) and so may be inaccurate........ 39

**Figure 9**. Predicted summer phosphorus concentration by basin in Lake Joseph between 2002 and 2009........ 41

**Figure 10**. Predicted summer phosphorus concentration by basin in Lake Muskoka between 2002 and 2009........ 42

**Figure 11**. Predicted summer phosphorus concentration by basin in Lake Rosseau between 2002 and 2009........ 42

**Figure 12**. Predicted summer *E. coli* (cfu/100mL) concentration phosphorus concentration by basin in Lake Muskoka between 2002 and 2009........ 48

**Figure 13**. Predicted summer *E. coli* (cfu/100mL) concentration phosphorus concentration by basin in Lake Rosseau between 2002 and 2009........ 48

**Figure 14**. Predicted summer *E. coli* (cfu/100mL) concentration by basin in Lake Joseph between 2002 and 2009........ 49

## List of Appendices

**Appendix A**. 2009 Data sheets.

**Appendix B**. MPN Table.

# 1. INTRODUCTION

The Muskoka Lakes Association (MLA) is an approximately 3,000-member, non-profit organization that has represented seasonal and permanent residents of Muskoka for nearly 112 years. The MLA's Mission Statement "to promote the responsible use, enjoyment and conservation of the unique Muskoka environment" and its Vision "that, through the achievement of our mission, present and future generations will benefit from our efforts" reflect the goals of this long-time organization.

In 2008, the MLA developed Strategic Planning directives directly related to the Water Quality Portfolio consisting of "water quality initiatives including testing" and "involvement in big picture environmental issues of land use that are precedent setting and have implications on other land uses in our area." The Water Quality Portfolio worked within these directives to complete the 2009 Water Quality Initiative following the principles of the MLA: integrity, respect, responsibility, accountability, and volunteerism.

The Water Quality Initiative (WQI) began as a formal, scientifically based ecological-monitoring and lake water-quality research program in 2001, with a pilot phase led by Dr. Neil Hutchinson of Gartner Lee Ltd. The development of the program was based on a review of the monitoring programs carried out by the Ministry of the Environment (MOE) and the District Municipality of Muskoka (DMM) at that time and on the premise that the nearshore of lakes is biologically important, and used by residents, and highly visible. The program was designed to "potentially reveal relationships between land use and nearshore water quality and could potentially generate results which could guide future management and stewardship activities." The studies were designed to determine if there was a difference in algae, phosphorus, or bacteria between nearshore and offshore sites and to determine if there were differences in these three parameters when highly developed sites were compared to low density or natural shoreline areas. Detailed descriptions of the study design are in the 2001 and 2002 MLA reports prepared by Gartner Lee Limited.

Between 2003 and 2008, the research/monitoring program continued to grow with an increase in the number of lakes and sites sampled. The algae sampling portion of the program was discontinued due the inconclusive nature of the data, and over the years, sampling methods were modified to fit the needs of the program. In 2007, additional monitoring efforts were directed towards specific lakes and bays classified as "over-threshold" by the DMM. The research objective of this effort was to "determine the sources of phosphorus loading and other contaminants in these areas."

The other aspect of the MLA program was to promote responsible use of the resources in Muskoka. Increased volunteer involvement and community stewardship activities reveal the popularity and the success of the program. Outside of the monitoring and research programs, volunteers are pioneering local Stewardship Initiatives to improve the lakes and watersheds in their immediate communities.

In the spring of 2009, the MLA retained RiverStone Environmental Solutions Inc. to assist with its WQI and Stewardship Initiative objectives. While RiverStone was not directly involved in the objectives and protocols for 2009, we had ongoing communications with the Water Quality Portfolio and volunteers, attended a training session, and reviewed the reports and manuals to familiarize ourselves with the program. RiverStone reviewed the data, as it became available, and noted sites with unusual measurements. Preparation of this document included a review of the historical WQI reports, an examination of the 2001–2009 data collected by the MLA, and a review of the current DMM and Lake Partner Program (LPP) data and sampling methods. The purpose of this Technical Report is to evaluate and, where possible, analyse the long-term data collected since 2001; to report on the research and monitoring findings; and to review the program methods. A second report titled "Water Quality Initiative Monitoring Program–Summary Report" provides summary data for each of the areas sampled in 2009.

## 1.1. <u>Purpose of the Water Quality Initiative</u>

> "The primary purpose of the MLA WQI monitoring program is to discover the *source* of problems, identified both by DMM modelling and community members. This is accomplished through monitoring over a longer season (Victoria Day to Labour Day) in the deepwater as well as the near shore zone of a number of lakes and bays. Results of monitoring in the nearshore zone are compared to comparable deepwater monitoring results to indicate land-based problem sources.
>
> The secondary purpose of WQI monitoring is to identify problems in areas where the DMM program cannot monitor due to limited resources or political jurisdiction. WQI monitoring can also provide additional evidence supporting regulation of vulnerable areas within Muskoka that should be protected. Monitoring is therefore concentrated in three types of areas:

- lakes and bays with problems identified by DMM;
- lakes and bays where past WQI data indicates a problem; and
- lakes and bays where DMM does not monitor."

**Citizens' Environment Watch, 2009**

## 1.2. Water Quality-Phosphorus Thresholds

The Ministry of the Environment (MOE) is responsible for provincial surface water quality. Its goal for surface water management is to "ensure that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation." Phosphorus is one of the most commonly used indicators of water quality as excess concentrations of this essential nutrient can decrease the aesthetic qualities of a lake by increasing plant and algae growth. The present MOE guideline, developed in 1979, is a two-tiered approach with thresholds set at 10 and 20 µg/L. The current thresholds provide guidance for planners when making planning decisions that could potentially affect lake water quality. Presently, the Province allows additional shoreline development to occur until a lake reaches the upper threshold of its category. According to limnologists, professionals that study inland water systems and their biology, lakes with concentrations of phosphorus of less than 10 µg/L can be classified as oligotrophic (Level 1–nutrient-poor) and those between 10 and 20 µg/L are mesotrophic (Level 2–mid-range). The MOE has recognized that this approach, while protecting water quality, does not "maintain the existing diversity in the clarity of water of Precambrian Shield lakes." The Province's new Lakeshore Capacity Assessment Handbook: Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield (Draft 2007) proposes a new approach to lake management with respect to phosphorus.

While the Province's phosphorus recommendations are not finalized, the DMM has taken a proactive approach to setting phosphorus "threshold" values for lakes in order to protect the diversity and recreational water quality. This progressive approach incorporates two new concepts. First, it considers development on lakes upstream and downstream from the candidate lake in a watershed. Second, it evaluates proportional phosphorus increases based upon conditions prior to human influence (a similar method has been advocated in the Lakeshore Capacity Assessment Handbook (MOE, 2007)). This requires the calculation of the pre-development phosphorus concentration or biological condition in each lake using Muskoka's Recreational Water Quality Model. Development may then be allowed to increase phosphorus concentration by a fixed percentage from that baseline. The District has selected an increase of 50% as the "threshold" to allow reasonable levels of development with little impact on water clarity or dissolved oxygen regimes. For example, if a lake was calculated originally to have had 4 µg/L phosphorus, development would be allowed to increase that to 6 µg/L. A lake calculated to originally have 8 µg/L would be permitted to increase to 12 µg/L. This approach will help to maintain a diversity of water quality across lakes in Muskoka. This method also permits reasonable levels of development on lakes which have large capacities (i.e., are considerably under-threshold), with more strict development practices on lakes that have been classified as over-threshold. This approach will provide a reasonable level of protection of the recreational water quality in the Muskoka Lakes.

A lake in the DMM is determined to be “over-threshold” if (1) the predicted phosphorus concentration exceeds the background plus 50%, when the lake is modelled based on the existing land use; and (2) the actual measured concentration of phosphorus exceeds the background plus 50% threshold concentration. In addition to a threshold value, each lake is assigned a level of **sensitivity** (low, moderate and high), which is based on a lake’s **responsiveness** to the load of phosphorus from the surface and the **mobility** of phosphorus from the watershed into the lake (based on soils). Lakes that are highly responsive and have high phosphorus mobility in the watershed are categorized as being highly sensitive. Lakes that are over-threshold and have high sensitivity will have limited development opportunities. All other lakes in the DMM have development opportunity, provided the appropriate studies are completed and development follows conditions outlined by the District’s Lake System Health Program.

There are always questions about how well the Muskoka Water Quality Model predicts the true baseline condition. It must be recognized that despite the model being based on sound science and being “fully calibrated with actual results of measured water quality from the DMM’s water quality program” (Hutchison, 2009-letter provided), it is just a model and should be used as a tool. As with any model used to generalize predictions for a large and diverse population—in this case lakes—it will have a margin of error and will not be perfect for all lake types. For example, the Muskoka Model does not work well for dark-coloured lakes or shallow water bodies. Sediment core sampling is the only accurate method to determine or confirm the true, natural phosphorus level for a given lake through the analysis of diatoms found in each sediment layer. In this manner, the lake phosphorus concentration over the last 100 to 200 years can be determined in an accurate manner to provide a realistic baseline prior to development. While the potential is high for sediment cores to provide a more accurate phosphorus history in any lake, the method is quite costly in comparison and is therefore applied in selective cases.

For those concerned with where their lake lies with respect to the modeled threshold concentration, it should be noted that any lakes that have phosphorus values less than 20 µg/L are highly unlikely to have blue-green algae blooms (Patterson, 2009-presentation). Algae blooms are one of the major concerns to waterfront residents as they can affect recreational activities, aesthetics, and drinking water quality. While blue - green algae are typically present in our lakes, an oversupply of nutrients, especially phosphorus, can result in excessive growth of blue-greens if the “right” conditions occur.

**Take Home Message**

Based on this discussion, it is important to understand that just because a lake is considered “over-threshold,” it does not necessarily mean that there is an immediate water quality concern from a biological perspective. It may only mean that actual measured values in that lake are 50% higher than the modelled baseline value (before human development), but when compared to phosphorus concentrations that would promote algae blooms, the values are not a concern. What the “over-threshold” value does suggest is that landowners need to be proactive in promoting and practicing good shoreline stewardship to ensure that each individual is not pushing that value higher, possibly to the point where water quality does becomes an issue.

# 2. PROGRAM DELIVERY AND METHODS

## 2.1. Program Implementers

The WQI would not be possible without a dedicated team of volunteers and staff. During the review of this program, RiverStone was impressed by the number of hours and dedicated efforts that volunteers and staff have contributed. The following provides a brief description of those involved. We have tried to include all those known to us, but are certain to have missed someone. Our congratulations to all of those mentioned and those not; this would not be the program what it is, without you!

### 2.1.1. Water Quality Portfolio

The WQP is one of four portfolio of the MLA. The following is a list of the dedicated volunteers that make up the Portfolio: Brian McElwain, Eleanor Lewis (Chair), Nick Kristoff, Lola Bratty, Mike Logan, Megan Mollard, Gord Ross, Peter Seybold, Janet Palmer, Mike Bidwell, Mike Muffels, Louise Cragg, Susan Murphy, and Andrew Watson.

### 2.1.2. Staff

Andrew Watson was hired as the Water Quality Field-Work Coordinator from April to October 2009. Cheryl Hollows and Lisa Noonan provided administrative support to the WQI. Mike Logan is recognized for his dedicated efforts with the WQI and for his role in passing on his valuable experience to Andrew for the 2009 field season.

**Scientific Advisor**

The monitoring/research program for the MLA WQI was originally developed by Dr. Neil Hutchinson of Gartner Lee Ltd. prior to the launch of the WQI in 2001. Dr. Hutchison continued to work with the MLA through 2003. Water Quality Initiative Reports were prepared by Michael Logan (Logan Environmental Consulting) between 2003 and 2008 and were peer reviewed by a variety of water quality experts including, Bev Clark (Coordinator, Lake Partner Program, Dorset Environmental Science Centre), Karl Schiefer (Ph.D., Bluewater Biosciences, Mississauga) and Harvey Shear (Ph. D., Department of Geography, University of Toronto).

RiverStone was retained in the spring of 2009 to organize, analyze, and interpret the large amount of data that the MLA volunteers collected for the 2009 season, as well as the historical data. In addition, RiverStone provided support and direction for the Stewardship Initiative Groups.

**Partnerships**

Nine affiliates participated in the MLA WQI in 2009:

- Brandy Lake Association
- Bass Lake
- Clear Lake Association
- Leonard Lake Association (returning)
- Moon River Property Owners' Association
- Muldrew Lakes Association
- Silver Lake Association (Township of Muskoka Lakes)
- Star Lake Woods Association
- Sucker Lake Association (returning)

It is important that the MLA maintain the ongoing participation of existing Affiliates to ensure a creditable long-term water quality data set, and to gauge the interest of other local associations to facilitate early involvement in the WQI for 2010.

## 2.2. Training and Volunteer Roles

In 2009, the WQI began with two volunteer training sessions in May. In total 65 volunteers attended the training sessions. These sessions allow Team Leaders and volunteers to update their training and knowledge on an annual basis. Volunteer Recognition

On August 21, the MLA held a volunteer appreciation BBQ at Eleanor Lewis's house and certificates of appreciation for 5 years of volunteering with the WQI program were awarded to 20 people. These committed volunteers were Doug Applegath, Carol Ball, Doug Ball, Perry Bowker, Steve Burdick, Chris Cragg, Louise Cragg, Joanne Davey, Liz Denyar, Beth Guy, Peter Hemming, Mark Johnstone, Bev Manchee, Gord Ross, Dirk Soutendijk, Al Ward, Carol Ward and John Wood.

### 2.2.1. Program Evaluation Survey

An online survey provided through Survey Monkey was available to volunteers to evaluate the 2009 WQI Program. Thirty-six responses were received, nearly twice that of last year. Survey responses were positive and offered the MLA some important feedback and suggestions to better the program for 2010. A summary of the comments are as follows:

***Team Size****:* Most responses indicated that team size was appropriate with about two to three volunteers per team. Some individuals did state they were short on volunteers and two said they had too many.

***Training****:* Many of the survey questions pertained to the training sessions. All responses indicated that the locations for the training sessions where appropriate and most volunteers made it to one of the training days. Some people commented that the day seemed rushed with volunteers signing in as the session was running. Returning and new volunteers agreed it would be beneficial to have demonstrations on how to use some of the equipment. There were numerous requests to provide a demonstration on how to read an incubated Coliplate. Most volunteers enjoyed having last year's results explained, but would like to see more description of the goals and objectives of the program.

***Equipment****:* Most responses were positive about the equipment; however, 25% of the volunteers had some difficulty. The comments included improper weighting of the Secchi disk, broken or not enough bottles for sampling, and difficulties with maintaining incubation temperature for the Coliplates. Some volunteers indicated that it was difficult to read the maps with sample site locations and recommended updating them with clearer and more up-to-date maps.

***Sample Drop Off****:* A new sample drop-off system was implemented for 2009. Most volunteers indicated that they preferred the new approach and supported the code system that allowed for more flexibility in drop-off time. Some participants in the southern end of the program area recommended an additional drop-off location or suggested having monthly drop-offs instead.

***Time Commitments****:* When asked about responsibilities and time requirements associated with volunteering with the WQI program, all agreed that the time commitment required was reasonable and they were happy to assist with the program. Most indicated they were willing to volunteer with the program again in 2010.

***Sampling Locations****:* Several volunteers questioned the appropriateness of some sample locations and expressed a desire to review sampling locations for 2010 to meet volunteer needs and better sample areas of environmental concern.

## 3. SCIENTIFIC METHODS

### 3.1. Sampling Schedule

During the 2009 WQI, sampling occurred on a biweekly schedule between May 15–18 and August 25–25 (**Table 1**). Eight sampling dates were established during this period. The dates were selected based on the availability of volunteers and to ensure an early-spring sample could be taken. Sample 1 was collected prior to lake stratification and provided a measurement of phosphorus during spring turnover.

**Table 1. Sampling Windows for 2009**

| Sample | Sampling Window |
|---|---|
| - Spring Turnover | May 15–18 |
| 2 | May 29–June1 |
| 3 | June 12–15 |
| 4 | June 26–29 |
| 5 | July 10–13 |
| 6 | July 24–27 |
| 7 | August 7–10 |
| 8 | August 21–24 |

### 3.2. Sites

The establishment of sites sampled for the 2009 data set occurred over a number of years starting in 2001. In 2002, seventy sites in Lakes Joseph, Rosseau, and Joseph, and Brandy Lake were established under the direction of Dr. Neil Hutchison. Sites were selected in deep-water locations to represent the average offshore conditions and selected in the nearshore based on their proximity to certain land uses. In 2002, seventeen groups/areas of sampling sites were identified. Each group had a number of sites clustered around a targeted land use, as well as an offshore/deepwater site intended to represent an "average" condition. Between 2002 and 2009, the monitoring program expanded to include many additional sites that were selected based their proximity to specific land uses (residential, golf courses, urban areas etc.). A summary of the adjacent land use is provided by sampling site in (**Table 2**). In 2009, the sites for each sampling area were again predetermined, with the number of sites sampled limited by volunteer participation. Volunteers were provided with a Google Map having satellite imagery with their sites marked, as well as digital photographs of each site. There were two types of sites: nearshore and offshore. Nearshore sites were located where the water depth was between 50 cm and 150 cm as this is the depth in which most recreational use occurs and is a good water/land interface. Offshore sites were located in deep water near the centre of the sampling area to ensure that the site was outside of the potential influence of nearshore land use factors (e.g. lake or bay).

"Bacteria monitoring was maintained in the nearshore zone, with total phosphorus monitoring in the deepwater zone. Nearshore phosphorus monitoring was also undertaken in areas that have been identified as 'over-threshold' by DMM as well as areas that are not monitored by DMM but previous WQI data suggest fit the 'over-threshold' criteria."—Citizens' Environment Watch, 2009.

### 3.3. Monitoring Parameters

The following methodologies were documented in the 2008 WQI Monitoring Program Technical report (CEW, 2009). Modifications were made as required to update the protocols and for clarity.

During the 2009 WQI sampling program, the following parameters were used as indicators of water quality:

- Total Phosphorus: Spring turnover and yearly mean (summer sampling)
- Bacteria: Total coliform and *E. coli*
- Secchi Depth
- Temperature

The parameters measured at each sampling date were also predetermined based on the rationale for the site location. Volunteers followed the Field Manual in measuring these parameters. In addition, supplementary information was also recorded on the datasheet (see **Appendix A**). **Table 2** provides a list of sampling sites and the parameters measured.

**Table 2. A List of all the sampled sites in 2009 and the parameters monitored at each site. Numbers indicate the number of samples and * indicates spring turnover samples were taken.**

| Lake | Lake Sites | Site | Land Use | Phosphorus | Bacteria | Secchi Depth | Temp |
|---|---|---|---|---|---|---|---|
| Brandy Lake | Brandy Lake | BDY-0 | Offshore | 1* | | 8 | 7 |
| | | BDY-1 | Creek or wetland | | 8 | | 8 |
| | | BDY-2 | Residential | | 8 | | 8 |
| | | BDY-3 | Residential | | 8 | | 8 |
| | | BDY-5 | Residential | | 8 | | 8 |
| | | BDY-6 | Wetland | | 8 | | 7 |
| Clear Lake (TML) | Clear Lake (TML) | CLR-0 | Offshore | 8* | | 8 | |
| | | CLR-1 | Residential | 7* | 8 | | 8 |
| | | CLR-2 | Residential | 8* | 8 | | 8 |
| | | CLR-3 | Residential | 8* | 8 | | 8 |
| | | CLR-4 | Residential | 8* | 8 | | 8 |
| Indian River | Indian River | IND-0 | Offshore | 1* | | 8 | 8 |
| | | IND-1 | Residential | | 8 | | 8 |
| | | IND-2 | Unknown | | 8 | | 8 |
| | | IND-3 | Unknown | | 8 | | 8 |
| | | IND-4 | Unknown | | 8 | | 8 |
| Joseph River | Joseph River | JOR-0 | Offshore | 8* | | 7 | 8 |
| | | JOR-1 | Residential | 8* | | | 8 |
| | | JOR-2 | Residential | 8* | | | 8 |
| | | JOR-3 | Residential | 8* | | | 8 |
| | | JOR-4 | Residential | 8* | | | 8 |
| Little Lake Joe | Little Lake Joe | LLJ-0 | Offshore | 8* | | | 6 |
| | | LLJ-6 | Wetland | | 4 | | 4 |
| | | LLJ-7 | Residential | | 4 | | 4 |
| | | LLJ-8 | Residential | | 4 | | 4 |
| | | LLJ-9 | Offshore | | 4 | | 4 |
| | | LLJ-10 | Offshore | | 4 | | 4 |
| | | LLJ-11 | Offshore | | 4 | | 4 |
| Lake Joseph | Cox Bay | COX-0 | Offshore | 7* | | 8 | 7 |
| | | COX-1 | Golf Course (Lake Joe) | 8* | 8 | | 8 |
| | | COX-2 | Golf Course (Lake Joe) | 8* | 8 | | 8 |
| | | COX-3 | Town (Port Sandfield) | 8* | 8 | | 8 |
| | | COX-4 | Resort (Pinelands) | 8* | 8 | | 7 |
| | Foot's Bay | FTB-0 | Offshore | 6* | | | 5 |
| | | FTB-3 | Marina | 6* | | | 5 |
| | Gordon Bay | GNB-0 | Offshore | 1* | | 1 | 1 |
| | Hamer Bay | HMB-0 | Offshore | 8* | 8 | 8 | 8 |
| | | HMB-1 | Marina / Creek (GC Rocky Crest) | 8* | 8 | | 8 |
| | | HMB-2 | Resort (Rocky Crest) | 8* | 8 | | 8 |
| | | HMB-3 | Resort (Rocky Crest) | 8* | 8 | | 8 |
| | | HMB-4 | Residential | 8* | 8 | 4 | 8 |
| | | HMB-5 | Creek | 8* | | | 5 |

| Lake | Lake Sites | Site | Land Use | Phosphorus | Bacteria | Secchi Depth | Temp |
|---|---|---|---|---|---|---|---|
| | Main Joseph | JOS-1 | Offshore | 8* | | 7 | 6 |
| | Still's Bay | STI-0 | Offshore | 5* | | | 6 |
| | | STI-2 | Creek (Golf Course?) | 5* | | | 6 |
| | Stanley Bay | STN-0 | Offshore | 8* | | 7 | 6 |
| | | STN-1 | Residential | 8* | | | 6 |
| | | STN-2 | Residential | 8* | | | 6 |
| | | STN-3 | Residential | 8* | | | 6 |
| Lake Muskoka | Arundle Lodge | ARN-0 | Offshore | 1* | | 1 | |
| | Bala Bay | BAL-0 | Offshore | 1* | | 1 | 1 |
| | Beaumaris | BMR-0 | Offshore | 7* | 8 | 7 | 8 |
| | | BMR-2 | Golf Course (BYC) | 7* | 8 | | 8 |
| | | BMR-3 | Town (Beaumaris) | | 8 | | 8 |
| | | BMR-5 | Golf Course (BYC) | 1* | 1 | | 1 |
| | | BMR-6 | Wetland (Golf Course-BYC) | 8* | 8 | | 8 |
| | | BMR-7 | Residential | 8* | 8 | | 8 |
| | | BMR-8 | Park | 7 | 7 | | 7 |
| | Boyd's Bay | BOY-0 | Offshore | 8* | 8 | 8 | 8 |
| | | BOY-1 | Residential | 8* | 8 | | 8 |
| | | BOY-2 | Residential | 8* | 8 | | 8 |
| | | BOY-3 | Marina | 8* | 8 | | 8 |
| | Dudley Bay | MUS-2 | Offshore | 1* | | 1 | 1 |
| | East Bay | EAS-0 | Offshore | 8* | 8 | 7 | 8 |
| | | EAS-1 | Undeveloped | 8* | 8 | | 8 |
| | | EAS-2 | Undeveloped | 7* | 8 | | 8 |
| | | EAS-3 | Undeveloped | 8* | 8 | | 8 |
| | Eilean Gowan | ELG-0 | Offshore | 1* | | 8 | 8 |
| | | ELG-1 | Residential | | | | |
| | | ELG-2 | Residential | | | | |
| | | ELG-3 | Residential | | | | |
| | Main Muskoka | MUS-3 | Offshore | 1* | | 1 | 1 |
| | | MUS-1 | Offshore | | | 1 | 1 |
| | Muskoka Bay | MBA-0 | Offshore | 8* | 7 | 8 | 8 |
| | | MBA-2 | Resort (Muskoka Center) | 8* | | | 8 |
| | | MBA-3 | Residential | 8* | 8 | | 8 |
| | | MBA-4 | Town (Gravenhurst) | 8* | 8 | | 8 |
| | | MBA-5 | Town (Gravenhurst) | 8* | 8 | | 8 |
| | | MBA-7 | Residential | 8* | | | 8 |
| | | MBA-8 | Residential | 8* | | | 8 |
| | | MBA-9 | Residential | 8* | | | 8 |
| | | MBA-10 | Town (Gravenhurst) | 8* | | | 8 |
| | Muskoka Sands | MSN-0 | Offshore | 7* | 8 | 8 | 8 |
| | | MSN-1 | Resort (Muskoka Sands) | | 8 | | 8 |
| | | MSN-2 | River Outlet / Golf Course (Taboo) | | 8 | | 8 |
| | | MSN-3 | Residential | | | | |
| | | MSN-4 | River (Hoc Roc) | | 8 | | 8 |
| | North Bay | NRT-0 | Offshore | 1* | | 1 | 1 |
| | Stephen's Bay | STE-0 | Offshore | 1* | | 1 | 1 |

| Lake | Lake Sites | Site | Land Use | Phosphorus | Bacteria | Secchi Depth | Temp |
|---|---|---|---|---|---|---|---|
| | Walker's Point | WAK-0 | Offshore | 1* | | 1 | 1 |
| | Whiteside Bay | WTS-0 | Offshore | 1* | | 1 | 1 |
| | Willow Beach | WLB-0 | Offshore | 8* | 8 | 8 | 8 |
| | | WLB-1 | Resort (Touchstone) | 8* | 8 | | 8 |
| | | WLB-2 | Resort (Touchstone) | 8* | 8 | | 8 |
| | | WLB-3 | Creek/Golf Course (Kirie Glen) | 8* | 8 | | 8 |
| Lake Rosseau | Arthurlie Bay | ART-0 | Offshore | 1* | | 1 | 1 |
| | Brackenrig Bay | BRA-0 | Offshore | 8* | | | 7 |
| | | BRA-1 | Residential | 8* | | | 7 |
| | | BRA-2 | Residential | 8* | | | 7 |
| | | BRA-3 | Residential | 8* | | | 7 |
| | Mid Rosseau | ROS-1 | Offshore | 1* | | 1 | 1 |
| | Minett | MIN-0 | Offshore | 7 | 7 | 7 | 7 |
| | | MIN-1 | Resort (Cleveland's House) | | 7 | | 7 |
| | | MIN-4 | Resort (Red Leaves)/Golf Course (The Rock) | | 7 | | 7 |
| | | MIN-5 | Residential/Golf Course (The Rock) | | 7 | | 7 |
| | Morgan Bay | MGN-0 | Offshore | 8* | 8 | 8 | 8 |
| | | MGN-1 | Residential | 7* | 8 | | 8 |
| | | MGN-2 | Residential | 8 | 8 | | 8 |
| | | MGN-3 | Wetland | 8 | 8 | | 8 |
| | | MNG-4 | Creek | 8 | 8 | | 8 |
| | Muskoka Lakes GCC | MLG-0 | Offshore | 1* | | 1 | 1 |
| | Portage Bay | POR-0 | Offshore | 7* | | 8 | 8 |
| | | POR-1 | Agricultural | 8* | | | 8 |
| | | POR-2 | Residential | 8* | | | 8 |
| | | POR-3 | Agricultural | 8* | | | 8 |
| | | POR-4 | Residential | 8* | | | 8 |
| | | POR-5 | Residential | 8* | | | 8 |
| | Rosseau (north) | RSH-0 | Offshore | 8* | 8 | 8 | 8 |
| | | RSH-2 | River (Shadow) | 8* | 8 | | 8 |
| | | RSH-3 | Town (Rosseau) | 8* | 8 | | 8 |
| | | RSH-4 | Town (Rosseau) | 8* | 8 | | 8 |
| | Royal Muskoka Island | RMI-0 | Offshore | 1* | | 1 | 1 |
| | Tobin's Island | TOB-0 | Offshore | 1* | | 1 | 1 |
| | Windermere | WIN-0 | Offshore | 8* | 7 | 7 | 8 |
| | | WIN-1 | River (Dee) | 8* | 7 | | 8 |
| | | WIN-3 | Creek (Culvert)/Golf Course (Windermere) | 8* | 7 | | 8 |
| | | WIN-4 | Resort (Windermere)/Creek (Culvert) | 7* | 7 | | 8 |
| | | WIN-5 | Wetland | 8* | 7 | | 8 |

| Lake | Lake Sites | Site | Land Use | Phosphorus | Bacteria | Secchi Depth | Temp |
|---|---|---|---|---|---|---|---|
| Leonard Lake | Leonard Lake | LEO-0 | Offshore | 6* | 7 | 8 | 8 |
| | | LEO-1 | Residential | | 7 | | 8 |
| | | LEO-2 | Residential | | 7 | | 8 |
| | | LEO-3 | Residential | | 7 | | 8 |
| Mirror Lake | Mirror Lake | MIR-0 | Offshore | 8* | 7 | 8 | 7 |
| | | MIR-1 | Creek | 8* | 7 | | 7 |
| | | MIR-2 | Creek | 8* | 7 | | 7 |
| | | MIR-3 | Residential | 8* | 7 | | 7 |
| Moon River | Moon River | MOO-1 | Offshore | | 8 | | 8 |
| | | MOO-3 | Residential | | 8 | | 8 |
| | | MOO-4 | Residential | | 8 | | 8 |
| | | MOO-5 | Residential | | 8 | | 8 |
| | | MOO-6 | Residential | | 8 | | 8 |
| | | MOO-7 | Camping | | 8 | 8 | 8 |
| | | MOO-8 | Residential | | 8 | | 8 |
| | | MOO-9 | Residential/Creek (Culvert) | | 8 | | 8 |
| Muldrew Lake | Muldrew Lake | MLD-1 | Offshore | 8* | | 8 | 8 |
| | | MLD-2 | Offshore | 8* | | 8 | 8 |
| | | MLD-3 | Offshore | 8* | | 8 | 5 |
| | | MLD-4 | Residential | | 8 | | 8 |
| | | MLD-5 | Creek | | 8 | | 8 |
| | | MLD-6 | Residential | | 8 | | 8 |
| | | MLD-7 | Residential | | 8 | | 8 |
| Muskoka River | Muskoka River | MRV-1 | River Mouth | 1* | 8 | 7 | 8 |
| | | MRV-2 | Wetland | 1* | 8 | 3 | 8 |
| | | MRV-3 | River | 1* | 8 | 8 | 8 |
| | | MRV-4 | Town (Bracebridge) | 1* | 8 | 1 | 8 |
| | | MRV-5 | Creek | 8* | | | 8 |
| Silver Lake (TML) | Silver Lake (TML) | SPC-0 | Offshore | 8* | | 8 | 8 |
| | | SPC-1 | Town (Port Carling) | | 8 | | 8 |
| | | SPC-2 | Residential | | 8 | | 8 |
| | | SPC-3 | Residential | | 8 | | 8 |
| Star Lake | Star Lake | STR-0 | Offshore | 1* | | 8 | 3 |
| | | STR-1 | River | | 8 | | 8 |
| | | STR-2 | Residential | | 8 | | 8 |
| | | STR-3 | Creek | | 8 | | 8 |
| | | STR-4 | Residential | | 8 | | 8 |
| | | STR-5 | Residential | | 8 | | 8 |
| Sucker Lake | Sucker Lake | SUC-0 | Offshore | 1* | | 8 | |
| | | SUC-1 | Creek | | 8 | | 8 |
| | | SUC-2 | Residential | | 8 | | 8 |
| | | SUC-3 | Residential | | 8 | | 8 |
| | | SUC-4 | Residential | | 8 | | 8 |

### 3.3.1. Phosphorus

Total phosphorus concentration (TP) was measured at the sites indicated in **Table 2**. Digest tubes were supplied by and returned to the Trent University Laboratory at the Ministry of Environment's Dorset Environmental Science Centre. Tubes were distributed to Team Leaders who applied appropriate labels and distributed them to Team Members.

The tubes were filled directly from surface water to avoid potential problems relating to the 'container effect' in which phosphorus may adhere to the sides of sampling vessels and not be transferred to the digest tube used for analysis (Clark and Hutchinson, 1992). Volunteers used the 'plunge and sweep' method to fill digest tubes: they turned the tubes upside-down, plunged them into the lake to approximately forearm depth, turned the tube 90˚ and 'swept' upwards towards the surface, filling the tube to the indicated fill line. Digest tubes were kept on ice and delivered to the Team Leader where they stayed chilled until they were sent to the lab in Dorset.

### 3.3.2. Total Coliform

Volunteers collected samples for total coliform analysis using 300 mL juice bottles. The bottles were purchased new from the Consolidated Bottle Company or reused from previous years. The bottles and caps were sterilized in boiling water, sealed and labelled either by MLA staff or Team Leaders.

The bottles were opened at the sampling location. Volunteers were instructed not to come in contact with either the inside of the bottle or the underside of the cap during sampling. The bottles were rinsed (completely filled and then emptied) with lake water three times. The bottle was then filled using the 'plunge and sweep' method described in Section 3.4.1. Samples were placed on ice in the field and returned to the Team Leader for analysis. If the bottle was contaminated, volunteers were instructed to empty any water in the bottle and rinse it with lake water three times before refilling.

Within the same day, analysis was completed as soon as possible after receiving all of the samples. The elapsed time was routinely within 3 hours of sample collection. The samples were kept on ice and in the dark to preserve the bacteria at the naturally occurring level. Water from each sample was poured into a commercially available bacteria-testing kit, as shown in **Figure 1**. The kit is known by the trade name *ColiPlate*, and is manufactured by Bluewater Bioscience Inc.

Each *ColiPlate* has 96 wells containing an agar that reacts with Coliform bacteria and turns blue. Actual bacterial counts are determined by comparing the number of blue cells to a table of Most Probable Numbers (MPN). The MPN table is shown in **Appendix B**.


**Figure 1.** ColiPlate with 11 blue wells

Wells that could be identified as any shade of blue or green was counted as a positive blue well, as per instructions from Bluewater Bioscience. Note that the ColiPlates have a detection limit of three counts/100mL (a count of zero blue wells corresponds to a count of "less than three" coliform/100mL). This barrier was handled by assigning all readings of "less than three" coliform/100mL with an absolute value of 1 count/100mL. This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

### *3.3.3. Escherichia coli (E. coli)*

After testing total coliforms, each *ColiPlate* was used to analyze for *Escherichia coli* (*E. coli*). This was done by exposing the plate to a 366 nm ultraviolet light. The wells that tested positive for *E. coli* fluoresced under the UV light. The number of fluorescent wells was counted and the MPN of organisms/100 mL was determined by comparison with the MPN tables. After the readings were finished, the *ColiPlates* were emptied into a septic system and the plastic plates were returned to Bluewater Bioscience office to be cleaned and reused.

As with the total coliform measurements, all readings of “less than three” *E. coli*/100mL were assigned an absolute value of 1 count/100mL. This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

### 3.3.4. Secchi Depth

A Secchi disk provides a measurement for water clarity and represents the distance that light will travel into the water column. Water clarity is typically affected by three different factors: algae, suspended sediment, and water colour. In 2009, a Secchi disk (**Figure 2**) was used to measure Secchi depth in metres. Each disk was attached to 15 metres of rope (length labelled at 50 cm intervals). To record the Secchi depth, the volunteer lowered the Secchi disk on the rope into the water on the shady side of the boat until they could no longer see it. At this point, the volunteer recorded the depth on the sample date’s data sheet, lowered the disk a little further, raised the disk towards the boat until it reappeared and recorded the second depth on the same data sheet. Secchi depth was calculated as the arithmetic mean of the two recorded measurements.

**Figure 2.** Secchi disk demonstration.

### 3.3.5. Temperature

Temperature readings were recorded for all sites in degrees Celsius. Volunteers hung a pool thermometer from a rope into the surface water when first arriving at each site. After all of the other protocols were completed, the sampler then read the thermometer and recorded the value.

## 3.4. Quality Assurance/Quality Control

The QA/QC protocols have been developed over the previous sampling years. The methods included here have been taken from Citizens' Environment Watch, 2009 and modified as necessary to reflect the 2009 program.

### 3.4.1. Quality Assurance

Reliability of experiments and results is paramount to the effective use of the scientific method. Collecting environmental data in the field is unfortunately subject to countless uncontrollable variables, which makes repeatability difficult. For this reason, quality control and quality assurance protocols that aim to identify misinformation and procedural error are of utmost importance in the WQI. As in all previous years since 2002, rigorous training, documentation and some random duplicate measures were used throughout the 2009 season.

Quality assurance (QA) is a set of systematic procedures designed to ensure reliable results. While QA cannot guarantee quality results, it improves the likelihood of achieving quality results.

Quality Control (QC) is a set of protocols that report back on the reliability of results. QC is therefore the measure of reliability.

### 3.4.2. Phosphorus Quality Control

Some quality control measures were in place for the phosphorus sampling protocols. All duplicates took place during the spring turnover period at deepwater sites. The samples were collected at the same time as the regular phosphorus samples using identical TP tubes and protocols. The duplicate measurements show the range of phosphorus results that can be expected because of sampling and laboratory variation.

**Table 3. Phosphorus Duplicates for 2009 Quality Control**

| Sample Number | Site | Phosphorus Concentration µg/L | P Duplicate | Absolute Difference | Sampler |
|---|---|---|---|---|---|
| 1 | ARN-0 | 4.8 | 5.1 | 0.3 | Brian & Diane Yeates |
| 1 | ART-0 | 5.8 | 4.6 | 1.2 | Peter Seybold |
| 1 | BAL-0 | 4.9 | 5.3 | 0.4 | Eleanor Lewis |
| 1 | BDY-0 | 13.8 | 21.9 | 8.1 | Tony Mathia |
| 1 | BMR-0 | 6.0 | 6.0 | 0 | Louise Cragg |
| 1 | BOY-0 | 6.8 | 7.5 | 0.7 | Dave & Lynne Langford |
| 1 | BRA-0 | 8.0 | 7.4 | 0.6 | Bud Purves |

| Sample Number | Site | Phosphorus Concentration µg/L | P Duplicate | Absolute Difference | Sampler |
|---|---|---|---|---|---|
| 1 | CLR-0 | 6.1 | 6.3 | 0.2 | Sharon Cleverdon |
| 2 | COX-0 | 3.1 | 3.2 | 0.1 | Gord Ross |
| 1 | COX-0 | 3.6 | 3.6 | 0 | Gord Ross |
| 1 | EAS-0 | 4.5 | 4.7 | 0.2 | Lloyd Walton |
| 1 | EAS-2 | 9.7 | 10.0 | 0.3 | Lloyd Walton |
| 3 | EAS-2 | 10.6 | 6.5 | 4.1 | Lloyd Walton |
| 1 | ELG-0 | 4.9 | 5.0 | 0.1 | Doug Tate |
| 1 | FTB-0 | 3.0 | 2.8 | 0.2 | Neil Shaw |
| 1 | GNB-0 | 3.8 | 3.5 | 0.3 | Andrew Watson |
| 1 | HMB-0 | 3.8 | 3.8 | 0 | John Offutt |
| 1 | IND-0 | 3.9 | 5.4 | 1.5 | Susan Carson |
| 1 | JOR-0 | 10.2 | 14.9 | 4.7 | Paul Heenan |
| 1 | JOS-1 | 3.7 | 3.4 | 0.3 | Dean Martin |
| 1 | LEO-0 | 4.7 | 6.0 | 1.3 | Gordon Roberts |
| 1 | LLJ-0 | 7.5 | 4.4 | 3.1 | Dirk Soutendijk |
| 1 | MBA-0 | 10.6 | 11.8 | 1.2 | Brian Yeates |
| 1 | MGN-0 | 3.8 | 27.3 | 23.5 | David Peacock |
| 1 | MIR-0 | 5.2 | 5.0 | 0.2 | Sandy Tozer Spence |
| 1 | MLD-1 | 7.4 | 7.0 | 0.4 | John Twist |
| 5 | MLD-1 | 5.7 | 5.5 | 0.2 | John Twist & Mike Foster |
| 8 | MLD-1 | 7.6 | 7.5 | 0.1 | John Twist & Mike Foster |
| 1 | MLD-2 | 9.0 | 7.9 | 1.1 | John Twist |
| 5 | MLD-2 | 8.7 | 5.7 | 3.0 | John Twist & Mike Foster |
| 8 | MLD-2 | 8.3 | 6.5 | 1.8 | John Twist & Mike Foster |
| 1 | MLD-3 | 6.5 | 7.7 | 1.2 | John Twist & Mike Foster |
| 1 | MLG-0 | 3.7 | 4.3 | 0.6 | Peter Seybold |
| 1 | MRV-1 | 6.9 | 6.6 | 0.3 | John Wood |
| 1 | MRV-2 | 6.3 | 6.9 | 0.6 | John Wood |
| 1 | MRV-3 | 5.3 | 5.3 | 0 | John Wood |
| 1 | MRV-4 | 7.3 | 8.5 | 1.2 | John Wood |
| 1 | MSN-0 | 5.2 | 5.7 | 0.5 | Al Ward |
| 8 | MSN-0 | 7.7 | 8.4 | 0.7 | Al Ward |
| 1 | MUS-2 | 5.0 | 5.5 | 0.5 | Eleanor Lewis |
| 1 | MUS-3 | 6.1 | 8.2 | 2.1 | Brian Yeates |
| 1 | NRT-0 | 5.8 | 5.2 | 0.6 | Eleanor Lewis |
| 1 | POR-0 | 4.9 | 4.3 | 0.6 | Lawton Osler |
| 1 | RMI-0 | 5.5 | 4.4 | 1.1 | Peter Seybold |
| 1 | ROS-1 | 4.7 | 4.6 | 0.1 | Peter Seybold |
| 1 | RSH-0 | 5.4 | 25.6 | 20.2 | David Peacock |
| 1 | SPC-0 | 6.3 | 10.3 | 4.0 | Perry Bowker |
| 1 | STE-0 | 4.2 | 4.4 | 0.2 | Brian Yeates |
| 1 | STI-0 | 4.1 | 3.3 | 0.8 | Neil Shaw |
| 1 | STN-0 | 4.3 | 4.2 | 0.1 | Dean Martin |
| 1 | STR-0 | 9.7 | 8.8 | 0.9 | Karen Gillies |
| 1 | SUC-0 | 5.7 | 5.9 | 0.2 | Greg Clarkson |

| Sample Number | Site | Phosphorus Concentration µg/L | P Duplicate | Absolute Difference | Sampler |
|---|---|---|---|---|---|
| 1 | TOB-0 | 5.8 | 5.8 | 0 | Peter Seybold |
| 1 | WAK-0 | 4.2 | 4.4 | 0.2 | Brian Yeates |
| 1 | WIN-0 | 5.3 | 7.3 | 2.0 | Bev Manchee |
| 4 | WIN-1 | 16.4 | 9.0 | 7.4 | Bev Manchee |
| 5 | WIN-1 | 15.7 | 4.2 | 11.5 | Bev Manchee |
| 1 | WLB-0 | 6.5 | 6.9 | 0.4 | Liz Denyar |
| 1 | WTS-0 | 4.6 | 5.3 | 0.7 | Eleanor Lewis |

For the purpose of this report, an analysis of "outliers" or data points that seem to be skewed from the normal data set was not completed. However, in graphing data in both this report and the Summary Report some outliers were identified and removed from the data set. These data points are easily identified when compared to the other long term or duplicate data points and are likely the result of sample contamination. Sample contamination can result when a phytoplankton or piece of other material is accidentally collected when lake water is swept into the tube, resulting in elevated phosphorus concentrations. Data was also removed from the set when comments were received from the laboratory about the condition or quantity of water in a tube that suggested data accuracy was questionable.

### 3.4.3. Bacteria Quality Control

Quality control measures were not conducted on bacteria samples in the 2009 sampling season.

## 4. MONITORING PROGRAM RESULTS

The water quality monitoring program being conducted by the MLA presently consists of the annual collection of water quality data on a biweekly basis throughout the summer months for a large number of sites. While a number of parameters were discussed in the methodology section, the data reviewed for inclusion in this section of the technical report includes spring turnover phosphorus (all areas in 2009), and water clarity as measured by Secchi disk.

### 4.1. WQI Data 2009 and Phosphorus Thresholds

To review the 2009 data collected for phosphorus concentrations at spring turnover, all sampling areas were graphed in **Figure 3.** In terms of lake classification according to phosphorus concentrations, the Lake Partner Program (MOE) uses three categories to describe the primary productivity of lakes: oligotrophic or nutrient poor (10 µg/L or less), mesotrophic or moderately enriched (11-20 µg/L), and eutrophic or higher levels of nutrients (21µ/L or more). In lakes, the primary producers are composed mostly of algae, which are limited in their growth by the concentration of phosphorus that is available. Based on the data collected in 2009, there are only three areas sampled that would be considered mesotrophic, with enough nutrients to support moderate algae growth: Brandy Lake, Joseph River and Muskoka Bay. The remainder of the sampling areas can be classified as oligotrophic and have low spring turnover phosphorus concentrations.

**Brandy Lake-** is a dystrophic or “brown-water lake” resulting from large inputs of organic material. While historically it was thought that these lakes had low productivity and low nutrient availability, this is not always true (Wetzel, 2001). In the case of Brandy Lake, the large number of wetlands in the upstream watershed and adjacent to the lake make it naturally rich in nutrients. It is highly unlikely that Brandy Lake would have ever been a nutrient poor or oligotrophic lake and always sustained higher concentrations of nutrients, including phosphorus.

**Joseph River**- Many samples collected in the Joseph River in the 2009 sampling season had unusually high phosphorus concentrations. It is possible that some of the 2009 samples were contaminated with material such as phytoplankton or detritus (pieces of leaves or plants) which has caused an unusually high concentration. This is not unexpected with a sampling protocol that does not require filtering of water after collection from the lake. A review of the 2010 data will provide a better understanding of the phosphorus concentrations in this area.

**Muskoka Bay**- This bay has a long history of nutrient enrichment and a brief summary as provided to the Stewardship Initiative Group is included here as a record for comparison. Historical records state that as early as 1875, Gravenhurst Bay was completely cleared of trees and the area used as a lumber mill. An extensive shipyard and boat building industry followed soon afterward. Until 1971, raw sewage from the Town of Gravenhurst was directly dumped into the bay. A high level of pollution in the form of heavy metals, phosphorus, and nitrates is to be expected from this type of effluent. The impacts of the past uses are evident in historical water quality data that shows high heavy metal and phosphorus concentrations found when sampling began in the mid 20$^{th}$ century. It is noted that from the time water quality sampling started in the late 1960s, very high phosphorus readings were recorded, peaking at 52 u/L in 1971.

On a more positive note, the water quality in Muskoka Bay has been improving since the inception of a proper water treatment facility in 1972. The present water quality conditions are very good and are similar in nature to many of the small oligotrophic lakes found in Muskoka. This in itself is remarkable as Muskoka Bay, while part of a large lake system, has the limnology characteristics of a small lake. The bay has limited connection to the main part of Muskoka Lake (at the narrows) and has a very low flushing rate (very few streams enter Muskoka Bay at the south end of the lake). This prevents the water in the majority of the bay from flushing out the nutrients and other deposited material, and from allowing it to move through the main part of Muskoka Lake; this slows the “diluting” of the nutrients and other pollutants. While several documents suggest surface water quality improvement soon after 1972, the hypolimnetic (deepwater) conditions have been slower to recover as indicated by the studies conducted on some biological communities (algae and benthos). The internal load of phosphorus (phosphorus that is bound to sediments) is likely very high in the bay due to historic uses and when anoxic conditions occur (very low oxygen conditions) this phosphorus can become available again through a number of mechanisms. In addition to the historic land use, a large portion of the watershed upstream of Muskoka Bay consists of urban development. The intense urban land use will continue to contribute to the nutrients that enter Muskoka Bay, and this combined with the low flushing rate will make the ongoing recovery of the bay slow. That said, it is really quite amazing how much improvement has occurred in terms of water quality over the past 30–40 years.

In addition to looking at the nutrient status of each sampling area, each area was cross-referenced with the DMM 2009 spring-turnover concentrations and the 10-year average as appropriate.

**Table** 4 shows the phosphorus concentration measured in each lake and lake segment monitored as part of the 2009 WQI. The table also compares these results with the lake-specific thresholds identified by the Muskoka Recreational Water Quality Model. The table indicates whether the Official Plan classifies the lake as over-threshold, shows DMM’s 2009 spring turnover measurements, 10-year averages of spring turnover measurements, and number of measurements collected in the past ten years to make up that average by both the MLA and DMM. In summary, there are eight areas sampled by the MLA that are classified as “over-threshold” by the DMM, there are 13 MLA sampling areas that measured “over threshold” in 2009, and 19 that have MLA 10-year averages that are “over-threshold.” A review of how a lake is classified in the DMM is provided in Section1.2.

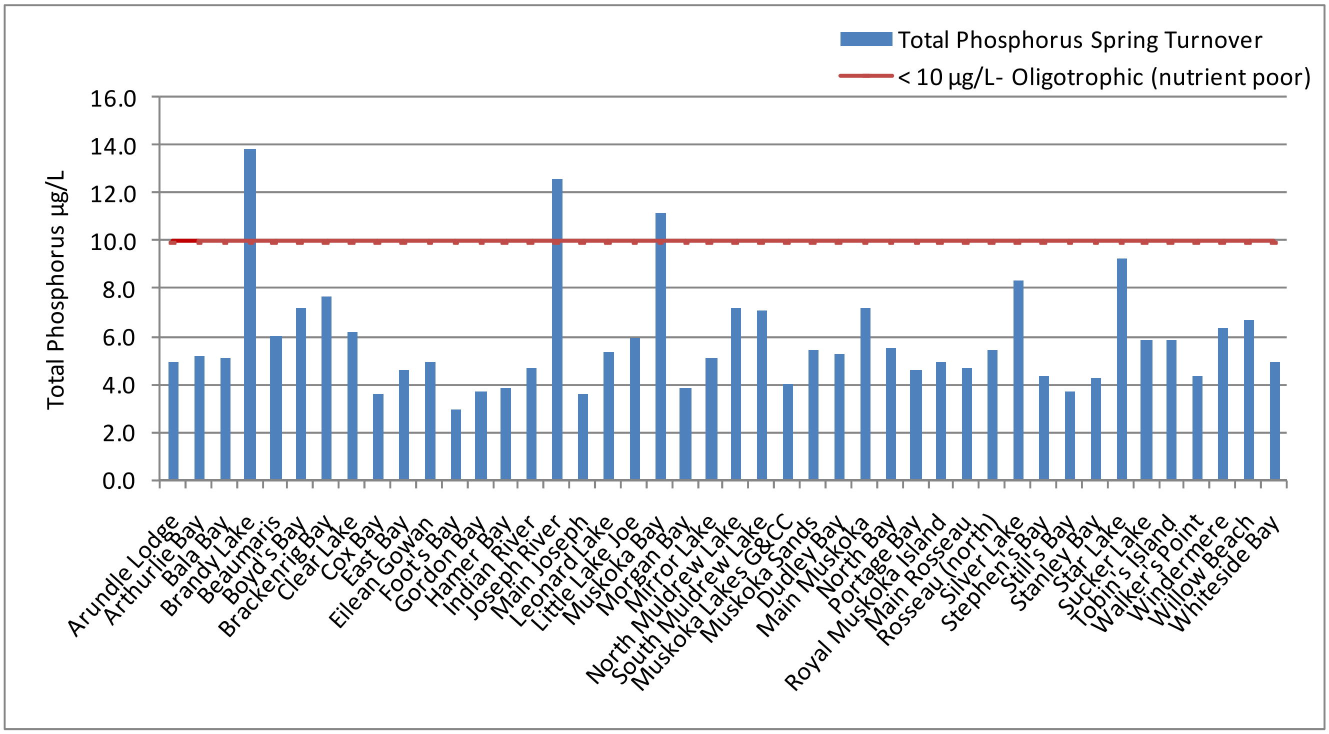


**Figure 3. Spring-turnover phosphorus concentrations for all deepwater sampling sites in 2009.**

In previous reports, if no threshold had been calculated for a sampling area, the “Threshold Area” column indicates the nearest area that does have a threshold associated with it. For example, the Willow Beach area on Lake Muskoka does not have a threshold associated with it in the Official Plan, but this area is part of the larger Lake Muskoka South basin, which does have a threshold. In this case, the “Threshold Area” column refers to the South basin, and monitoring results are compared to that threshold value. In most cases for the 2009 report, the threshold values have remained the same; however, a few sampling areas having no DMM threshold had been associated with other small bays. This has been changed in the 2009 technical report so that comparisons are made with the main basins. The rationale for this change is that often small bays that have been modelled separately have distinct characteristics that cannot be applied to other bays, even if they are adjacent to one another. Also, note that for data included in the MLA 10-year average, samples must have been collected in May. Data collected after May have been removed from the calculation (mostly from 2002 and 2003)

In terms of the results presented in **Table 4,** if the concentration in the “Threshold” column is shaded red, that sampling area is classified as over-threshold by the Muskoka Official Plan. Cells that have bold numbers indicate that the 2009 measurement as collected by the MLA is over the DMM phosphorus threshold.

**Table 4. 2009 Spring Turnover (µg/L) comparison to threshold concentrations identified in the Muskoka Official Plan**

| | | | | WQI Data | | | DMM Data | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sampling Area** | **Threshold Area** | **DMM Threshold*** | **Sensitivity** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** |
| **Arthurlie Bay** | Rosseau Main Basin | 6.2 | Moderate | 5.2 | 5.7 | 4 | | | |
| **Arundle Lodge** | Muskoka South Basin | 7.9 | Moderate | 5.0 | 5.9 | 2 | | | |
| **Bala Bay** | Bala Bay | 6.6 | Moderate | 5.1 | 6.4 | 6 | | 6.1 | 6 |
| **Brandy Lake** | Brandy Lake | 28.4 | Moderate | 13.8 | 20.3 | 5 | | 28.4 | 4 |
| **Beaumaris** | Muskoka North Basin | 6.7 | Moderate | 6.0 | 6.8 | 6 | | | |
| **Boyd Bay** | Muskoka South Basin | 7.9 | Moderate | 7.2 | 7.6 | 3 | | | |
| **Brackenrig Bay** | Brackenrig Bay | 5.2 | Moderate (OT) | **7.7** | **6.2** | 6 | **12.3** | **8.9** | 6 |
| **Clear Lake** | Clear Lake | 5.6 | Moderate (OT) | **6.2** | **8.6** | 3 | | 6.0 | 4 |
| **Cox Bay** | Cox Bay | 3.9 | Moderate (OT) | 3.6 | **7.1** | 8 | **5.6** | **5.4** | 6 |
| **Dudley Bay** | Dudley Bay | 6.6 | Moderate | 5.3 | 5.4 | 4 | | 6.1 | 5 |
| **East Bay** | Muskoka South Basin | 6.6 | Moderate | 4.6 | **8.9** | 5 | | | |
| **East Portage Bay** | East Portage Bay | 3.9 | High (OT) | **5.3** | **5.6** | 4 | **6.4** | **7.0** | 6 |
| **Eilean Gowan Island** | Muskoka South Basin | 7.9 | Moderate | 5.0 | 6.2 | 2 | | | |
| **Foot's Bay** | Joseph Main Basin | 3.5 | High | 2.9 | 2.9 | 1 | | | |
| **Gordon Bay** | Joseph Main Basin | 3.5 | High | **3.7** | **4.9** | 5 | | | |
| **Hamer Bay** | Joseph Main Basin | 3.5 | High | 3.8 | **5.1** | 8 | **4.1** | **4.1** | 2 |
| **Indian River** | Indian River | 6.2 | Moderate | 4.7 | 5.9 | 8 | | | |
| **Joseph River** | Joseph River | 4.2 | Moderate | **12.6** | **8.1** | 5 | **7.9** | **8.3** | 5 |
| **Lake Joseph Main Basin** | Lake Joseph Main Basin | 3.5 | High | **3.6** | **4.3** | 5 | **3.7** | **4.8** | 5 |

| | | | | WQI Data | | | DMM Data | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sampling Area** | **Threshold Area** | **DMM Threshold*** | **Sensitivity** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** |
| **Lake Muskoka South Basin** | Lake Muskoka South Basin | 7.9 | Moderate | 7.2 | 6.5 | 3 | | 5.6 | 5 |
| **Lake Rosseau Main Basin** | Lake Rosseau Main Basin | 6.2 | Moderate | 4.7 | 5.9 | 4 | 6.0 | 5.8 | 6 |
| **Leonard Lake** | Leonard Lake | 6.1 | Moderate (OT) | 5.4 | 5.7 | 2 | **6.4** | **6.4** | 4 |
| **Little Lake Joe** | Little Lake Joe | 4.6 | Moderate | **6.0** | **5.0** | 4 | **6.0** | 5.9 | 6 |
| **Minett** | Rosseau Main Basin | 6.2 | Moderate | | **6.6** | 5 | | | |
| **Mirror Lake** | Mirror Lake | 6.2 | Moderate (OT) | 5.1 | 6.1 | 3 | | **7.3** | 5 |
| **Morgan Bay** | Morgan Bay | 4.2 | Moderate | 3.8 | **4.6** | 2 | | | |
| **Muskoka Bay** | Muskoka Bay | 10.3 | Moderate (OT) | **11.2** | 9.5 | 6 | | **11.7** | 5 |
| **Muskoka Lakes G&CC** | Rosseau Main Basin | 6.2 | Moderate | 4.0 | 4.3 | 3 | | | |
| **Muskoka Sands** | Muskoka South Basin | 7.9 | Moderate | 5.5 | 7.5 | 5 | | | |
| **North Bay** | Muskoka North Basin | 7.9 | Moderate | 5.5 | 6.3 | 3 | | | |
| **North Muldrew Lake** | North Muldrew Lake | 12.0 | Moderate | 7.2 | 9.7 | 3 | | 10.6 | 5 |
| **Rosseau (North)** | Rosseau Main Basin | 6.2 | Moderate | 5.4 | **7.9** | 5 | **10.3** | **8.6** | 2 |
| **Royal Muskoka Island** | Rosseau Main Basin | 6.2 | Moderate | 5.0 | 6.9 | 5 | | | |
| **Silver Lake (Muskoka Lakes)** | Silver Lake (Muskoka Lakes) | 5.2 | Moderate (OT) | **8.3** | **10.9** | 6 | **6.1** | **8.2** | 3 |
| **South Muldrew Lake** | South Muldrew Lake | 10.0 | Moderate | 7.1 | 6.5 | 3 | | 8.5 | 5 |
| **Stanley Bay** | Joseph Main Basin | 3.4 | High | **4.3** | **5.6** | 5 | | | |
| **Still's Bay** | Joseph Main Basin | 3.4 | High | **3.7** | **5.6** | 6 | | | |

| | | | | WQI Data | | | DMM Data | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sampling Area** | **Threshold Area** | **DMM Threshold*** | **Sensitivity** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** | **2009 $[TP]_{so}$** | **10 Year Average** | **No. of Years** |
| **Star Lake** | N/A | N/A | NA | 9.3 | 10.4 | 3 | | | |
| **Stephen's Bay** | Muskoka South Basin | 7.9 | Moderate | 4.3 | 5.7 | 2 | | | |
| **Sucker Lake** | Sucker Lake | 5.4 | Moderate | **5.8** | **5.8** | 1 | | | |
| **Tobin's Island** | Rosseau Main Basin | 6.2 | Moderate | 5.8 | 6.0 | 3 | | | |
| **Walker's Point** | Muskoka South Basin | 7.9 | Moderate | 4.3 | 6.0 | 6 | | | |
| **Whiteside Bay** | Whiteside Bay | 10.2 | Moderate | 5.0 | 6.1 | 3 | | 6.1 | 5 |
| **Windermere** | Rosseau Main Basin | 6.2 | Moderate | **6.3** | **6.6** | 5 | | | |
| **Willow Beach** | Muskoka South Basin | 7.9 | Moderate | 6.7 | **10.7** | 4 | | | |

*A lake in the DMM is determined to be "over threshold" when (1) the predicted phosphorus concentration exceeds the background plus 50% when the lake is modeled based on the existing land use, and (2) the actual measured concentration of phosphorus exceeds the background plus 50%.

## 4.2. WQI data 2009 and Secchi Disk

Water clarity is a measure of how much light penetrates through the water column. The clarity of water is influenced both by suspend particulate matter (sediment, and plankton) and by coloured organic matter (tea coloured lakes). According to the MOE, "If your Secchi disc appears **yellow or green** as it is lowered into the lake it means that algae are controlling the light penetration in your lake. In this case you can use the Secchi readings to estimate your lake's nutrient status. If your Secchi disc appears **orange or brown** as it is lowered into the lake then the light penetration in your lake is being controlled by dissolved organic carbon (DOC) and you must use your total phosphorus values to estimate the nutrient status of your lake."

Based on the data presented in **Figure 4,** it appears that a large number of the sampling areas fall into the mesotrophic and eutrophic categories. This is likely a result of variable amounts of Dissolved Organic Carbon (DOC) found in the sampling areas. DOC is the very fine organic matter that leaches from soils and plants. Lakes with high levels of DOC often appear tea coloured and result in reduced lake clarity. It is quite likely that the results above are a result of variable DOC concentrations between sampling areas and, thus, the data should not be used to indicate nutrient status. However, the data are important for monitoring long-term trends.

INTERPRETING YOUR SECCHI DISC RESULTS

| **Secchi Reading** | **Lake Nutrient Status** |
|---|---|
| Over 5m | Oligotrophic-unenriched, few nutrients |
| 3.0m to 4.9m | Mesotrophic-moderately enriched, some nutrients |
| Less than 2.9m | Eutrophic-enriched, higher levels of nutrients |

Source: MOE-Ontario Lake Partners Program

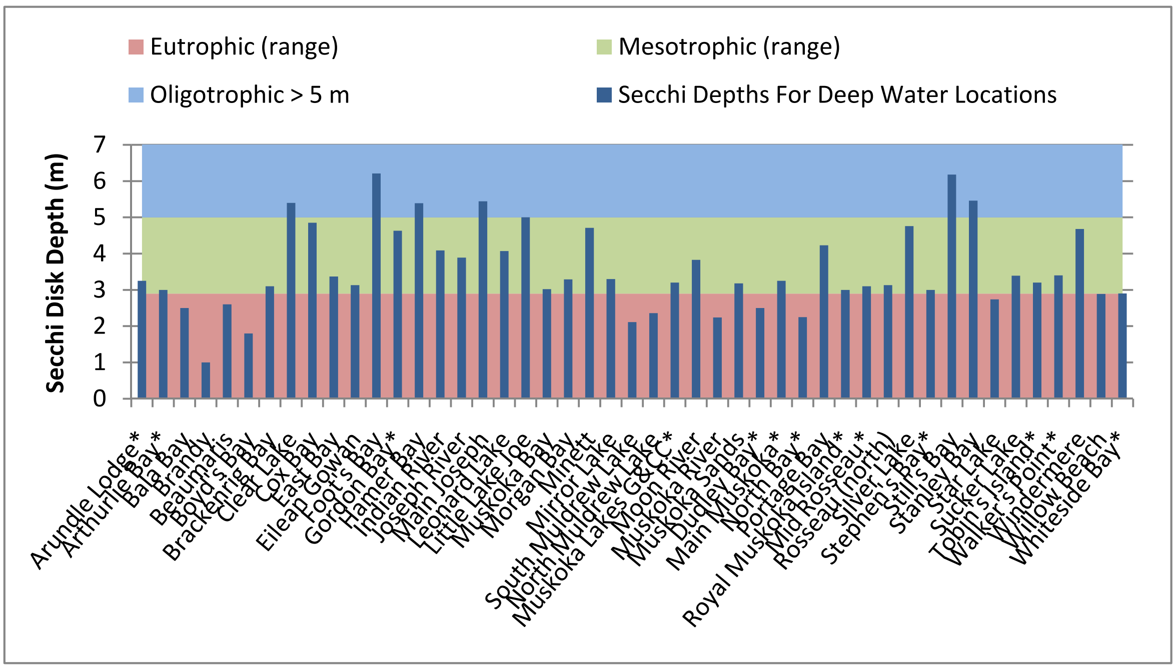


**Figure 4. Mean Secchi disk reading at deepwater sites over the summer sampling period for 2009. *Note sites that are based on a single spring turnover sample. Muskoka River data is based on (n=25) pooled data from all sampling sites.**

## 5. <u>RESEARCH PROGRAM RESULTS</u>

For the first time the WQI monitoring program, RiverStone has analyzed the long-term data set to look for significant long-term trends. Based on the 2008 WQI report, the objective of the monitoring program is “to discover the source of the problems.” The program was designed to compare nearshore sites with deepwater sites to “indicate land-based problems.” The data were reviewed and statistical analyses completed to determine how well the data, as collected, could provide answers to the following questions:

- Can the data demonstrate a significant difference between nearshore and offshore phosphorus within lakes sampled (Lakes Muskoka, Rosseau, and Joseph)?*****
- Can the data demonstrate a significant difference between nearshore and offshore phosphorus within a specific lake (Lakes Muskoka Rosseau and Joseph)?*****
- Can any detected differences between nearshore phosphorus concentrations be attributed to a type of land use (urban, agricultural etc) or landform (wetland or creek)?

*It must be noted that the selection of sites for the MLA WQI was not random and for this reason, we cannot make general conclusions. Our findings pertain only to the sites that were sampled.

### 5.1. Review of Long-term WQI Data

Over the past nine years, the MLA WQI has collected a large and useful database. There is long-term data for phosphorus concentrations (spring turnover and summer averages), Secchi disk depths, total coliform, and *E. coli* for a substantial number of sites in both the big Muskoka Lakes and a number of smaller ones. Portions of this data set have also been related to land use (agriculture, urban, wetland golf courses etc.). The largest data set available is for the big lakes (Muskoka, Rosseau, and Joseph) with smaller datasets available for affiliate lakes.

In reviewing the MLA's **long-term data**, a number of problem areas were noted. These problems are not atypical in any long term monitoring program and some minor changes in the existing program will improve the quality of the long-term data set. The items noted were:

- Large variation in phosphorus data, possibly resulting from lack of filtration
- Missing data points (possibly resulting from labelling error, changing volunteer support, removal of extreme data points, addition of new sites, broken sample tubes etc)
- Coliform numbers that do not correspond to the MPN table values
- Changes in site locations
- Changing methodologies
- Changing QA/QC efforts
- Some of the MLA methodologies are different from other monitoring programs

After taking these problems into consideration, several types of analyses were performed for inclusion in the 2009 technical review. These analyses were completed to determine if the data set was able to detect long-term differences, with the above noted questions in mind. Note that many of the analyses performed were on "transformed" data, a technique used by statisticians to "normalize" data that show large variation in one direction (skewed). Transforming data allows for appropriate statistical analysis, makes the data appear more uniform and easier to visualize, and permits better interpretation. A general description of the transformations and types of analyses completed on the data is provided in the following sections. A summary table is included for those who are interested at the end of Section 4 (**Table 10**). A section titled "**What does this mean**?" is included at the end of each sub-section for people without a statistical or scientific background.

#### 5.1.1. Analysis of long term Phosphorus trend during Spring Turnover at deepwater sites

The WQI has collected spring turnover phosphorus data for the past seven years. The data for the big three lakes (Muskoka Rosseau and Joseph) were analyzed to look at the long term generalized trends. In terms of significant differences between sites sampled over the seven sampling years for all three lakes, there was a significant difference noted between 2005 and 2006 and between 2008-2009 (**Table 5**). Note that only consecutive years were compared in this analysis.

**Figure 5** provides an illustration of the generalized spring turnover phosphorus trend at the deepwater sites on the three big lakes. The graph illustrates a similar behaviour for all lakes over the sampling period. The difference noted is a likely a result of variable baseline phosphorus concentrations for each lake, with Joseph having the lowest and Muskoka the highest baseline concentration. Creation of an individual model was not possible due to insufficient data being available for individual lakes, thus the presented model is an amalgamation of data for all three lakes. The number of observations used to develop this model is provided in **Table 6**.

## What does this mean?

The fact that Lakes Muskoka, Rosseau and Joseph all show the same long term trend suggests that spring turnover phosphorus concentrations are highly influenced by global factors. These factors could include things like climate change, precipitation, global industrial influence etc. With this much variability linked to larger factors, it is a difficult task to identify more local impacts. The good news is that the long term trend in the MLA data and other long term data sets in Ontario indicate that the for the most part phosphorus concentrations in our lakes is either decreasing or remaining stable.

**Table 5. Results of a 3-level linear mixed model of year regressed on annual spring turnover phosphorus concentrations at deepwater sites on Lakes Joseph, Muskoka, and Rosseau between 2002 and 2009. Data was log-transformed prior to analysis, thus the coefficients are presented on the log-scale. Each of the three lakes had differing 2002 baseline phosphorus concentrations (see graph below), hence, an overall non-log-transformed coefficient cannot be presented. Yearly changes in phosphorus concentration did not vary by lake on the log-scale.**

| Sampling Years | Coefficient (log scale) | p-value | 95% Confidence Interval |
|---|---|---|---|
| 2002–2003 | 0.24 | 0.051 | 0.00–0.49 |
| 2003–2004 | 0.15 | 0.123 | -0.04–0.35 |
| 2004–2005 | -0.16 | 0.087 | -0.34–0.02 |
| **2005–2006** | **-0.22** | **0.016** | **-0.40–0.04** |
| 2006–2007 | -0.05 | 0.667 | -0.26–0.16 |
| 2007–2008 | 0.13 | 0.208 | -0.07–0.32 |
| **2008–2009** | **-0.28** | **<0.001** | **-0.43–-0.14** |

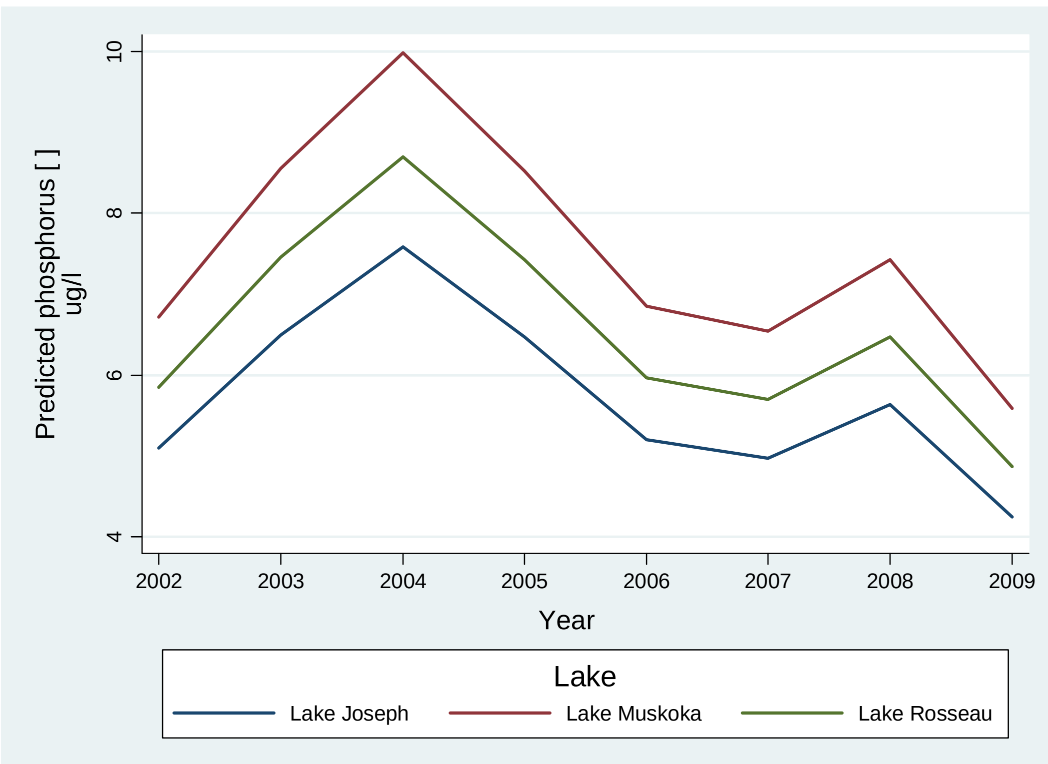


**Figure 5. Predicted annual spring turnover phosphorus concentrations (base-10 scale) at deepwater sites on Lakes Joseph, Muskoka, and Rosseau from 2002 to 2009.**

**Table 6**. Number of observations per year included in a 3-level mixed linear model evaluating yearly changes in spring turnover phosphorus concentrations at deep-water sites on Lakes Joseph, Muskoka, and Rosseau. Years with low Total numbers of observations (i.e., 2002 and 2007) will produce less accurate results in the analysis than years with higher numbers of observations. Years in which the observations were not evenly distributed between the lakes would have results based mainly on the lake with the highest number of observations. (e.g., results derived from 2007 data would have been mainly based on Lake Joseph data).

| Year | Numbers of Observations | | | |
|---|---|---|---|---|
| | Total Observations | Lake Joseph | Lake Muskoka | Lake Rosseau |
| 2002 | 8 | 2 | 4 | 2 |
| 2003 | 13 | 3 | 6 | 4 |
| 2004 | 16 | 5 | 7 | 4 |
| 2005 | 18 | 6 | 7 | 5 |
| 2006 | 18 | 3 | 8 | 7 |
| 2007 | 11 | 6 | 3 | 2 |
| 2008 | 25 | 6 | 10 | 9 |
| 2009 | 28 | 8 | 11 | 9 |

### 5.1.2. Analysis of the nearshore/offshore effect on Phosphorus during Spring Turnover

The first question that needs to be answered prior to looking for land-based problems is the following: Can the data demonstrate a significant difference between nearshore and offshore phosphorus within lakes sampled (Lakes Muskoka, Rosseau, and Joseph)? The results of the statistical analysis conducted to answer this question can be found below.

In general, for the sites sampled in Lakes Joseph, Muskoka, and Rosseau between 2002 and 2009, nearshore phosphorus was significantly higher than offshore phosphorus during spring turnover ($p < 0.001$). The near shore ln[P] concentrations (i.e., logarithmically transformed concentrations) were 0.28 µg/L higher than the offshore equivalents. Note that 0.28 µg/L does not represent the **actual** concentration and cannot be equated to a specific concentration change. The data was skewed and had to be transformed using a natural-log transformation prior to analysis; consequently, the effect being measured was the difference in ln[P] between nearshore and offshore sites.

The analysis also tested for an effect by group (basin) and we could detect a significant effect of the basin on the difference between nearshore and offshore concentrations (as represented by the intercepts depicted in **Figure 6, Figure 7** and **Figure 8**). This effect remained when the results were back-transformed. It should be noted that the number of data points that was useable for this analysis was small (sample size = 367) compared to the actual size of the data set. Data points had to be removed from the set when there was no nearshore/offshore pair within a given year.

**Figure 6, Figure 7** and **Figure 8** show the concentration differences between nearshore and offshore spring-turnover phosphorus concentrations as predicted by the statistical model (slopes of lines). Time and software limitations have not allowed us to complete the extended analysis required to determine which of these are significant, but a visual prediction is possible based on the slopes of the lines. Lines that have a more gradual slope (closer to 0) are less likely to be significant. However, other factors beyond the slope of the line (e.g., the sample sizes used to make the predictions for each group) will influence the significance of the predictions, so visual interpretation may not be accurate.

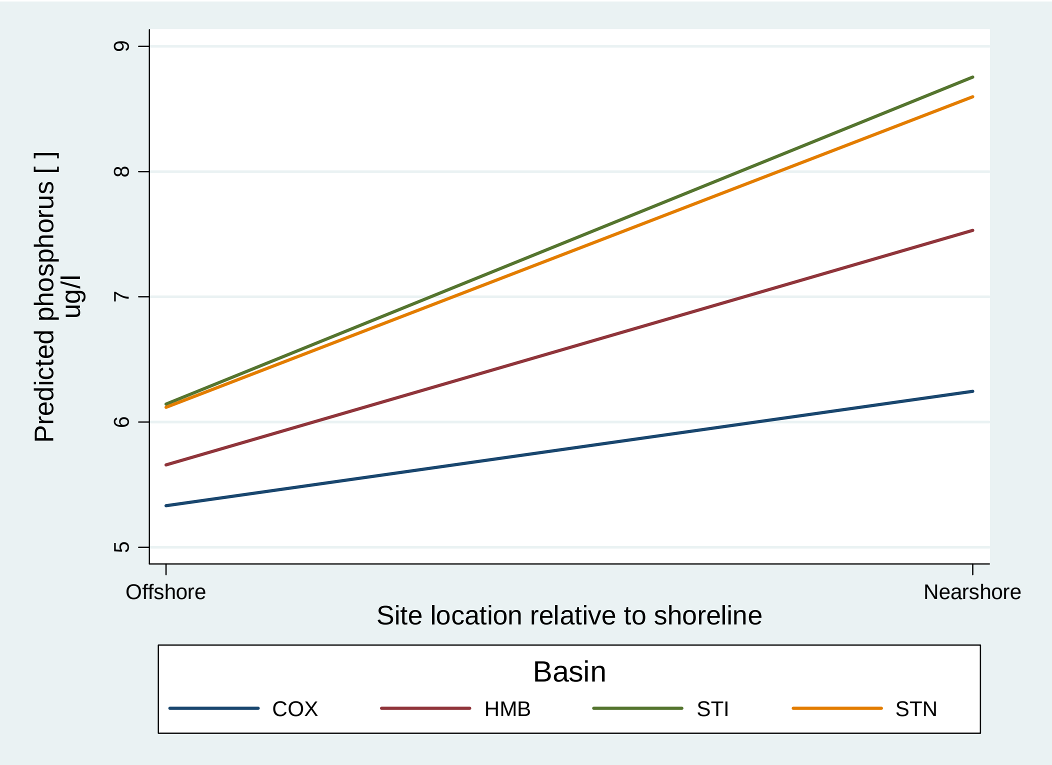


**Figure 6. Effect of proximity to shore on spring-turnover phosphorus concentrations for basins in Lake Joseph. Note STI (single nearshore site) and STN (2 years of data) have high data variation.**

Based on visual analysis of the graphs and a review of the data, significant differences between nearshore and offshore phosphorus concentrations may occur within Stills Bay (STI), Stanley Bay (STN), Muskoka Sands (MSN), Muskoka Bay (MBA), Willow Beach (WLB), Brackenrig Bay (BRA), Windermere (WIN) and Rosseau North (RSH).

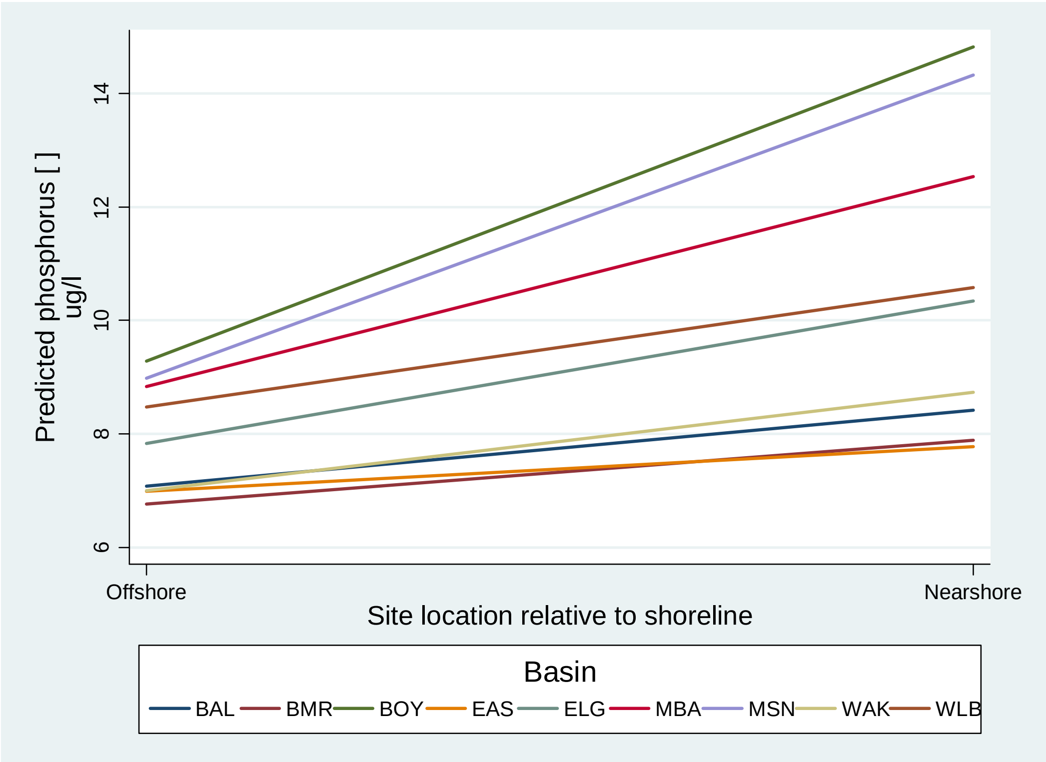


**Figure 7. Effect of proximity to shore on spring turnover phosphorus concentrations for basins in Lake Muskoka. Note the BOY and ELG results are based on only one year of data (one offshore sample and three nearshore samples) and so may be inaccurate.**

## What does this mean?

After analyzing the data that the MLA volunteers have collected for Spring-Turnover phosphorus, we can provide the following general findings/comments.

- Data confirm that the nearshore phosphorus concentration is higher than the offshore concentrations at spring turnover in the areas sampled and we can detect a significant difference using the MLA data. (This finding should not be generalized to the rest of the lake; it is only applicable to the areas sampled.)
- The difference between the nearshore and offshore phosphorus concentration was not the same for all areas sampled.
- The relationship between the nearshore and offshore concentrations is not the same for all areas sampled.

**Summary: Overall in the areas sampled in the big three lakes, higher concentrations of phosphorus were found in the nearshore sites when compared to the deepwater sites. However, the movement of phosphorus from near the shore to deep water was potentially different for**

**each area of the lakes: some areas had obvious differences between nearshore and deepwater phosphorus concentrations and some areas had little difference at all.**

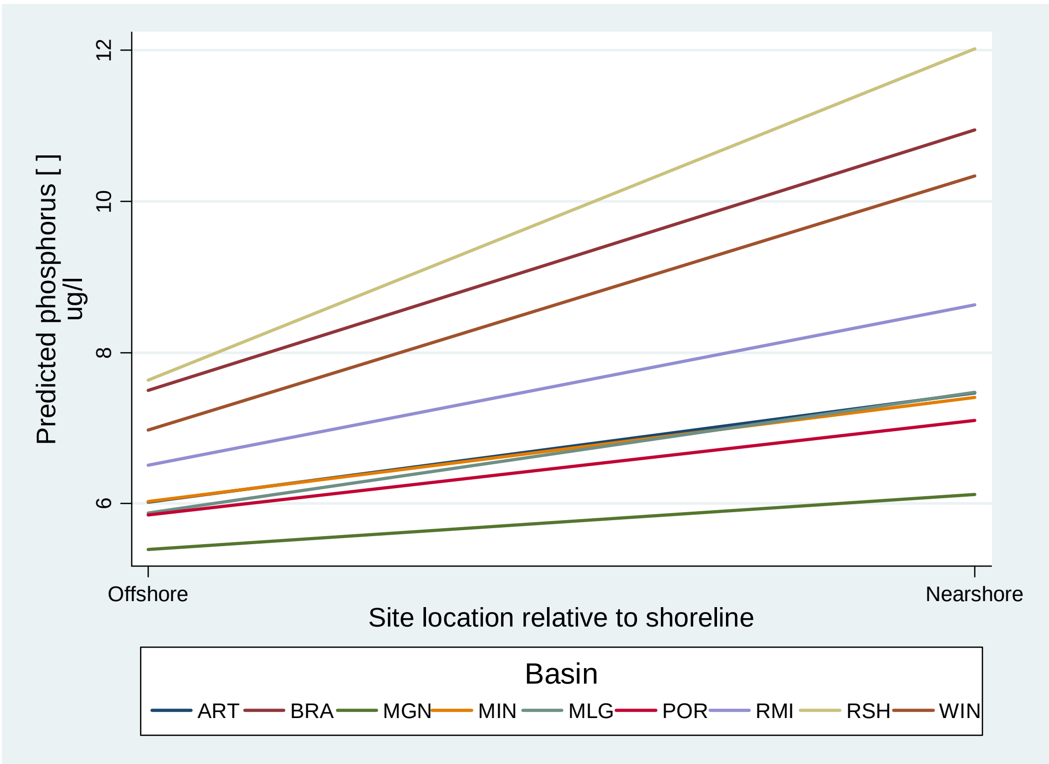


**Figure 8. Effect of proximity to shore on spring turnover phosphorus concentrations for basins in Lake Rosseau. Note the ART, MGN, and MLG results are based on only one year of data (one offshore sample and three nearshore samples) and so may be inaccurate.**

### 5.1.3. Analysis of the nearshore/offshore effect on Phosphorus during the summer

Again, as for spring turnover data, analysis of data for sites sampled in Lakes Joseph, Muskoka, and Rosseau between 2002 and 2009 showed that nearshore phosphorus was significantly higher than offshore phosphorus during the summer sampling season ($p = 0.008$, $n = 2,777$). This data was also skewed and was transformed for analysis. Overall **for the samples used in the analysis**, the general nearshore ln[P] concentration was 0.20 µg/L higher than the general offshore ln[P] concentration ($p = 0.008$). However, different lakes, areas, and sites had different baselines for ln[P] concentration and the nearshore/offshore effect on ln[P] concentration varied by basin/group. In other words, the difference that we detected between nearshore and offshore ln[P] concentration was not significant for every basin/group, but overall, the difference was significant. The areas used in the analysis are provided in **Table 7.** The analysis also tested for an effect by group (basin) and we could detect a significant effect of the basin on the difference between nearshore and offshore concentrations (as represented by the intercepts depicted in **Figure 9**, **Figure 10**, and **Figure 11**). This effect remained when the results were back-transformed.

**Figure 9**, **Figure 10**, and **Figure 11** show the concentration differences between nearshore and offshore summer phosphorus as predicted by the statistical model (slopes of lines). Time and software limitations have not allowed us to complete the extended analysis required to determine which of these are significant, but a visual prediction is possible based on the slopes of the lines. Lines that have a more gradual slope (closer to 0) are less likely to be significant. However, other factors beyond the slope of the line (e.g., the sample sizes used to make the predictions for each group) will influence the significance of the predictions, so visual interpretation may not be accurate.

Based on visual analysis of the graphs and a review of the data, significant differences between nearshore and offshore phosphorus concentrations may occur within Stills Bay (STI), Stanley Bay (STN), Muskoka Sands (MSN), Muskoka Bay (MBA), Willow Beach (WLB), Brackenrig Bay (BRA), Windermere (WIN) and Rosseau North (RSH).

In addition, based on visual interpretations, within Lake Joseph, both Cox Bay and Hamer Bay may have different (lower) baseline deepwater conditions than Still’s Bay and Stanley Bay, and within Lake Muskoka, Willow Beach, Muskoka Sands and East Bay may have higher deepwater baseline conditions than the other basin/areas sampled. Graphical interpretation was not completed for Lake Rosseau.

## What does this mean?

After analyzing the data that the MLA volunteers have collected for summer phosphorus, we can provide the following general findings/comments:

- Data confirm that the nearshore phosphorus concentration is higher than the offshore concentrations during the summer months in the areas sampled and we can detect a significant difference using the MLA data. (This finding should not be generalized to the rest of the lake; it is only applicable to the areas sampled.)
- The difference between the nearshore and offshore phosphorus concentration was not the same for all areas sampled. It is possible that for some sampling areas there is no difference between the nearshore and offshore summer phosphorus concentrations.

- The relationship between the nearshore and offshore concentrations is not the same for all areas sampled.

**Summary: Overall in the areas sampled in the big three lakes, higher concentrations of phosphorus were found at the nearshore sites when compared to the deepwater sites during the summer sampling period; however even if the nearshore concentration was higher, it did not always affect the deepwater sites in the same way.**

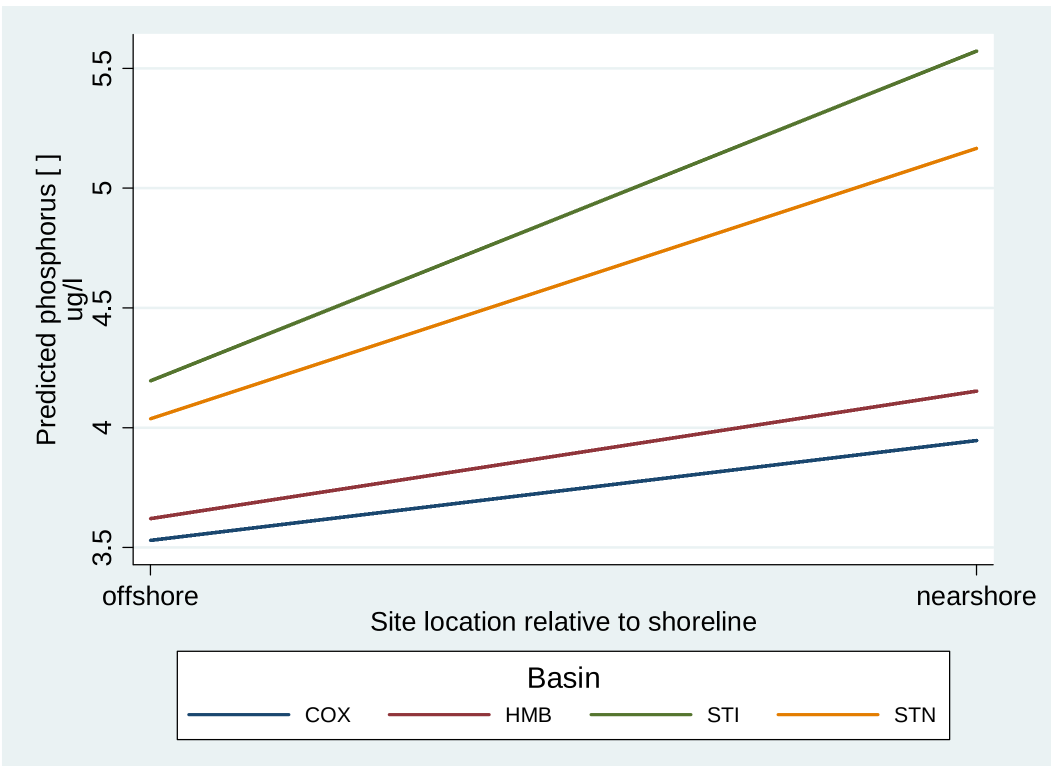


**Figure 9**. Predicted summer phosphorus concentration by basin in Lake Joseph between 2002 and 2009.

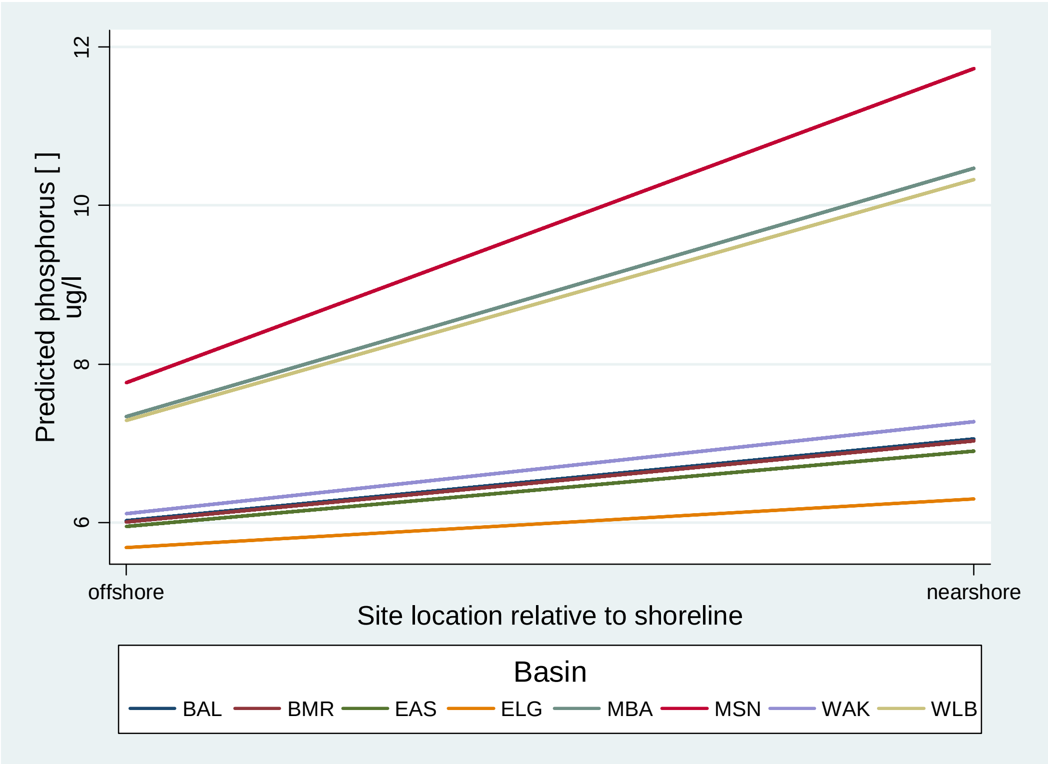


**Figure 10**. Predicted summer phosphorus concentration by basin in Lake Muskoka between 2002 and 2009.

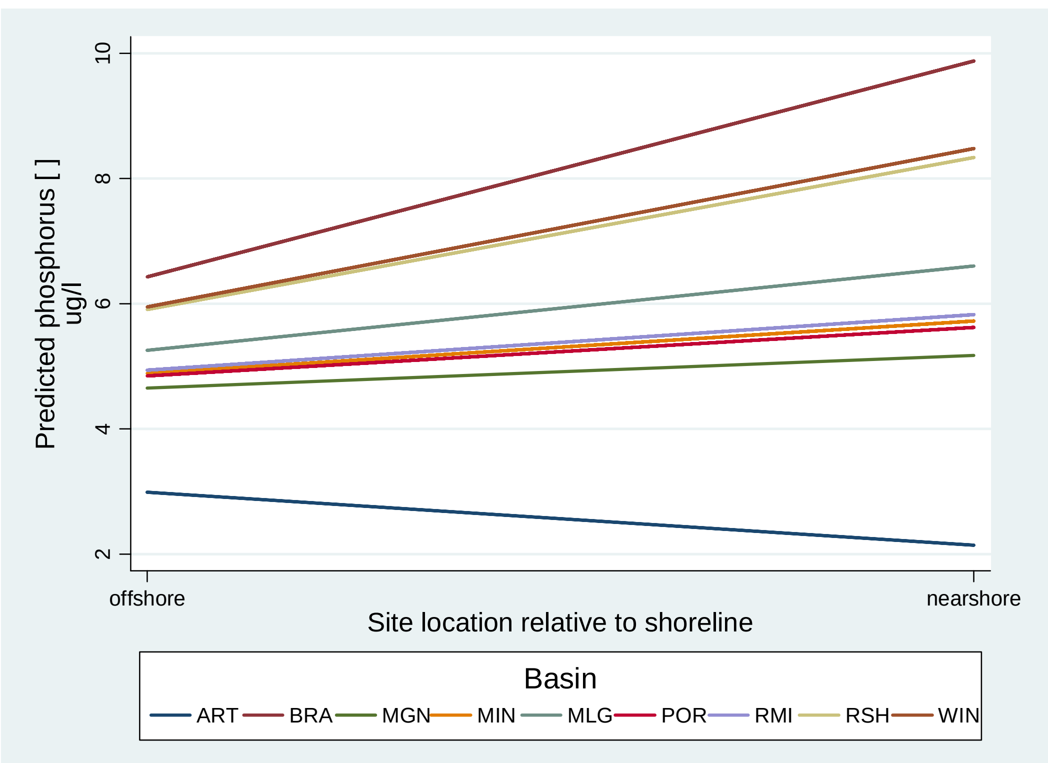


**Figure 11**. Predicted summer phosphorus concentration by basin in Lake Rosseau between 2002 and 2009.

**Table 7. List of sites used in analysis of the effect of nearshore/offshore sites on phosphorus concentrations.** The findings of the analysis can only be interpreted to be valid for these particular sites.

| | Lake | | |
|---|---|---|---|
| **Sites used in analysis** | **Joseph:**<br>COX-0 - COX-4<br>HMB-0 - HMB-5<br>STI-0, STI-2<br>STN-0 - STN-3 | **Muskoka:**<br>BAL-0 - BAL-3<br>BMR-0 - BMR-8<br>EAS-0 - EAS-3<br>ELG-0 - ELG-3<br>MBA-0 - MBA-10<br>MSN-0 - MSN-4<br>WAK-0 - WAK-4<br>WLB-0 - WLB-3 | **Rosseau:**<br>ART-0 - ART-3<br>BRA-0 - BRA-3<br>MGN-0 - MGN-4<br>MIN-0 – MIN 2, MIN 4, MIN5<br>MLG-0 - MLG-3<br>POR-0 - POR-5<br>RMI-0, RMI-1, RMI-4<br>RMI-5<br>RHS-0 - RHS-4<br>WIN-0 - WIN-5 |

### 5.1.4. Analysis of Phosphorus by Land Use (summer data) 2002–2009

One of the research objectives of the MLA was to identify areas of different land use that may be contributing high phosphorus loads to either a lake or a basin of lake. Prior to discussing our findings, it is important to discuss the measurement of phosphorus **concentration** and how it relates to phosphorus **load**. The measurement of phosphorus concentration at a particular location over time can provide some indication of whether the nutrient is coming off the land into the water or from a point source. The difficultly with this is that we do not know how this concentration relates to the load of phosphorus a lake is receiving from this source on a yearly basis. To calculate the load of phosphorus from a given source it requires both the **concentration** and the **volume** running off. Load is typically measured in kg/year or tonne/year. It is common to have a very high phosphorus concentration in a small creek in the middle of summer, but that same small creek may only contribute a small volume of water to a lake or basin over a given year. Alternatively, it is possible that the outflow from a sewage treatment plant has a very low concentration of phosphorus when sampled at the outflow, but it delivers a large volume of water over a given year. The loading from the creek may be 75 kg/year, whereas the loading from the sewage treatment plant may be 1,000 kg/year. Based on this discussion it is important to realize that just because we have high concentrations of phosphorus at a given site, it does not implicitly imply that the site has a large contribution to the load of phosphorus on a yearly basis and is driving the overall lake/basin concentration (spring turnover) up.

It should also be noted that land-use categories reported for some of the sites changed between 2005 and 2009. It was unlikely that the actual land use for many of the sites changed, so some of the data was misclassified meaning the reported findings may be biased. With the above said, the analysis of summer phosphorus data by land use for sites sampled in Lakes Joseph, Muskoka, and Rosseau between 2002 and 2009 showed that the nearshore phosphorus concentration was significantly higher at sites with wetlands/creeks or golf courses when compared to offshore, nearshore residential, urban, and resort sites (**Table 8**). There were no other land uses that had significantly different phosphorus concentrations during the summer sampling season ($p = 0.008$, $n = 2,777$). RiverStone reviewed the sampling sites with members of the Water Quality Portfolio and volunteers, and it was determined that the majority of the golf course sites were located at creek or culvert outlets thought to be draining lands that were adjacent to golf courses. Based on how the sites were selected, it was determined that **it is not possible to separate the effect of a golf course from that of a creek or river**. To determine a direct connection between the golf course and water quality, we would need to have sampling sites immediately upstream and downstream of the golf course.

Note that from a technical perspective in completing the analysis, data was skewed and had to be transformed. Results indicated that **for the samples used in the analysis**, the general nearshore ln[P] concentration was 0.20 µg/L higher than the general offshore ln[P] concentration ($p = 0.008$). However, different lakes, areas, and sites had different baselines for ln[P] concentration and the nearshore/offshore effect on ln[P] concentration varied by basin/group. In other words, the difference that was detected between nearshore and offshore ln[P] concentration was not significant for every basin/group, but overall, the difference was significant.

**Table 8.** Differences in the natural log of phosphorus concentrations (ln[P]) by land use type for summer samples. Estimates of the change in ln[P] are presented with their associated p-values in brackets below. Values in bold text are significant at the 95% level (n = 2,496).

| | **Offshore**<br>(n = 774, 22 groups) | **Residential**<br>(n = 454, 11 groups) | **Urban**<br>(n = 180, 5 groups) | **Wetland/River**<br>(n = 189, 5 groups) | **Golf Course**<br>(n =564, 9 groups) | **Resort**<br>(n = 321 in 7 groups) |
|---|---|---|---|---|---|---|
| **Offshore** | * | 0.00<br>(0.963) | -0.08<br>(0.574) | **-0.45**<br>**(0.004)** | **-0.43**<br>**(<0.001)** | -0.21<br>(0.059) |
| **Residential** | 0.00<br>(0.963) | * | -0.07<br>(0.632) | **-0.44**<br>**(0.011)** | **-0.42**<br>**(<0.001)** | -0.20<br>(0.116) |
| **Urban** | 0.08<br>(0.574) | 0.07<br>(0.632) | * | **-0.37**<br>**(0.045)** | **-0.35**<br>**(0.016)** | -0.13<br>(0.390) |

| | **Offshore** (n = 774, 22 groups) | **Residential** (n = 454, 11 groups) | **Urban** (n = 180, 5 groups) | **Wetland/River** (n = 189, 5 groups) | **Golf Course** (n =564, 9 groups) | **Resort** (n = 321 in 7 groups) |
|---|---|---|---|---|---|---|
| **Wetland/ River** | **0.45 (0.004)** | **0.44 (0.011)** | **0.37 (0.045)** | * | 0.02 (0.911) | 0.24 (0.188) |
| **Golf Course** | **0.43 (<0.001)** | **0.42 (<0.001)** | **0.35 (0.016)** | -0.02 (0.911) | * | 0.22 (0.057) |
| **Resort** | 0.21 (0.059) | 0.20 (0.116) | 0.13 (0.390) | -0.24 (0.188) | -0.22 (0.057) | * |

**Table 9.** Number of land use samples by lake (samples = individual data points, site = sampling site and group = bay or basin). This information will give you an idea of what lakes were included in the analysis of each land use effect in the table above (e.g., data from Wetland/river sites were only available for Lakes Muskoka and Rosseau and, therefore, the findings can only be attributed to those sites). ).

| | **Lake Joseph** | **Lake Muskoka** | **Lake Rosseau** |
|---|---|---|---|
| **Offshore** | samples = 194<br>site = 5<br>group= 5 | 333<br>8<br>8 | 247<br>9<br>9 |
| **Residential** | samples= 98<br>site = 4<br>group = 2 | 195<br>12<br>5 | 161<br>8<br>4 |
| **Urban** | samples= 42<br>site = 1<br>group = 1 | 103<br>4<br>3 | 35<br>2<br>1 |
| **Wetland/River** | samples= 0<br>site = 0<br>group = 0 | 154<br>5<br>3 | 35<br>3<br>2 |
| **Golf Course** | samples = 207<br>site = 4<br>group = 3 | 249<br>7<br>3 | 108<br>6<br>3 |
| **Resort** | samples = 154<br>site = 3<br>group = 2 | 113<br>4<br>3 | 54<br>3<br>2 |

## What does this mean?

After analysing the data that the MLA volunteers have collected for nearshore phosphorus as related to land use, we can provide the following general findings/comments (note that findings may be biased due to misclassification of land uses for some sites):

- Data indicate that there is a significant difference between the creek sites sampled and all other sites sampled using the MLA data. (This finding should not be generalized to other creeks on these lakes or on other lakes; it is only applicable to the sites sampled.)
    - Based on the data used in the analysis, it was not possible to detect a significant difference between land uses with the exception of creeks.
    - Based on how the sites were selected it was determined that **it is not possible to separate the effect of a golf course from that of a creek or river**.
    - Even where differences were detected, it is not possible to suggest an area is a "source of the problem" as there is no data to confirm the load of phosphorus.

**Summary: Overall for the sites sampled in the big three lakes, higher concentrations of phosphorus were found in sampling areas containing creek outlets. Findings may have been biased by misclassification of land uses at some sites.**

### 5.1.5. Nearshore/offshore analysis of *E. coli* data 2002–2009

*E. coli*, an indication of faecal contamination, is often measured in the nearshore where most recreational activities occur. The MLA has been collecting *E. coli* data since 2002 for both nearshore and offshore locations. To determine if the existing monitoring program is able to detect a significant difference between these two zones with the present monitoring protocols, the 2002–2009 data were analyzed. The general findings indicate that there is a significant difference ($p < 0.001$) between the nearshore and offshore concentrations of *E. coli*, with higher concentrations found in the nearshore (**Figure 12**, **Figure 13** and **Figure 14**). Within a given sampling area, as a site changed from being offshore to nearshore, the ln[*E. coli*] increased by 0.64 cfu/100 ml. The analysis could not tell us conclusively that this was true for all sampling areas because the area sample sizes are not high enough (and the data erratic).

**Figure 12**, **Figure 13** and **Figure 14** show the difference in concentrations of *E. coli* between the nearshore and offshore sites as predicted by the statistical model (slopes of lines). Random effects were generated for lake, area, and site levels; however, random slopes were not significant for the nearshore/offshore variable at the area level. Because of the log transformation, when predicted values for each area were back-transformed, the effect of the nearshore/offshore variable varied according to the random intercept that was generated for each area. Areas with higher intercepts (i.e., higher predicted offshore *E. coli* values) had slightly higher slopes, but this difference between areas was negligible because the areas all had very similar predicted offshore *E. coli* values.

## What does this mean?

After analysing the data that the MLA volunteers have collected for *E. coli*, we can provide the following general findings/comments.

- The current monitoring method can detect differences between nearshore and offshore *E. coli* concentrations.
- For the sites sampled in the big three lakes, *E. coli* concentrations were significantly higher in the nearshore sites than offshore sites.
- Using the long-term data set as an indicator of general trends for the sites sampled on Lakes Muskoka, Rosseau, and Joseph, it evident that all sites sampled on the three lakes have average nearshore concentrations that are **well below** the MLA's establish upper limit of 10 cfu/100 ml.
- In terms of the offshore and nearshore *E. coli* concentrations, it appears that they are related; the highest *E. coli* concentrations for both nearshore and offshore sampling areas are found in Lake Muskoka, followed by Lake Rosseau, with the lowest nearshore and offshore concentrations found in Lake Joseph. This interpretation is only valid for the sites sampled and should not be generalized to the entire lake (i.e., the findings do not indicate that Lake Muskoka in general has higher *E. coli* concentrations than the other lakes, they are only valid for the areas sampled).
- It is quite likely that these overall trends are driven by a few sampling areas within Lake Muskoka and Lake Rosseau.

**Summary: Overall, the concentrations of *E. coli* for the sites sampled in the big three lakes are well below the MLA suggested limit of 10 cfu/100mLand lake water is safe for recreational purposes at these sites. There appears to be a direct relationship between the average concentration of *E. coli* found at the nearshore sites sampled and that found in the offshore sites sampled.**

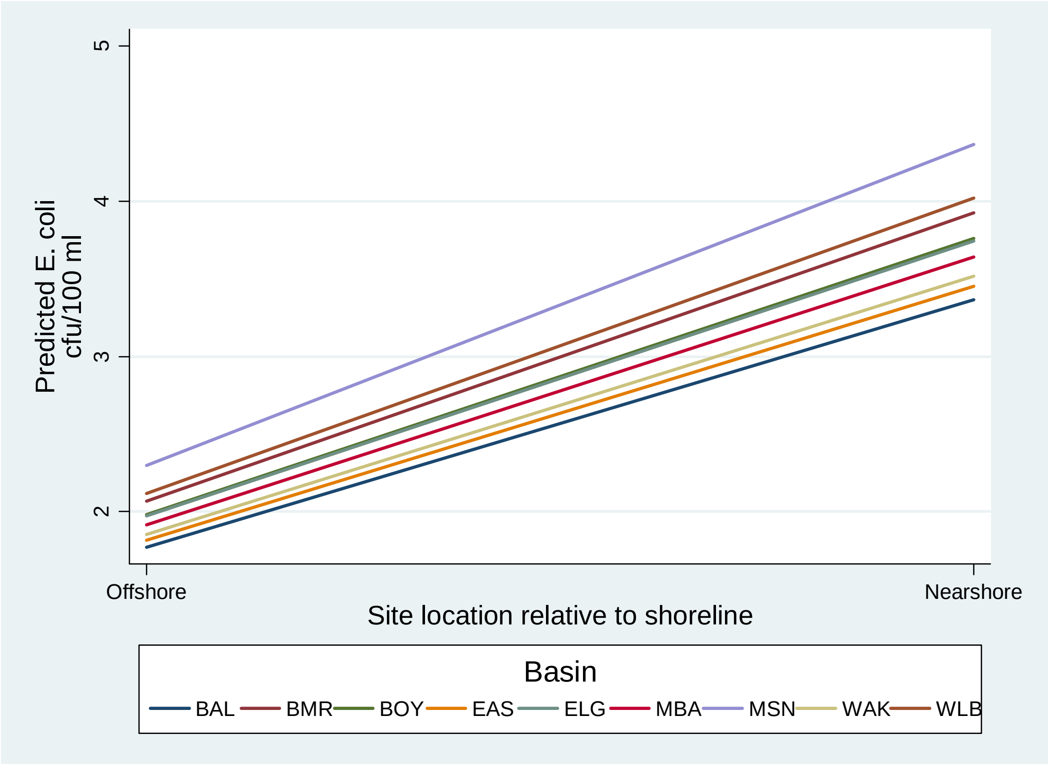


**Figure 12**. Predicted summer *E. coli* (cfu/100mL) concentration phosphorus concentration by basin in Lake Muskoka between 2002 and 2009.

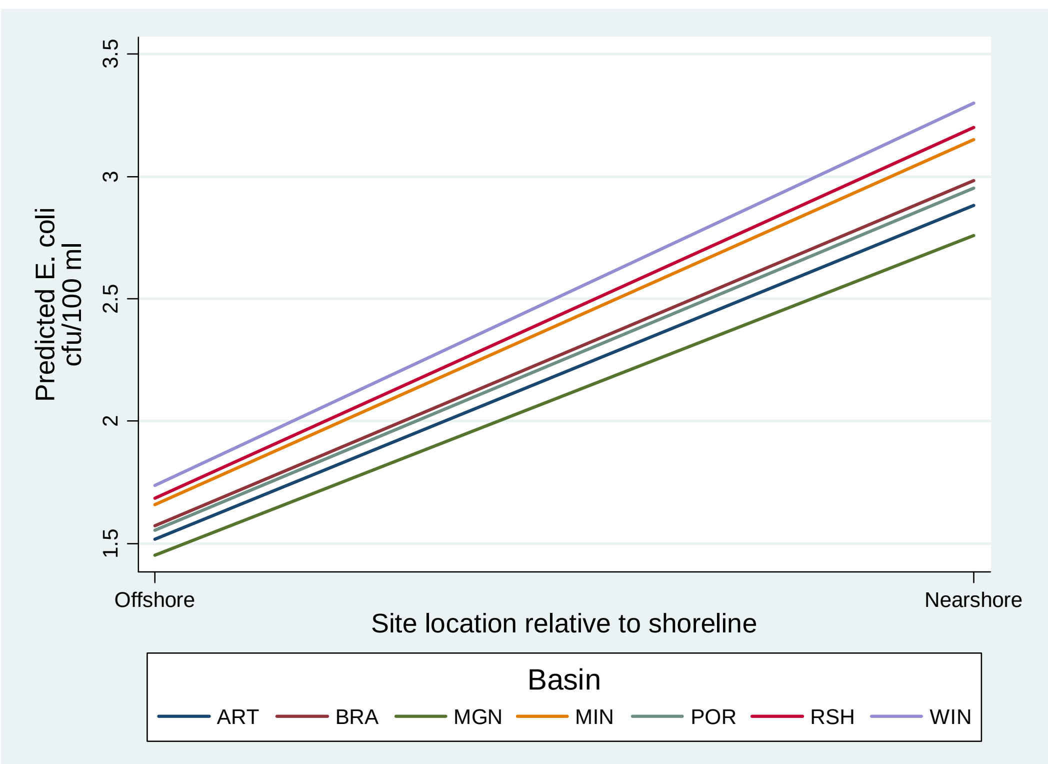


**Figure 13**. Predicted summer *E. coli* (cfu/100mL) concentration phosphorus concentration by basin in Lake Rosseau between 2002 and 2009.

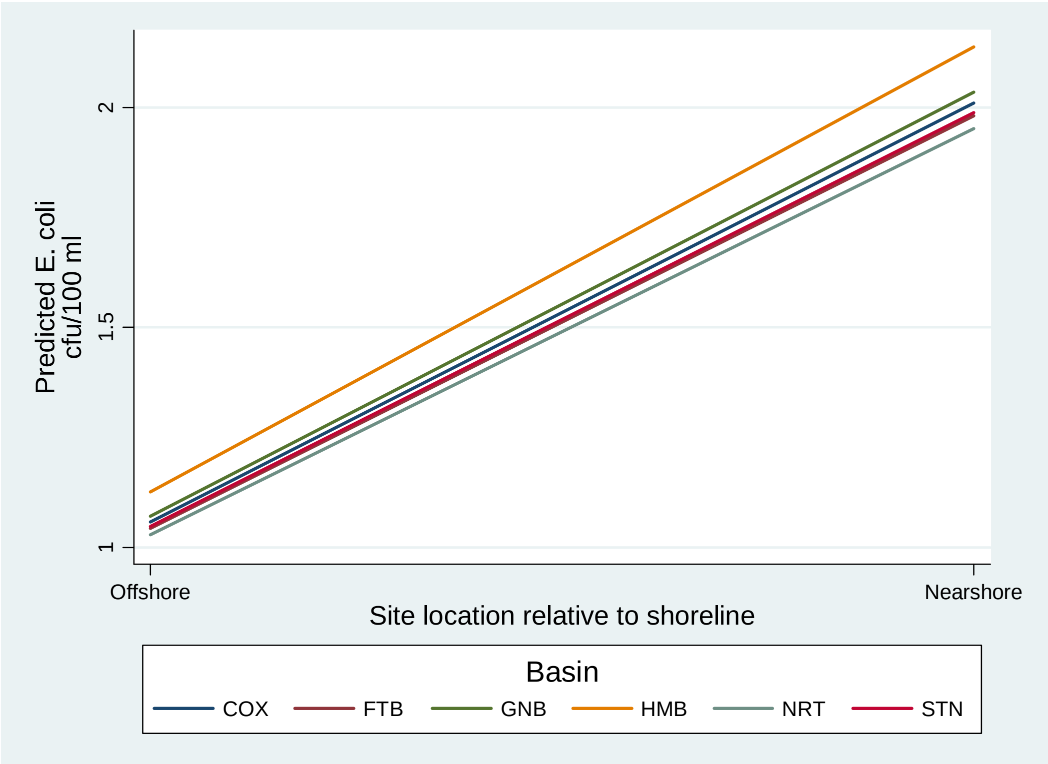


**Figure 14**. Predicted summer *E. coli* (cfu/100mL) concentration by basin in Lake Joseph between 2002 and 2009.

### 5.1.6. Statistical Methods

## Table 10. Statistical methods used for data analysis:

| Research question | Statistical analysis and sample size | Transformation | Sites included in the analysis | Limitations, assumptions, and comments |
|---|---|---|---|---|
| Do phosphorus concentrations differ between nearshore and offshore sites at spring turn-over? | 3-level[1] generalized linear mixed model. Random slopes were not significant.<br><br>n = 367 | Natural-log | ART-0,1,2,3<br>BAL-0,1,2,3<br>BMR-0,1,2,3,4,5,6,7<br>BOY-0,1,2,3<br>BRA-0,1,2,3<br>COX-0,1,2,3,4<br>EAS-0,1,2,3<br>ELG-0,1,2,3<br>HMB-0,1,2,3,4,5<br>MBA-0,1,2,3,4,5,6,7,8,9,10<br>MGN-0,1,2,3,4<br>MIN-0,1,2,4,5<br>MLG-0,1,2,3<br>MSN-0,1,2,4<br>POR-0,1,2,3,4,5<br>RMI-0,1,4,5<br>RSH-0,1,2,3,4<br>STI-0,2<br>STN-0,1,2,3<br>WAK-0,1,2,3,4<br>WIN-0,1,3,4,5<br>WLB-0,1,2,3 | Findings cannot be generalized beyond the sites included in the analysis because site selection was not random.<br><br>Data from different years were assumed to be independent. |
| Do phosphorus concentrations differ between nearshore and offshore sites during the summer months after spring turn-over? | 4-level[2] generalized linear mixed model with random slopes at the basin level and an exchangeable correlation structure<br><br>n = 2,777 | Natural-log | ART-0,1,2,3<br>BAL-0,1,2,3<br>BMR-0,1,2,3,4,5,6,7,8<br>BRA-0,1,2,3<br>COX-0,1,2,3,4<br>EAS-0,1,2,3<br>ELG-0,1,2,3<br>HMB-0,1,2,3,4,5<br>MBA-0,1,2,3,4,5,6,7,8,9,10<br>MGN-0,1,2,3,4<br>MIN-0,1,2,4,5<br>MLG-0,1,2,3<br>MSN-0,1,2,3,4<br>POR-0,1,2,3,4,5<br>RMI-0,1,4,5<br>RSH-0,1,2,3,4,5<br>STI-0,2<br>STN-0,1,2,3<br>WAK-0,1,2,3,4<br>WIN-0,1,2,3,4,5<br>WLB-0,1,2,3 | Findings cannot be generalized beyond the sites included in the analysis because site selection was not random.<br><br>Data from different years were assumed to be independent. |

[1] The three levels of the data hierarchy were as follows: (1) site, (2) basin, (3) lake. The variable of interest (nearshore/offshore effect) was at the basin level.

[2] The four levels of the data hierarchy were as follows: (1) sample, (2) site, (3) basin, (4) lake. The variable of interest (nearshore/offshore effect) was at the basin level.

| **Research question** | **Statistical analysis and sample size** | **Transformation** | **Sites included in the analysis** | **Limitations, assumptions, and comments** |
|---|---|---|---|---|
| Do *E. coli* levels differ between nearshore and offshore sites? | 4-level[2] generalized linear mixed model. Random slopes were not significant.<br><br>n = 3,145 | Natural-log | ART-0,1,2,3<br>BAL-0,1,2,3,4,5,6<br>BMR-0,1,2,3,4,5,6,7,8<br>BOY-0,1,2,3<br>BRA-0,1,2,3<br>COX-0,1,2,3,4<br>EAS-0,1,2,3<br>ELG-0,1,2,3<br>FTB-0,1,3,4<br>GNB-0,1,2,3,4<br>HMB-0,1,2,3,4<br>MBA-0,1,2,3,4,5,6,7,8,9,10<br>MGN-0,1,2,3,4<br>MIN-0,1,2,3,4,5<br>MSN-0,1,2,3,4<br>NRT-0,1,2,3<br>POR-0,1,2,3,4,5<br>RSH-0,1,2,3,4,5<br>STN-0,1,2,3<br>WAK-0,1,2,3,4<br>WIN-0,1,2,3,4,5<br>WLB-0,1,2,3 | A 4-level Poisson model could not be fit using the software available. A 2-level Poisson model gave similar results to the 4-level linear model presented.<br><br>Findings cannot be generalized beyond the sites included in the analysis because site selection was not random.<br><br>Data from different years were assumed to be independent. |
| Do land-use types influence nearshore phosphorus concentrations? | 4-level[2] generalized linear mixed model. Random slopes were not significant.<br><br>n = 2,496 | Natural-log | ART-0,1,2,3<br>BAL-0,1,2,3<br>BMR-0,1,2,3,4,5,6<br>BRA-0,1,2,3<br>COX-0,1,2,3,4<br>EAS-0,1,2,3<br>ELG-0,1,2,3<br>FTB-0<br>HMB-0,1,2,3,4<br>MBA-0,1,2,3,4,5,6<br>MGN-0<br>MIN-0,1,2,4,5<br>MSN-0,1,2,3,4<br>POR-0<br>RMI-0,1,4,5<br>RSH-0,1,2,3,4<br>STI-0,2<br>STN-0,1,2,3<br>WAK-0,1,2,3,4<br>WIN-0,1,2,3,4<br>WLB-0,1,2,3 | Misclassification of sites by land-use type prevented a non-biased analysis of this data. Inferences and conclusions can not be drawn from these results.<br><br>Data from different years were assumed to be independent.<br><br>Spring turn-over data removed from analysis.<br><br>Site land-use classification based on 2003 and 2005 reports. |

## 6. RECOMMENDATIONS AND CONCLUSIONS

The for the past nine years, the Muskoka Lakes Association (MLA) and its affiliates have been conducting both research and monitoring programs on many of the lakes in Muskoka. Gartner Lee Limited in part directed the program, which started in 2001, under the direction of Neil Hutchison. The early program was developed as a combined monitoring and a scientific research program. Its design was intended to involve lake residents, promote good lake-stewardship practices, and to test the hypothesis that water quality conditions in the nearshore differed from that in open water. All parts of the program were very successful. The first two years of data demonstrated that differences between water quality in the nearshore and deepwater stations were detectable through the measurement of nutrients and bacteria. The data showed that nearshore waters were more enriched with phosphorous and bacteria. In addition to the collection of good data, the program also had “enthusiastic and diligent volunteer support”, indicating the success, popularity and support for the program.

Between 2003 and 2009, the focus of the MLA program appears to have shifted more towards a monitoring program, having less focus on specific research questions. This monitoring program allowed the MLA to look for general trends, target potential “trouble” areas, and to have more in-house involvement and control of the Water Quality Initiative. At this time, it is important for the MLA to decide the future objectives of the Water Quality Initiative and to implement the appropriate changes to the present program to both achieve the objectives and maximize the use of the resources available. This review has been the basis of the following recommendations for 2010.

### 6.1. Specific Program Recommendations for 2010

Based on the volunteer surveys, observations of the program through the 2009 sampling season, and a complete data review RiverStone would provide the following recommendations for the various components of the WQI program:

***Training***

- *Require that all team leaders attend training sessions and encourage as many team members as possible to attend.*
- *Review the present sampling locations with Team Leaders and discuss the implications of changing sites. Prepare new maps with sample locations.*

***Methods***

- *Resume the appropriate QA/QC protocols for phosphorus duplicates and coliform testing (duplicates and field blanks, and consider sending 5% of samples to an accredited lab for testing).*

- *Resume filtering of phosphorus samples using an 80 micron filter.*

- *Continue to have a Field Coordinator to support the volunteers and manage data.*

- *Continue to have the Field Coordinator review data forms and data after every sampling date, including the E. coli results and follow up quickly to obtain missing information.*

***Education***

- *Continue to work with the Stewardship Initiative Groups and facilitate discussions with the DMM as required to help groups promote good practices in their own back yard as well as have a voice in the greater community.*

- *Continue to monitor the development practices of each municipality and provide input when possible for local official plans and zoning by-laws. Buffers around rivers, streams, and wetland and forest preservation go a long way toward protecting the water quality in the downstream watershed.*

- *Continue to review available public education programs and provide information for such programs on the MLA website. This will assist in promoting Good Stewardship Practices and awareness of Muskoka's Natural Environment with the membership and others.*

***Program***

- *Continue to review the data from all sites and determine the value of each sampling area and its contribution to the objectives of the WQI monitoring program.*

- *Consider promoting participation in Biological Monitoring Programs. The present WQI monitoring focuses on collecting water chemistry data for the detection of long term change. Biological indicators in a lake can often provide a more sensitive means of detecting change in water quality over the long term than water chemistry. This type of data can support water chemistry information. Biological indicators that are often associated with water quality monitoring include: phytoplankton, aquatic plants, benthic invertebrates (bottom dwelling bugs), algae, and fish. The DMM presently offers assistance with the OBBN program (benthic monitoring) offered by the MOE. For some WQI sampling areas it would be beneficial to have a reference sample collected as part of this program for use in future studies. Sampling areas that presently monitor both deepwater and nearshore phosphorus, that also have both developed and relatively undisturbed shorelines are good candidates for this program. Specific areas are recommended in the 2009 Summary Report.*

## 7. CONCLUSIONS

The WQI has collected nutrient data for many of the lakes in Muskoka since 2001. This data has been reviewed and used by many organizations over the last nine years. The program has allowed members of the lake communities to take an active role in monitoring water quality in their neighbourhood. Of greatest importance is the opportunity to become educated and take an active role in good lake stewardship and to feel confident in passing the message on to your neighbour. The data itself will allow for long term monitoring of trends with respect to phosphorus and coliform in the participating lakes. This data can be used as the foundation for ongoing stewardship plans and discussions with local governments on how to best protect our lakes for the future.

## 8. DEFINITIONS

**Note these definitions have been taken from the WQI Monitoring Program Summary Report-Citizens Environment Watch 2009 and have only been updated as required by changes in text.**

**10-year Average Total Phosphorus:** Arithmetic mean of all spring turnover total phosphorus concentration measurements collected within one program over a ten year period. In order for the District of Muskoka to classify a lake or segment as over-**threshold**, the 10-year average of measurements collected by the District of Muskoka through the Lake System Health Monitoring Program (consisting of at least three measurements) must exceed the **threshold** calculated by the Muskoka Recreational Water Quality Model.

**Arithmetic mean:** This type of average is calculated by adding together a group of numbers and dividing the sum by the number of numbers.

**Clarity:** Water clarity is a measure of how much light penetrates through the water column. The clarity of water is influenced both by suspend particulate matter (sediment, and plankton) and by coloured organic matter (tea coloured lakes). Clarity can provide some indication of a lake's overall water quality, especially the amount of algae present.

***E. coli*:** Fully known as *Escherichia coli,* it is a subset of total coliform, and is exclusively associated with faecal waste (Scheifer, 2001) making it a good indicator of faecal contamination. There are several different strains of *E. coli*; most waterborne strains are themselves not harmful, but some (such as *E. coli* O157:H7) can cause serious illness.

**Geometric Mean:** This type of average is calculated by multiplying together a group of $n$ numbers and then taking the $n^{th}$ root of the resulting product. Geometric mean is used to indicate the central tendency or typical value of a set of numbers. It is typically used to calculate average bacteria counts because as a living organism, bacteria counts are highly sporadic and inconsistent.

**Lake System Health Monitoring Program**: A field-based program designed and operated by the District of Muskoka that monitors approximately 192 sample locations across Muskoka on a rotating basis depending upon development pressures and the specific characteristics of the lake. The purpose of the program is to establish a long-term record of key water quality parameters so that trends in water quality can be identified. Spring turnover total phosphorus results of this program inform Muskoka's Recreational Water Quality Model.

**Mesotrophic**: A mesotrophic lake typically has phosphorus concentrations between 10 and 20 µg/L (Level 2–mid-range, MOE). Mesotrophic lakes are lakes with an intermediate level of productivity, greater than oligotrophic lakes, but less than eutrophic lakes. These lakes are commonly clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients.

**Oligotrophic**: An oligotrophic lake typically has phosphorus concentrations less than 10 µg/L (Level 1–nutrient-poor, MOE). These lakes have low primary productivity, due to the low nutrient content. These lakes have low algal production, and consequently, often have very clear waters, with high drinking-water quality. The bottom waters of such lakes typically have ample oxygen; thus, such lakes often support many fish species, like lake trout, which require cold, well-oxygenated waters.

**OBBN:** (Ontario Benthic Biomonitoring Network) The Ministry of the Environment and Environment Canada has developed an aquatic macroinvertebrate biomonitoring network for Ontario's lakes, streams, and wetlands. The program is built on the principles of partnership, free data sharing, and standardization. The OBBN is biological monitoring program (not chemistry) that uses a reference-condition approach to define criteria: samples from minimally impacted sites define an expectation (the normal range) for biological condition at a test site. Assessments evaluate whether a test site's biological condition is within the normal range. New partnerships, and the ability to generate local information on aquatic condition, will build capacity for adaptive water management and enhance the link between science and decision making (Jones et al. 2006).

**Background Phosphorus:** The "Background" phosphorus concentration is the baseline concentration calculated by Muskoka's Recreational Water Quality Model to represent the expected phosphorus concentration within the lake or bay without any development.

**Phosphorus:** Phosphorus is a chemical element that is essential for all living cells. Amongst other sources, it is found in fertilizers, soaps, and in human waste. Typically phosphorus is not removed from waste streams by conventional private treatment systems (septic systems) nor by some municipal treatment systems.

**Phosphorus Threshold:** The "Threshold" phosphorus concentration is 50% more than the baseline (Background) concentration calculated by the District of Muskoka. The threshold is used to classify lakes and bays as requiring a higher level of development control as a precautionary action to protect the long-term health of the lake.

**Moderately Developed**: Areas where much of the adjacent shoreline is converted to residential or commercial development with docks, houses, and clearing of vegetation for yards, septics, etc. Patches of native vegetation remain, mostly separating lots from each other. No large sections of natural shoreline remain, but native and non-native vegetation cover is found along much of the shoreline.

**Muskoka Recreational Water Quality Model:** An advanced numerical model operated by the District of Muskoka designed to predict the response of all individual lakes in Muskoka to the input of phosphorus. The model is based on the Ontario Lakeshore Capacity Simulation Model, originally published in 1986 by a Provincial inter-ministerial working group. This model was substantially updated in 2005 by Dr. Neil Hutchinson of Gartner Lee Ltd. for the District of Muskoka (GLL, 2005).

The model includes a detailed phosphorus budget. Its inputs are the results of the District's Lake System Health Monitoring Program. Among the model's outputs is lake-specific Natural Phosphorus, Phosphorus Threshold and predicted phosphorus concentrations.

**Sampling Area:** A geographic location encompassing a group of WQI monitoring sites.

**Secchi Depth:** A measure of water **clarity**, measured using a Secchi disk - a small disk attached to a rope. Alternating quarters of the top side of the disk are coloured white and black. The Secchi depth is the depth of water whereby the sampler can no longer distinguish the white and black quarters of the disk.

**Site:** The discrete and unique location where samples are to be collected on each sample date.

**Spring Turnover Phosphorus:** A single phosphorus concentration measurement taken in a typically stratified lake during the spring turnover period. This measurement has been shown to adequately represent the overall phosphorus concentration in a lake (Clark, 1992). Typically the spring turnover lasts for a few days when the temperature of the entire water column is consistent (usually 4˚C) allowing the water column to mix. In practice, measurements taken anytime in May are considered adequate by Ontario's Ministry of the Environment. (http://www.ene.gov.on.ca/envision/water/lake_partner/index.htm).

**Yearly Mean Phosphorus:** The arithmetic mean of phosphorus concentration measurements taken above a stratified water column's thermocline over the ice-free period. ***Note:*** **yearly mean phosphorus concentration as reported by the WQI is for summer months only.**

**Total Coliform:** Coliform includes a variety of bacteria. In practice, detectable coliform are usually enteric, found in the intestinal tracts of humans and other warm-blooded species.

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