Muskoka Lakes Association
2002 Water Quality Program

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Executive Summary

The summer of 2002 marked the successful second year of the MLA's innovative nearshore water quality program. The program was launched in 2001 in response to members' concerns about the overall quality of water in Lakes Muskoka, Joseph and Rosseau. The 2001 program was carried out through a combination of volunteer effort, the MLA Marine Patrol and technical supervision by Gartner Lee Limited

One of the key recommendations of the 2001 program was that the MLA increase its direct involvement in the water quality program by a) identifying internal water quality champions and b) hiring an internal co-ordinator to run the day to day aspects of the summer program. These recommendations were made to provide long-term continuity to the MLA program and increase the cost effectiveness of the overall program.

The 2002 program represented a first-rate response to these recommendations. John Curran assumed the role of "champion" for the program and received the full support of the Board for his efforts. Mike Logan was hired to run the program for the summer and did a superb job in retaining volunteers, organizing their efforts, summarizing program results and drafting the report. Mike served as a visible and effective ambasssador for the MLA and ensured that all geographic areas of the three lakes were covered in the program. He met with planning and political representatives in local municipalities and the District Municipality of Muskoka. He attended an international conference on water protection in June and presented the MLA program to a national meeting (The Society of Canadian Limnologists) in Ottawa in January of 2003, as a guest of the MLA and Gartner Lee Limited

Mike is presently attending Dalhousie University, studying for his Master of Science Degree in the combined disciplines of Coastal Engineering and Urban Planning. As a result of the summer 2002 program, he has identified the MLA Water Quality Program as the topic of his major thesis. Mike will return to the Water Quality Program for the summer of 2003.

At the technical level, the 2002 program achieved its goals. Our intent is to document water quality in the nearshore areas of our lakes – those areas where we swim and draw our water - and to look for evidence of water quality problems due to:

a) bacterial contamination from septic systems or runoff;

b) runoff of the algal nutrient phosphorus from lawns, agriculture, leaking septic systems, golf courses or urban areas; and

c) growth of excessive amounts of algae, or undesirable types of algae.

The three lakes were divided into 17 smaller areas for sampling and a total of 75 different sites were sampled within the 17 areas. Bacterial measurements were made at all 75 sites, phosphorus measurements at 39 sites in 11 areas and algal growth was measured at 11 sites. Turbidity, a measure of water clarity, was measured at all sites. Each site was visited every two weeks, for a total of 8 samples between the end of May and mid-September. On each visit, a water sample was taken in the nearshore area, at a depth of approximately 1m. Every tenth sample was taken as a duplicate to check for measurement error and natural variance. We filled up test bottles with distilled water to check for contamination by our sampling methods and sent samples to a commercial laboratory, to compare their bacterial estimates against the counts we made ourselves using the "Coli Plates".

The volunteers were enthusiastic and diligent. They completed all scheduled sampling on time and on schedule. In mid-July, the MLA hosted a "Volunteer Recognition Luncheon" at the Curran's residence on Royal Muskoka Island to thank the volunteers for their hard work and determination . This was popular with the volunteers, the hosts and the local press and is recommended for all future years.

The 2002 program confirmed the results of the 2001 program and expanded on them. Overall, water quality in the Muskoka Lakes is excellent – whether described by bacterial counts, nutrient status or algal growth. There are no water quality restrictions on their recreational use for swimming, nor on their aesthetics and water clarity.

The 2002 program confirmed the hypothesis that water quality programs should focus on near shore areas and not just on open water areas as they have done in the past. Results showed that nutrient and bacterial levels were higher in near shore areas than in open water and that there are areas of concern, where land uses adjacent to the lakes may threaten water quality over the long term. Phosphorus levels were higher in nearshore areas and the type of land use and land stewardship which is practiced did influence the amounts of bacteria, phosphorus and algae which were present in the near shore. Water quality was measurably influenced by runoff from urban areas, agricultural areas and golf courses but, for golf courses in particular, results varied. Some had no effect and others did, dependent on age of the course, on site practices and exposure of the shoreline to wind and waves. Water quality responds to natural factors, human influences and the physical characteristics of the Muskoka Lakes where they receive runoff from adjacent lands and their watersheds.

Bacteria and turbidity were also sampled in Brandy Lake as part of the MLA program. Water quality was very good at all sites with the exception of the inflow of Brandy Creek, which had very high levels of total coliform and *E. coli*. These high inputs may reflect the high percentage of wetlands in the catchment or upstream land uses such as agriculture but it is also clear that the lake assimilated these inputs so that overall, water quality was maintained. Full interpretation of water quality in Brandy Lake awaits the results of the water quality study done by MOE in the summer of 2002.

We have now divided the MLA program in to two objectives. These are research (to develop new tools and land stewardship advice) and monitoring (to track changes over time and build public support for and contribution to the program). These needs will guide the 2003 program The 2002 program was very popular, and requests for participation were received from all areas of the large lakes and from associations outside of the MLA. Politically, the visibility of the program and local press coverage were translated into good will among members of the MLA, associations outside of the MLA and with local government.

The three-year pilot program will finish with the 2003 studies. For 2003, we plan to :

a) consolidate our findings;

b) continue to maintain and build public support for the program;

c) maintain the focus on algae, phosphorus and bacteria in the near shore area;

d) finalize the recommendations for future monitoring tools; and

e) increase the program size slightly by adding more sites and addressing specific geographic concerns of our membership.

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1. Introduction

The Muskoka Lakes Association (MLA) has represented the communities surrounding Lake Rosseau, Lake Joseph and Lake Muskoka since 1894. The MLA constitution states that the purpose of the organization, in part, is to

> *"…protect the healthful, sanitary condition and scenic beauty of the vicinity."*

The statement has been subject to many different interpretations since its inception. In the current incarnation, as a call to protect the ecological integrity and biodiversity of the aquatic systems that make the Muskoka region unique, it is perhaps more applicable and comprehensive than ever before.

In the early spring of 2001, the MLA approached Gartner Lee Limited (GLL) for help in initiating a program designed to protect these aquatic ecosystems. The resulting Water Quality Testing Program has proven to be an ambitious initiative that continues to grow and evolve. As outlined here, the Program is quickly becoming an effective tool for the MLA in building knowledge about local aquatic ecosystems, engaging members and building community around common ecological interests, and developing relationships with various levels of government and academia.

This report is the result of a partnership between the MLA and GLL. It describes the water quality results and interpretation from the 2002 program, but also includes a discussion of program objectives, long term planning and recommendations for subsequent years. The report was prepared as a collaboration between Mike Logan (MLA) and Sean Miller and Neil Hutchinson (GLL).

The results from the 2002 Water Quality Testing Program provide additional evidence of land use influence on the nearshore water quality in the Muskoka Lakes. While further research will aid to the quantification of these effects, it is clear that the program is returning meaningful results. Several conclusions and recommendations are made to direct the continuing evolution of the Water Quality Testing Program.

2. Background

Past water quality programs of the District Municipality of Muskoka and the Ministry of Environment have focussed on analysis and protection of the entire water mass of each lake, as inferred from measurements of water quality made in central portions of each lake. In 2001, the MLA retained GLL to provide a technical assessment of the water quality status in the three large Muskoka Lakes (The "Big 3", Lakes Muskoka, Joseph and Rosseau) and to develop a water quality program for the MLA which would address their own concerns and expand beyond the routine programs of the municipal and provincial governments. The MLA felt that, in general, the community would benefit from a more detailed understanding of lake ecosystems and the effects of development. It was also felt that the MLA should be more involved in protecting and enhancing the quality of the water in the Muskoka Lakes.

2.1 Long-Term Objectives

The long term vision for the Water Quality Testing Program was originally captured in five tasks:

1. **Review existing information** on water quality in Lakes Muskoka, Lake Joseph and Lake Rosseau.
2. **Give an opinion on the water quality stresses of most significance** to the Muskoka Lakes and the MLA, along with rationale for that opinion, with particular emphasis on acid rain, nutrient enrichment and bacterial contamination.
3. **Develop a research and monitoring program** to document conditions of nutrient runoff, bacterial contamination and algal growth in the nearshore waters as they are influenced by bottom substrate, development density and shoreline vegetation.
4. **Liaise with other management initiatives** (District of Muskoka, Ministry of Environment, non-governmental organizations (NGOs)).
5. **Advise on future stewardship initiatives** for the MLA.

2.2 Achievements

Objectives 1 and 2 have been undertaken as part of the work performed by Gartner Lee Limited, and results are outlined in the report *Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau* (GLL, 2001).

2.3 Ongoing Efforts

Objectives 3, 4 and 5 represent open-ended tasks. Success in these areas will potentially become a legacy of the Association and its work in water quality. We note significant progress already in these tasks. The Muskoka Watershed Council (MWC) was formed in 2001 with a mandate to foster co-operative water management and protection throughout the entire Muskoka River Watershed by a variety of stakeholders. The MWC is a joint project of the Muskoka Heritage Foundation and the District Municipality of

Muskoka and it includes membership from a broad spectrum of Muskoka Stakeholders. The MLA are an active participant on the MWC and both John Curran, of the MLA, and Dr. Neil Hutchinson, of GLL, are members of the Board of Directors. This participation plays a strong role in achieving Objectives 4 and 5 of the MLA water quality program.

2.3.1 Research & Monitoring Program

The research and monitoring program was initiated in 2001. Gartner Lee Limited designed a pilot program that tested the feasibility of investigating the effects of land use and land-based activities on nearshore water quality. The 2001 report concluded that even though there were no consistent or significant patterns relating land use to degraded water quality, there were strong indications of impacts on nearshore nutrients, bacteria and algal density for specific land uses. These were sufficient to recommend that investigations continue for an additional 2 years (2002 and 2003), after which a complete program review was recommended. Several immediate changes to the program were recommended for 2002 and 2003. These included:

a) Increase expertise by hiring students of environmental science and related fields to work on the Marine Patrol, to facilitate the Water Quality Testing Program.

b) Maintain and increase the involvement of the MLA office staff in the operation of the Water Quality Testing Program in order to develop internal expertise.

c) Identify an internal "champion" of water quality to maintain continuity of initiatives.

d) Start testing earlier in the season.

e) Expand number of testing sites without stressing financial and human resources.

f) Reduce reliance on Gartner Lee Limited for data analysis and report preparation through internalization of expertise.

g) Support graduate student research into factors influencing the growth of nearshore algae.

To a great extent, these recommendations were adopted by the MLA in 2002, most notably by identifying John Curran as the "internal champion" for water quality and by retaining Mike Logan as a student intern in water quality and planning. Mike's role included working with GLL to develop the technical program, identifying and co-ordinating volunteers from within the MLA, ensuring that the program ran smoothly, providing liaison with GLL, the MLA Board and governmental and non-governmental organizations and providing substantial input into report preparation.

The water quality monitoring program continues to evolve with the understanding of which parameters are best studied, which questions are best asked and which land uses are best targeted. The bulk of this report is dedicated to the results of the 2002 research and monitoring program.

2.3.2 Future Objectives

Prior to 2002, the MLA water quality program was independent of other local initiatives. Planning staff at the District Municipality of Muskoka, as well as a few of the townships in the area were aware of the program, and were willing to support it, but were not actively involved. Likewise, many smaller NGOs in the area were watching to see how the program would develop. Other government agencies and NGOs were not aware of the program. Through the MLA's involvement with Gartner Lee Limited, a relationship has developed with the Lake of Bays Association, who organize a very similar program. Through this relationship, ideas, results and best management techniques are shared. In addition, John Curran represented the MLA on the Muskoka Watershed Council. The MLA also held several meetings with planning staff of the District Municipality of Muskoka and area municipalities to explain the water quality program and its implications.

It is clear that for the Water Quality Testing Program initiative to be successful, partnerships will need to be developed and maintained amongst many interested parties, providing a united voice. The representation of the MLA on the Muskoka Watershed Council will help provide this continuity and co-ordination among parties.

Future stewardship initiatives may take many forms. Some already exist, delivered by various government agencies and NGOs. Septic system inspection programs within local municipalities are an example of such initiatives. As we learn more about various land uses and how they affect nearshore water quality, the MLA will be in a better position to develop and deliver effective stewardship initiatives to its own membership.

3. Methods

In modifying the Water Quality Testing Program for 2002, the MLA addressed each of the recommendations outlined in the Gartner Lee report from 2001 either directly or indirectly.

The Marine Patrol's involvement with the Water Quality Testing Program was reduced for two important reasons. The MLA realized that the primary purpose of the Marine Patrol was to address issues of boating safety, and educate the public about boating safety. The results from the 2002 MLA membership survey indicate that the Association's membership strongly supports these safety-oriented objectives. While it may be appropriate to broaden the Marine Patrol's mandate to include disseminating environmental information along with information about boating safety, their mandate is safety issues. Moreover, an opportunity to involve interested MLA members in the program was realized.

The majority of sample collection responsibility was transferred from the Marine Patrol to a dedicated group of volunteers from the local community. The Marine Patrol continued to collect samples one morning per week, at locations where volunteers did not come forward.

The role of the MLA office staff was reduced to allow them more time for other initiatives such as the Biannual Antique and Classic Boat Show. However, an additional staff member was hired specifically to manage the program. Recommendations b) and g) noted above were therefore both addressed through the employment of Mike Logan as program director, who is a graduate student of Environmental Engineering and Urban Planning. While gaining expertise in water quality and community involvement, Mike is sharing this knowledge with the MLA and will train appropriate personnel to operate the program in the future.

Internally, MLA Director John Curran became the 'champion' of water quality. John oversaw the operation of the program, and acts as a liaison with interested agencies through direct involvement with the Muskoka Watershed Council. The Board of Directors has decided that it will be a responsibility of the 1st Vice President to maintain these important initiatives in perpetuity.

By hiring a water quality program co-ordinator and relying on volunteers to collect samples, the MLA was able to reduce their reliance on Gartner Lee Limited. The program was expanded to 70 sites, with samples collected biweekly between May 27th and September 9th. A total of 1072 samples were collected, including field blanks and duplicates, up from 200 samples in 2001.

3.1 Volunteers & Management

Volunteers collected most of the samples during the 2002 Water Quality Testing Program and were integral to its success. A listing of volunteers and MLA staff who contributed are provided in Appendix A.

Volunteers are the first contact for public education regarding water quality. Involving enthusiastic community members to collect samples, helps to expand knowledge of the program and its findings. Enthusiastic volunteers are the best way to begin educating other community members (volunteers' neighbours, relatives etc) about water quality problems and solutions. The volunteers also proved to be an important source of input to the program; they provided many suggestions, and demonstrated what types of education might be appropriate for the broader community.

Volunteers allowed the program to expand by taking pressure off the MLA staff (both Marine Patrol and office staff). Without the help of the nearly 40 volunteers, the 2002 Water Quality Testing Program would have been much more expensive, with much less sampling coverage.

On Sunday, May 26th, a volunteer training session was held on the public wharf in Port Carling. During the session, each volunteer was taught how to take the various types of samples and how to fill out their data sheet. They were also able to ask any questions about the Water Quality Testing Program. The majority of volunteers were able to attend the session, along with John Curran, Mike Logan of the MLA, and Sean Miller of Gartner Lee Limited. The few volunteers who were not able to attend the session were given private instruction at another time.

After being trained, the volunteers proved to be proficient, needing only minimal supervision. Some confusion about duplicate samples remained throughout the summer, and will need to be addressed more carefully in future years. More detailed instruction regarding the data sheet will improve clarity and reduce confusion in future programs.

Overall, the use of volunteers proved to be very successful. The volunteers were enthusiastic, eager to learn more about water quality issues in the Muskoka Lakes, and good ambassadors of the program. A volunteer recognition luncheon was held at he Curran residence in July of 2002. The event was successful and is recommended for future year to provide public recognition of the important contribution made to the program by volunteers.

3.2 Site selection

The research and monitoring program portion of the Water Quality Testing Program was designed to meet two objectives. The first was to determine the effects of various land uses on nearshore water quality in the Muskoka Lakes. The second was to establish a database of measured water quality in the lakes. The database will allow the MLA to track longer-term changes in water quality.

The primary goal of the 2001 program was to determine if nearshore water quality is significantly different than that of the larger water mass within the lakes. The 2002 program was the first attempt to relate water quality to land use. The program is a work in progress and the details are still being refined.

Five indicators of water quality were tested.

- Turbidity (Turb.)
- Total Coliforms (TC)
- Escherichia coli (*E. coli*)
- Total Phosphorus (TP)
- Periphyton (algae) growth

Seventy sites were selected throughout Lakes Joseph, Lake Rosseau, Lake Muskoka and Brandy Lake. They were each tested eight times, between May and October of 2002, for turbidity, total coliforms and *E. coli*. The total phosphorus concentration was measured at 49 of the 70 sites, and periphyton was measured (qualitatively and quantitatively) at 11 sites.

The locations of some sites were similar to sites used in the 2001 program, however no sites were exactly the same. A few sites were chosen in deep water to represent offshore water quality. At the same time, sites were chosen in the nearshore zone of each lake adjacent to certain land uses. Sites were spread evenly over Lake Joseph, Lake Rosseau and Lake Muskoka.

The "big three" Muskoka Lakes were not sampled equally in 2002. This was because lakeside development is not evenly distributed and the program specifically sought out areas where land use was most intense.

Sites were selected that would most effectively exhibit the effects of land use on water quality. To achieve this, clusters of sites were located around specific land uses. At each targeted land use, one site was located offshore (removed from land-based influence and representative of deep water quality), and nearshore sites were placed adjacent to different land use types. Seventeen groups of sites were identified, they are shown in Table 1. Individual land use classifications for each site are presented in Table 2.

Table 1. Summary of Water Quality Testing Sites, Grouped by Location and Test

Location	Group	Number of Test Sites	Tests (additional to turbidity and bacteria)
Hamer Bay	HMB	1 offshore 4 nearshore	Phosphorus Algae (2)
Little Lake Joseph	LLJ	3 nearshore	
Cox Bay	COX	1 offshore 4 nearshore	Phosphorus
Rosseau/Shadow River	RSH	1 offshore 3 nearshore	Phosphorus
Royal Muskoka Island	RMI	3 nearshore	
Cleveland's House	CLE	3 nearshore	
Brackenrig Bay	BRA	3 nearshore	
Arthurlie Bay	ART	1 offshore 3 nearshore	Phosphorus Algae (1)
Indian River	IND	1 offshore 4 nearshore	Phosphorus Algae (3)
Brandy Lake	BDY	1 offshore 5 nearshore	
Beaumaris	BMR	1 offshore 3 nearshore	Phosphorus Algae (1)

Table 1. Summary of Water Quality Testing Sites, Grouped by Location and Test

Location	Group	Number of Test Sites	Tests (additional to turbidity and bacteria)
East Bay	EAS	1 offshore 3 nearshore	Phosphorus Algae (1)
Montcalm Point	MON	1 offshore 4 nearshore	Phosphorus
Arundel	ARN	3 nearshore	
Eilean Gowan Island	ELG	1 offshore 3 nearshore	Phosphorus
Muskoka Sands	MSN	3 nearshore	Phosphorus
Muskoka Bay	MBA	1 offshore 5 nearshore	Phosphorus Algae (3)

Table 2. Summary of Water Quality Testing Sites, Grouped by Land Use

Lake Joseph			Lake Rosseau			Lake Muskoka		
Location	Code	Land Use	Location	Code		Location	Code	Land Use
Hamer Bay	HMB-0	Offshore	Rosseau/Shadow River	RSH-0	Offshore	Beaumaris	BMR-0	Offshore
	HMB-1	Golf Course		RSH-1	Agricultural		BMR-1	undeveloped
	HMB-2	Resort		RSH-2	wetland		BMR-2	Golf Course
	HMB-3	Resort		RSH-3	Urban		BMR-3	Urban
	HMB-4	Residential	Royal Muskoka Island	RMI-1	Residential	East Bay	EAS-0	Offshore
Little Lake Joseph	LLJ-1	Residential		RMI-2	Residential		EAS-1	undeveloped
	LLJ-2	Residential		RMI-3	Residential		EAS-2	wetland
	LLJ-3	Residential	Cleveland's House	CLE-1	Resort		EAS-3	undeveloped
Cox Bay	COX-0	Offshore		CLE-2	Resort	Montcalm Point	MON-0	Offshore
	COX-1	Golf Course		CLE-3	Residential		MON-1	Residential
	COX-2	Golf Course	Brackenrig Bay	BRA-1	Residential		MON-2	Residential
	COX-3	Urban		BRA-2	Residential		MON-3	Residential
	COX-4	Resort		BRA-3	Residential		MON-4	Residential
			Arthurlie Bay	ART-0	Offshore	Arundel	ARN-1	Residential
				ART-1	Agricultural		ARN-2	Resort
				ART-2	Agricultural		ARN-3	Residential
				ART-3	Residential	Eilean Gowan	ELG-0	Offshore
			Indian River	IND-0	Offshore		ELG-1	Residential
				IND-1	Residential		ELG-2	Residential
				IND-2	Urban		ELG-3	Public Park
				IND-3	Trailer Park	Muskoka Sands	MSN-1	Resort
				IND-4	Agricultural		MSN-2	Golf Course
							MSN-3	Residential
Brandy Lake	BDY-0	Offshore				Muskoka Bay	MBA-0	Offshore
	BDY-1	Agricultural					MBA-1	wetland
	BDY-2	Residential					MBA-2	Institutional
	BDY-3	Residential					MBA-3	Urban
	BDY-4	wetland					MBA-4	Urban
	BDY-5	Residential					MBA-5	Urban

Offshore site locations were selected to be sufficiently removed from physical and anthropogenic land use effects on water quality. In areas where a group of sites was located in a more confined water mass, the offshore site represented general water quality for the confined mass. The water quality in these confined areas may have been different from the offshore water quality of the whole lake but was important for comparison to nearshore effects. Deeper and further-removed offshore sites may be added to the program for comparing whole lake water quality to that at the offshore sites in more confined areas.

3.3 Data Sheets

Volunteers completed a data sheet for each sample date of the 2002 Water Quality Testing Program. An example of a data sheet is shown in Appendix B.

These site records added descriptive parameters to the data set that may help to explain some of the variability in water quality. Physical conditions, both permanent (i.e., shoreline orientation) and temporal (i.e., temperature and wind direction) can have a significant effect on nearshore water quality. Quantifying these effects and separating them from anthropogenic effects was an important component of the research program.

The consistency of data collected by the volunteers was variable. More emphasis on the data sheets at the volunteer training session would improve the quality of data. As well, the need to revise the form such that the fields were less subjective was identified.

The importance of accurately completing the data sheets needs to be communicated more effectively to the volunteers. Careful attention must be given to consistency. If possible, the program co-ordinator should make the effort to help each volunteer fill out the first data sheet. Subsequently, volunteers can maintain consistency in observations. In future years, it would be sufficient to record *wave height* as either "rough" or "calm." In addition, *estimated distance from shore* and *water depth* are parameters that should be added to the data sheet.

3.4 Total Coliforms

The volunteers collected samples for total coliform analysis using 300mL juice bottles. The bottles were purchased new from Consolidated Bottle Company, and were identical to bottles conventionally used to hold fruit juices.

The bottles and caps were sterilized in boiling water, sealed and labelled before the volunteers received them. The bottles were opened at the testing location, filled with water and resealed. The volunteers were instructed not to come in contact with either the inside of the bottle or the underside of the cap. The samples were placed on ice in the field, and returned to a "drop-off" location. From the "drop-off" location, the samples were brought to a central location for testing.

Testing 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, 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 used in the MLA Water Quality Testing Program is the ColiPlate, produced by Environmental Biodetection Products Inc. (EBPI) (http://www.ebpi-kits.com). This product is widely used in water quality programs co-ordinated by private and non-governmental interests, and has been scientifically tested (Schiefer, 2001). 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).

Figure 1. ColiPlate Test Kit, Blue Cells are Positive for Total Coliforms

Counting the number of blue wells was challenging due to the wide range of shades visible after incubation. A convention was devised to only count the wells that were sufficiently dark, as had been done in 2001. During the season, Dr. Karl Schiefer of EBPI advised that any well that could be classified as any shade of blue or green should be counted as a positive blue well. At that time, it was determined that it was best to continue with the convention. For this reason, total coliform readings from the ColiPlates may be lower than the actual coliform concentration. In the future, it would be helpful to visit EBPI to discuss interpretation of ColiPlate results.

3.5 *Escherichia Coli*

After testing for total coliforms, the ColiPlates were used to analyze for *Escherichia coli* (*E. coli*) by exposing the plate to a 366nm 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 the EBPI office to be cleaned and reused.

3.6 Turbidity

Turbidity is a measure of water clarity, where lower turbidity indicates clearer water. It is measured as the amount of light scattering as it passes through water. The value is reported in Nephelometric Turbidity Units (NTU). One NTU is defined as the turbidity of water with a concentration of 1.0 mg/L of silica in suspension (Viessman and Hammer, 1998). Many water quality programs use Secchi disks to measure water clarity. Turbidity testing was used for the 2002 program instead of Secchi disk readings for two reasons. First, Secchi disk readings can vary based on the observer and the weather whereas a turbidity measurement is less subjective. Second, the MLA program was focussed on the nearshore where water was too shallow to record a Secchi depth as the water clarity exceeded the depth. Turbidity was therefore an accurate estimate of land use effects on nearshore water clarity and so measurements were made using water left over from the bacterial tests.

After the ColiPlates had been filled and placed in the incubator, the remaining volume was tested using an Orbeco Portable Turbidimeter (Figure 2). Initially, the turbidimeter was calibrated using commercial calibration standards measuring zero and 40 NTU. Approximately 5 mL of each sample (allowed to warm to outside temperature) was placed in a vial similar to those on the right hand side of Figure 2. The vial was then inserted in the turbidimeter for analysis.

Figure 2. Orbeco Hollige Portable Turbidmeter

Most of the samples had a turbidity close to the detection limit of the meter. As a result there were some minor fluctuations in the reading. The recorded turbidity was estimated as an average of the readings. Occasionally there were larger fluctuations, which are most likely attributable to the settling of particles in a sample.

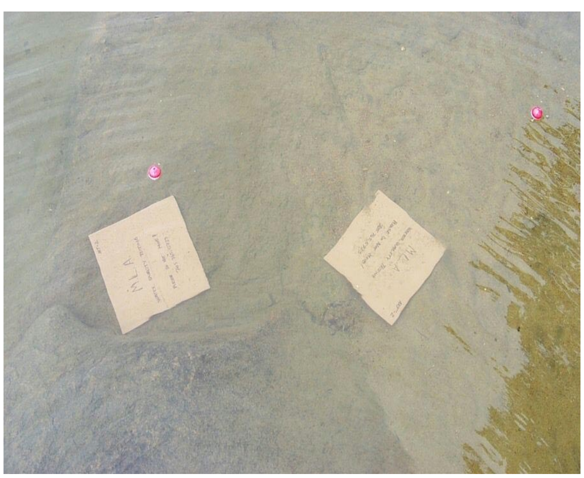
Turbidity readings were not recorded for the first two sample periods, because the method was still being developed. Two recommendations were generated from this process. The samples should be tested within 24 hours of being collected; and the standards and batteries for the turbidimeter should be replaced at the onset of each season.

3.7 Phosphorus

Total phosphorus (TP) was analyzed at the Trent University Laboratory located at the MOE Dorset Environmental Science Centre. The laboratory supplied the MLA with borosilicate digest tubes for sample collection. Water samples were collected directly into these tubes to prevent 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). The tubes were labelled and distributed to the volunteers along with the bacteria testing equipment. Samples were collected using the same technique as the bacteria samples. The TP tubes were kept on ice and delivered to the sample drop-off locations. After sampling, the tubes were taken to the Gartner Lee Limited office in Bracebridge, to be delivered to the laboratory in Dorset. Results of phosphorus analyses were sent to the MLA by e-mail approximately 3 months after the last samples were submitted. In future years, an effort should be made to improve the turn-around-time with the laboratory.

3.8 Algae

Periphyton growth was measured throughout the season both quantitatively and qualitatively. Two 'algae plates' as shown in Figure 3, were placed at each sampling location. These plates were 12" square unglazed clay tiles. Each plate was placed in 30 cm of water, along a southern shore (azimuth within 22.5º of due south). Each plate was checked over the summer to ensure the tiles had not moved or been affected by lower water levels.



At the end of the season, the plates were retrieved. Upon collection, one of the two plates was placed in a sealed plastic bag, put on ice and sent for qualitative assessment (taxonomic analysis and algal cell volume and biomass). The second plate was scraped with a razor blade and rinsed with deionized water into a 1 L mason jar, which was wrapped in foil, placed on ice and sent for quantitative assessment (chlorophyll *a*).

Figure 3. Algae Plates

While great care was taken to maintain field conditions for the algae tiles during the entire season, it was difficult to ensure that the ideal conditions were always maintained. When the plates were checked, they had often been moved, overgrown (thus blocked from sunlight) or otherwise affected. They should be considered when interpreting the algal test results.

3.9 Quality Assurance / Quality Control

A research program like the MLA Water Quality Testing Program achieves recognition and support by using sound scientific methods. In order to ensure the integrity of results several steps were taken. These included duplicate samples and field blanks as quality control and quality assurance measures.

3.9.1 Bacteria Duplicates

A duplicate field sample was collected by filling a sterilized 1 L mason jar, and decanting water into two separate 300 mL bacteria sample jars. For each sample period, six duplicate bacteria samples were collected. Three of the samples were tested with ColiPlates, the other three were sent to the Central Ontario Analytical Laboratory in Orillia for professional testing. This way the duplicate samples had three roles, monitoring the consistency of field techniques, a check on the variation of the ColiPlates method and a comparison of the ColiPlates with another the laboratory testing procedure.

3.9.2 Bacteria Blanks

Six field blanks were collected for each sample period. A 500 mL bottle of sterile *Aquafina* water was taken into the field and then used to fill a bacteria sample bottle. If bacteria were found in the sample, it would imply that there was contamination introduced in the sampling process.

3.9.3 Phosphorus Duplicates

Three duplicate phosphorus samples were taken for each sample period. The samples were collected at the same time as the regular phosphorus samples using identical TP tubes. The duplicate measurements then show the range of phosphorus results that can be expected as a result of sampling and laboratory variation.

4. Results

A review of results from the 2002 research and monitoring program showed trends that built on the results of the 2001 program. The 2002 results were more robust because of the changes made to the program, including a longer sampling season and more sites. Although it would not be responsible at this stage to draw any conclusions about the relationship between land uses and land-based activities, it is appropriate to form hypotheses. The current results allow further changes to the research program that will in turn clarify findings.

Results are presented first for the QA/QC program and then for the individual sampling locations across the study lakes. A final section then presents results relating to land use which were obtained by combining results for the entire program.

4.1 Quality Assurance / Quality Control

Quality control is very important in any scientific study – especially when the data are collected by volunteers, who are not professionally trained in field protocol. Quality control methods must agree with and support general conclusions in order to confirm that samples were collected and tested properly. Non-conforming values from the QA/QC program may raise concerns with the collection process. If the cause of the concern can not be resolved than the entire study could be dismissed. Therefore, results of the 2002 research and monitoring program were very carefully checked and verified.

In all, six forms of quality control were considered. Bacterial results were double-checked using duplicate ColiPlate tests, laboratory results and field blanks. Duplicate phosphorus samples were tested by the MOE laboratory in Dorset, and turbidity results were checked using duplicates and blanks.

The sampling protocols for duplicates and blanks are described in Section 3.9.

4.1.1 Bacteria Blanks

The potential sources of introduced contamination include insufficient sterilization of the bottles, loss of the seal after sterilization, inadvertent contamination by the volunteer samplers or the source water. Field blanks for bacteria were tested using the ColiPlate technology, as were the normal bacteria samples. Since the blanks did not contain any bacteria, test results should show no bacteria.

Results of bacteria blank tests are shown in Tables 3a and 3b. Blank samples were taken on every sampling day, and were spread evenly throughout the sampling sites. Only 5 of 48 (10%) tests showed bacteria present in the field blank. For 3 of these 5 samples, the ColiPlates only showed one blue cell. A fourth field blank showed two blue cells, and a fifth registered a high number of blue cells. None of the field blanks were positive for *E. coli*. Further, Table 3a shows that two of the non-zero bacteria blanks were sampled at the beginning of the program, and three were sampled near the end of the season. As shown in Table 3b no two of the contaminated bacteria blanks were sampled by the same volunteer.

The results indicate that the sampling protocol was not subject to any significant bacterial contamination. No spatial trends in the non-zero bacteria blanks were evident, suggesting that bacterial contamination was random and did not bias the data. More attention to the sterilization of collection bottles, and increased communication with the volunteers on the importance of sterile technique may reduce the number of non-zero blanks in the future.

Table 3a. Bacteria Blank Results Sorted by Date

Date	Site	MPN Total Coliforms	MPN E.Coli
27-May-02	HMB-3	>3	>3
27-May-02	RSH-2	>3	>3
27-May-02	ART-0	>3	>3
03-Jun-02	EAS-1	5	>3
03-Jun-02	MBA-3	>3	>3
10-Jun-02	LLJ-1	>3	>3
10-Jun-02	COX-0	>3	>3
10-Jun-02	CLE-1	>3	>3
17-Jun-02	BMR-1	3	>3
17-Jun-02	ARN-2	>3	>3
17-Jun-02	ELG-2	>3	>3
24-Jun-02	RMI-1	>3	>3
24-Jun-02	BRA-1	>3	>3
24-Jun-02	IND-0	>3	>3
01-Jul-02	BDY-0	>3	>3
01-Jul-02	MON-0	>3	>3
08-Jul-02	HMB-0	>3	>3
08-Jul-02	LLJ-2	>3	>3
08-Jul-02	COX-1	>3	>3
15-Jul-02	ARN-1	>3	>3
15-Jul-02	MSN-2	>3	>3
15-Jul-02	MBA-1	>3	>3
22-Jul-02	RSH-0	>3	>3
22-Jul-02	RMI-2	>3	>3
22-Jul-02	CLE-2	>3	>3
29-Jul-02	EAS-0	>3	>3
29-Jul-02	ELG-1	>3	>3
29-Jul-02	MON-1	>3	>3
05-Aug-02	BRA-3	>3	>3
05-Aug-02	ART-1	>3	>3
05-Aug-02	IND-1	>3	>3
12-Aug-02	BDY-1	>3	>3
12-Aug-02	BMR-0	>3	>3
19-Aug-02	HMB-2	>3	>3
19-Aug-02	LLJ-3	>3	>3
19-Aug-02	COX-2	>3	>3
26-Aug-02	BDY-2	>3	>3
26-Aug-02	MON-2	>3	>3
26-Aug-02	ARN-3	5	>3
26-Aug-02	MBA-2	>3	>3
02-Sep-02	CLE-3	>3	>3
02-Sep-02	BRA-2	136	>3
02-Sep-02	ART-2	3	>3
09-Sep-02	BMR-2	>3	>3
09-Sep-02	EAS-2	>3	>3
09-Sep-02	ELG-2	>3	>3

Table 3b. Bacteria Blank Results Sorted by Location

Date	Site	MPN Total Coliforms	MPN E.Coli
15-Jul-02	ARN-1	>3	>3
17-Jun-02	ARN-2	>3	>3
26-Aug-02	ARN-3	5	>3
27-May-02	ART-0	>3	>3
05-Aug-02	ART-1	>3	>3
02-Sep-02	ART-2	3	>3
01-Jul-02	BDY-0	>3	>3
12-Aug-02	BDY-1	>3	>3
26-Aug-02	BDY-2	>3	>3
12-Aug-02	BMR-0	>3	>3
17-Jun-02	BMR-1	3	>3
09-Sep-02	BMR-2	>3	>3
24-Jun-02	BRA-1	>3	>3
02-Sep-02	BRA-2	136	>3
05-Aug-02	BRA-3	>3	>3
10-Jun-02	CLE-1	>3	>3
22-Jul-02	CLE-2	>3	>3
02-Sep-02	CLE-3	>3	>3
10-Jun-02	COX-0	>3	>3
08-Jul-02	COX-1	>3	>3
19-Aug-02	COX-2	>3	>3
29-Jul-02	EAS-0	>3	>3
03-Jun-02	EAS-1	5	>3
09-Sep-02	EAS-2	>3	>3
29-Jul-02	ELG-1	>3	>3
17-Jun-02	ELG-2	>3	>3
09-Sep-02	ELG-2	>3	>3
08-Jul-02	HMB-0	>3	>3
19-Aug-02	HMB-2	>3	>3
27-May-02	HMB-3	>3	>3
24-Jun-02	IND-0	>3	>3
05-Aug-02	IND-1	>3	>3
10-Jun-02	LLJ-1	>3	>3
08-Jul-02	LLJ-2	>3	>3
19-Aug-02	LLJ-3	>3	>3
15-Jul-02	MBA-1	>3	>3
26-Aug-02	MBA-2	>3	>3
03-Jun-02	MBA-3	>3	>3
01-Jul-02	MON-0	>3	>3
29-Jul-02	MON-1	>3	>3
26-Aug-02	MON-2	>3	>3
15-Jul-02	MSN-2	>3	>3
24-Jun-02	RMI-1	>3	>3
22-Jul-02	RMI-2	>3	>3
22-Jul-02	RSH-0	>3	>3
27-May-02	RSH-2	>3	>3

Note: Values marked as "> 3" should be marked as "<3"

4.1.2 Turbidity Blanks

De-ionized water was used a blank for turbidity. Variation in the turbidity readings would suggest a compromised water supply, or problems with the turbidimeter. All but one of the results for the turbidity blanks were less than 0.5 NTU. The one value above 0.5 NTU was recorded on the first day of measuring turbidity and may have been an artifact of inexperience.

4.1.3 ColiPlate Duplicates

Field duplicates were run as described in Section 3.9.1. Half of the samples collected as duplicates were tested using the ColiPlates. Overall, the duplicate analyses showed satisfactory agreement. Some variation is expected due to the clustered nature of bacteria. Since bacteria are prone to grouping, and adsorbing to suspended particles, it is likely that there will be a different number of organisms in sub-samples of the same water. The results of the ColiPlate duplicates for total coliform and *E. coli* are shown in Figures 4 and 5. The total coliform results were more closely correlated than the *E. coli* results. However, the range of values from the *E. coli* testing was much lower range than the total coliform range. The result is that small differences in *E. coli* counts will be inflated compared to the same variation in total coliform results.

Figure 4. Total Coliform ColiPlate Duplicate Results

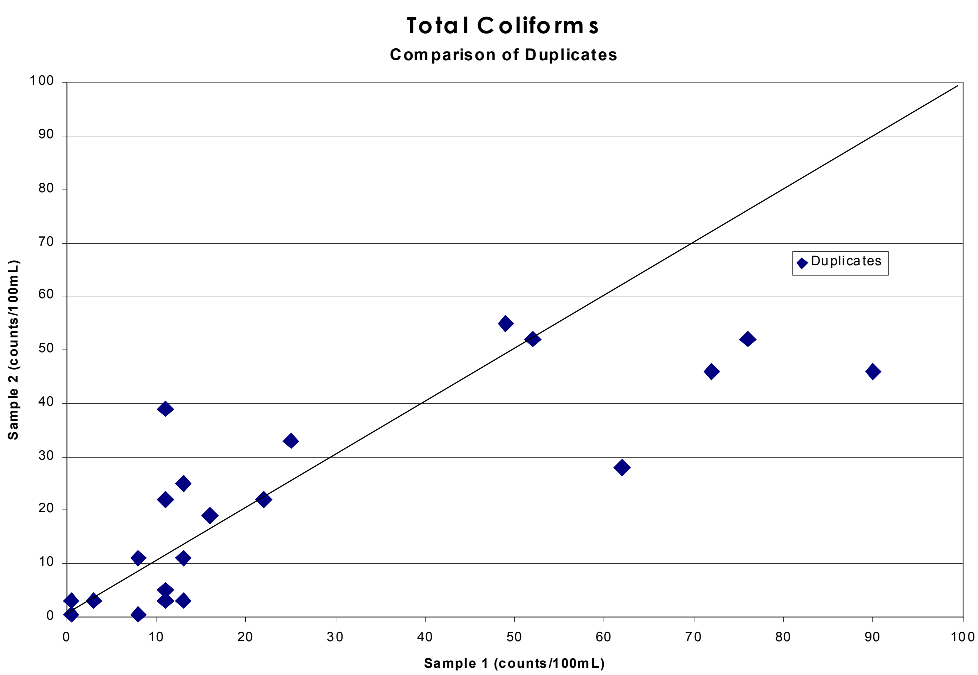
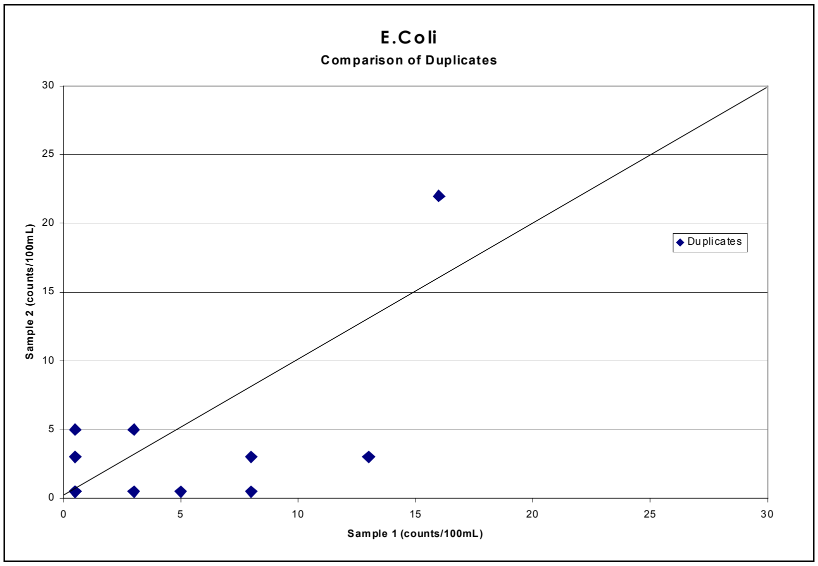


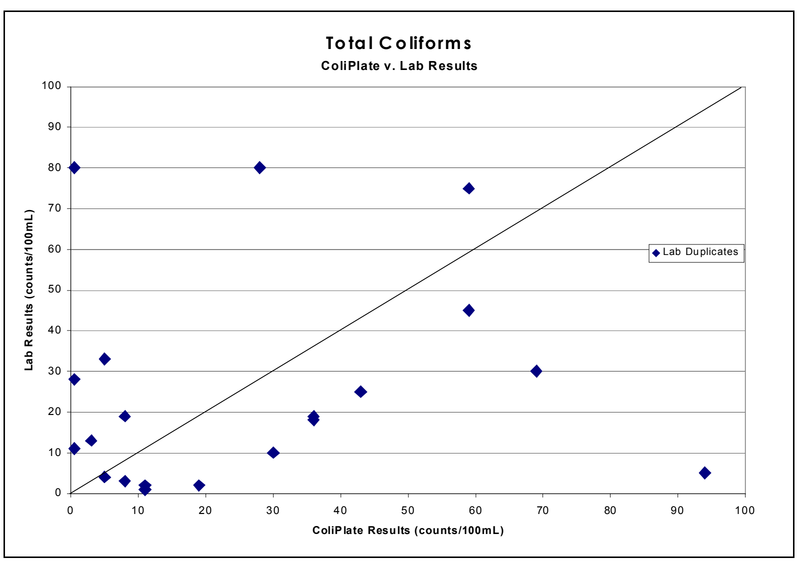
Figure 5. *E. coli* ColiPlate Duplicate Results



4.1.4 Laboratory Duplicates

Section 4.2.3 described results for field duplicates tested using the ColiPlates. The other half of the duplicate samples collected for bacteria were tested by an accredited laboratory in Orillia (*Central Ontario Analytical Laboratory,* COAL). These samples were sent to COAL to validate the ColiPlate method. The total coliform and *E. coli* duplicate samples that were tested by COAL are shown in Figures 6 and 7 with the values recorded using the ColiPlate method.

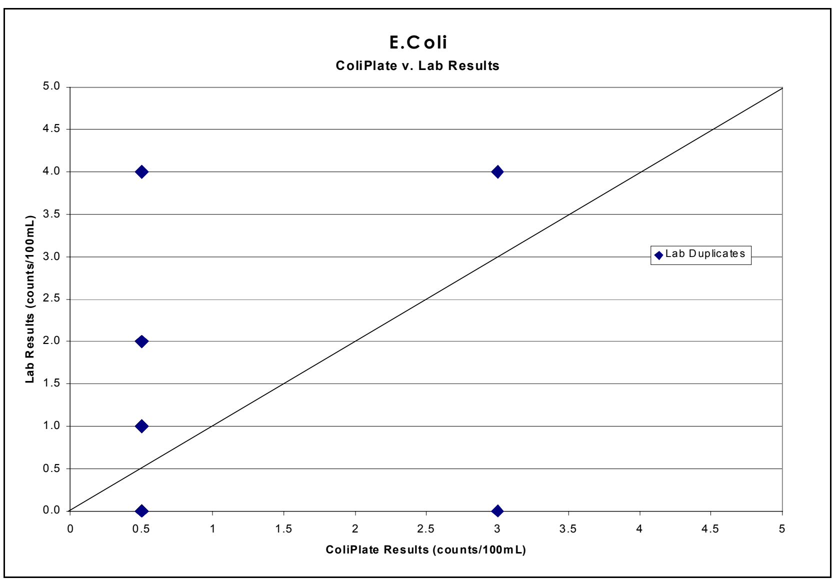
Figure 6. Total Coliform Laboratory Duplicate Results



The difference between laboratory and ColiPlate values was larger than the difference between ColiPlate duplicates. There was not a consistent pattern of over or under-estimation by the ColiPlates versus the laboratory. This implies that some variation exists for both methods but, most importantly, there was no pattern suggesting a bias between methods and that both the commercial laboratory and the ColiPlates gave acceptable results.

For 2003, it is recommended that results be compared to the results of sampling programs carried out by the Muskoka-Parry Sound Health Unit to check if the variation between samples is similar. The Health Unit takes several samples at public beaches in the area and calculates a geometric mean. To comply with the Provincial Protocol they need collect 5 samples at each location. The variation amongst the five samples will give an example of the natural variation of bacteria between samples taken in surface waters in Muskoka and provide a valuable comparison against MLA results.

Figure 7. *E. coli* Duplicate Results, Comparing COAL with ColiPlates



The *E. coli* laboratory duplicates were less conclusive than the total coliform results. In most cases, the number of bacteria that were found were so low that minor differences were inflated. When the ColiPlate returned only one positive cell, the corresponding MPN value was less than 3. These instances are represented by 0.5 counts per 100 mL on the X-axis in Figure 6. Once again, however, there was no evidence of a consistent bias between the methods.

4.1.5 Phosphorus Duplicates

Duplicate phosphorus samples were collected as described in Section 3.9.3. All phosphorus samples were tested at the Trent University Laboratory at the MOE's Dorset Environmental Science Centre in Dorset. The results from the duplicate samples are shown in Figure 8. Sources of between sample variance include real differences between samples, the inclusion of particulate mater such as zooplankton in samples (B. Clark, MOE Dorset. pers. comm.) and laboratory error. The results showed an average, between-sample variability of 1.6 µg/L or 27%. Although this did not represent ideal conditions we note that collection of samples from nearshore areas is more likely to include particulate matter. For 2003, the MOE advise that samples should be filtered through a fine mesh screen to reduce the incidence of coarse particulate matter in phosphorus samples.

Figure 8. Duplicate Phosphorus Results

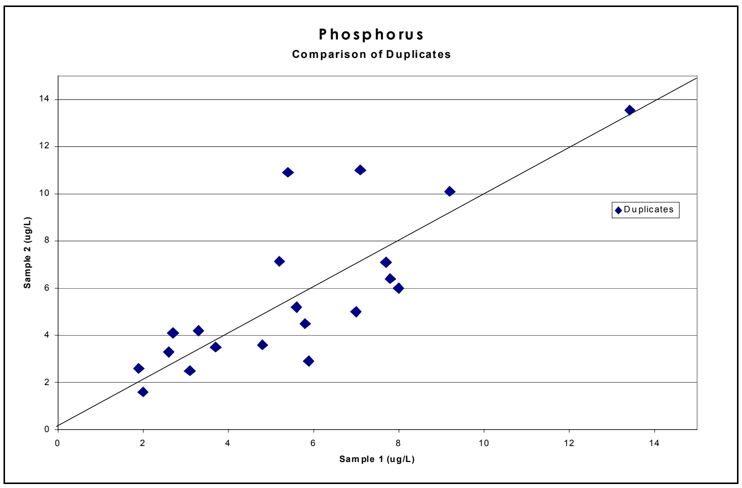
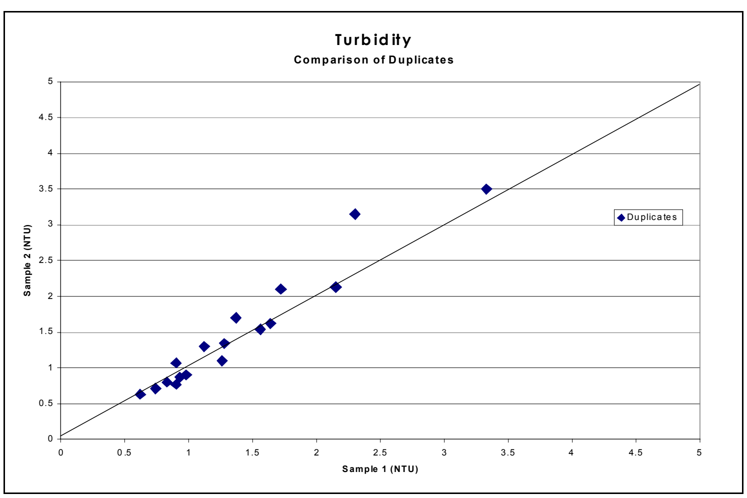


Figure 9. Duplicate Turbidity Results



4.1.6 Turbidity Duplicates

The turbidity of each sample was measured as described in Section 3.6 and field duplicates obtained from duplicate bacteria samples. Results of these tests are shown in Figure 9 and show an excellent correlation between turbidity duplicates.

4.2 Results for Individual Sites and Areas of the Study Lakes

The following is a summary of the water quality at each of the areas studied over the 2002 season. The bacteria data are presented in the tables below as the geometric mean for the season. The phosphorus and turbidity data are presented as the arithmetic mean for the season. The raw data are provided in Appendix C. For the purpose of site averages, a values of 1 was assigned when the ColiPlates only returned one blue cell (<3 on the MPN table).

4.2.1 Arundel Lodge

The Arundel Lodge sites were chosen to represent the water quality effects of a resort development. Site locations are shown in Figure 10. Total coliforms (TC), *E. coli* (EC) and turbidity (Turb) were measured in this group.

Arundel Lodge is a small resort featuring rooms and small cabins, all within 100 feet of the water's edge (Muskoka Tourism, 2002). The lodge is located at site ARN-2. Seasonal residential development surrounds the resort. Sites ARN-1 and ARN-3 were located adjacent to residential land use areas.

Figure 10. Arundel Lodge (ARN) Sites

The results (Table 4) show a small but distinct difference between water quality at ARN-2 and the other two sites. Turbidity stayed constant throughout the season at all three sites. The in total coliform trends at ARN-1 and ARN-3 were similar, both increased in August and declined in September. The total coliform levels at ARN-2 were elevated in late June and early August compared to the other sites. *E. coli* measurements were generally less than three, but were higher at ARN-2 on June 17, corresponding to a high total coliform result.

Table 4. ARN Average Results

Site	TC	EC	Turb.
ARN-1	29	1	0.9
ARN-2	29	1	1.1
ARN-3	21	1	1.0

The Arundel group of sites shows good potential for further study of land use effects on nearshore water quality. The results were consistent, the land use is easily identified and the shoreline is typical of the area.

Recommendation

Continue research program at Arundel Lodge. Add an offshore test site, and phosphorus measurements in 2003.

4.2.2 Arthurlie Bay

Arthurlie Bay, at the south end of Lake Rosseau (Figure 11), was tested in 2002. It was chosen for the two agricultural land uses situated on the bay. The agricultural properties are located at ART-1 and ART-2; the property at ART-2 also borders on Brandy Lake. Both properties are currently used as ‘hobby farms’, although cows have been seen near the shoreline. ART-3 is in the nearshore close to several seasonal properties. It was chosen to give context to the results from the agricultural sites.

The bathymetry at sites ART-1 and ART-3 is steep. As a result they were sampled very close to shore. ART-2 features sandy substrate and had a shallow slope. It was not possible to get as close to shore to collect the sample.

Total coliforms, *E. coli*, turbidity and total phosphorus (TP) were measured at the Arthurlie Bay sites.

Figure 11. Arthurlie Bay (ART) Sites

The results (Table 5) indicate that Arthurlie Bay is among the sites with the highest water quality in 2002. The agricultural land uses at ART-1 and ART-2 appear to have no effect on the nearshore water quality. Site ART-2 in particular has better water quality than the residential ART-3 site, and lower phosphorus than the offshore ART-0 site. The total coliform levels remained relatively constant over the summer, with a few exceptions. One value over 100 counts/100 ml was recorded at ART-3 on June 9th. *E. coli* was consistently low throughout the season. The phosphorus measurements show a decreasing trend over the season at all sites. The spring values were slightly higher at Site ART-1 and ART-3. The turbidity remained constant, fluctuating around 1 NTU.

Table 5. ART Average Results

Site	TC	EC	Turb	TP
ART-0	2	1	1.0	3.9
ART-1	12	1	1.1	5.1
ART-2	9	2	1.1	3.8
ART-3	15	2	1.1	4.7

There is no conclusive evidence from the 2002 testing of Arthurlie Bay on the effects of agricultural land use on the nearshore environment. The properties are no longer full agricultural operations and as such may not be impacting the nearshore environment

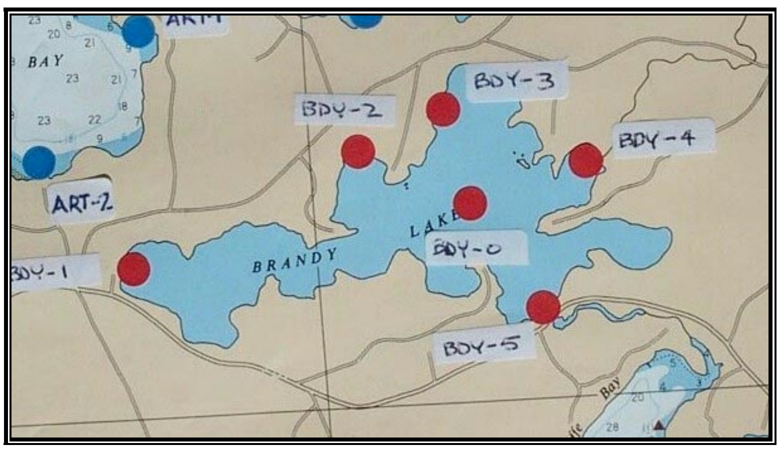
Recommendation

Continue monitoring one or two sites within Arthurlie Bay as part of the long-term monitoring program and to continue to investigate any effects of agriculture. Include rain event samples and an offshore site.

4.2.3 Brandy Lake

Brandy Lake was selected as a location for the 2002 Water Quality Testing Program at the request of the Brandy Lake Property Owners' Association. Bacteria and turbidity samples were collected to compliment the phosphorus and algae study by the Ontario Ministry of the Environment. Brandy Lake has very high levels of organic carbon which originate from wetlands in the watershed.

Figure 12. Brandy Lake (BDY) Sample Sites



Brandy Lake has a total surface area of 1.1 km^2, and a maximum depth of 7.5 m (Cockburn, 1975). The surrounding land use is almost entirely residential consisting of seasonal and permanent users. There is at least one cottage resort on the lake, located towards the west end. Site BDY-1 is adjacent to one of the agricultural properties discussed in Section 4.3.2 (Figure 12). The inlet from Brandy Creek is towards the east end of the lake. It flows in through a wetland at site BDY-4 and drains a watershed with agricultural land use and wetlands. Site BDY-0 is offshore, over the deepest part of the lake.

A summary of the 2002 results for Brandy Lake is shown in Table 6. The bacterial indicators were well within the Provincial Water Quality Objective of 100 E. coli per 100 ml for body contact recreation (MOE, 1994) and the water quality targets suggested for Georgian Bay recreational waters by Schiefer (2001). The exception was BDY-4, which exceeded Schiefer's criterion but met the PWQO. The bacterial levels in the vicinity of BDY-4 were also elevated in1974 (MOE, Cockburn 1975). Therefore, it is likely that the wetland and upstream catchment has been supplying bacteria to the lake for several years.

Table 6. BDY Average Results

Site	TC	EC	Turb.
BDY-0	12	2	7.2
BDY-1	24	6	5.7
BDY-2	28	3	7.3
BDY-3	20	3	6.9
BDY-4	657	34	5.0
BDY-5	17	2	7.3

Site BDY-5 was most similar to the offshore site, BDY-0 when looking at the average data (Table 6) and the temporal trends (Appendix C). Site BDY-5 was at the outlet of the lake. The water in this area was likely well mixed with the offshore water mass as the current moved it toward the outlet. Sites BDY-2 and BDY-3 showed a similar pattern of results over the season. Both sites are adjacent to residential land uses, suggesting that any specific land use signals may not be detectable in lakes with such a strong wetland influence.

The turbidity of water samples collected from Brandy Lake was higher than most other areas because of the naturally high carbon content. There was a dramatic turbidity increase at all sites in early September (Sept. 9^{th} sampling event). An algal bloom is most likely the cause of the measured turbidity increase. The results should be compared with results of the Ministry of Environment study.

Brandy Lake is a unique aquatic system compared to the other lakes in this study. The greater range of values will broaden our understanding of nutrient and bacterial relationships with the surrounding watershed.

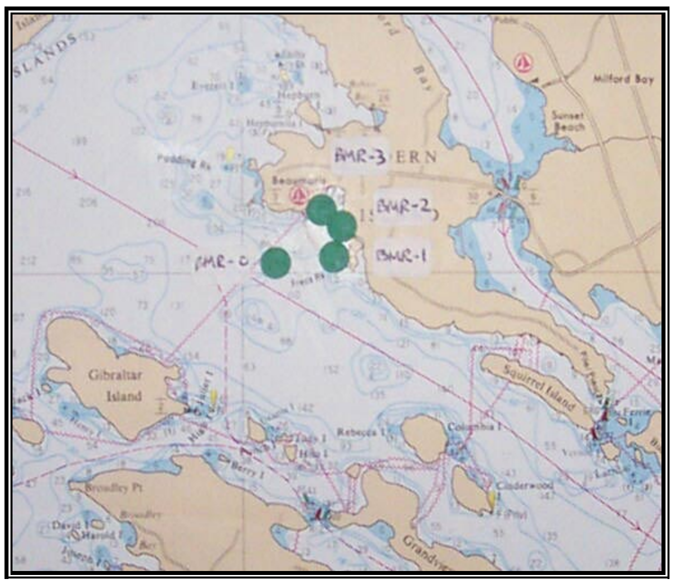
Recommendation

Continue to monitor Brandy Lake. Investigate the source of bacterial contamination at BDY-4. Continue to co-ordinate with the BLPOA and the MOE.

4.2.4 Beaumaris

Beaumaris is a small community on Torndern Island, at the eastern part of north Lake Muskoka. It is one of the oldest developments on the Muskoka Lakes, and anecdotally has suffered from poor water quality since the late 19th Century. The Beaumaris Yacht Club and Golf Course are historic developments, and were tested in order to determine the effects of older commercial developments on nearshore water quality. Beaumaris Marina is also situated in this area.

Figure 13. Beaumaris (BMR) Testing Sites



Site BMR-1 was to the south of the Beaumaris Yacht Club. The site was adjacent to a barren rock outcropping where the bathymetry is steep. The main Yacht Club building was onshore adjacent to BMR-2. This area was also steep and rocky, but the shoreline was thickly treed for several metres creating a buffer between the water's edge and the facility. Site BMR-3 was on the north side of the Beaumaris Marina. The area had sandy substrates and a gentle slope. Total coliform, *E. coli*, total phosphorus and turbidity were measured at the Beaumaris sites. Site locations are shown in Figure 13.

The results (Table 7) indicate that Beaumaris has very clear water. The phosphorus concentrations were consistently well below the PWQO, with little variation. BMR-1 had the lowest bacteria of the nearshore sites. The highest levels of total coliform bacteria during the summer months were measured at site BMR-2 (adjacent to the Yacht Club building).

Table 7. BMR Average Results

Site	TC	EC	Turb.	TP
BMR-0	14	1	1.0	5.3
BMR-1	19	1	1.0	5.7
BMR-2	32	1	1.1	5.4
BMR-3	27	3	1.0	6.2

The 2002 study of Beaumaris dispels the historical perception of poor water quality nearshore. It is a useful monitoring location with mature development and marina activities in all in close proximity.

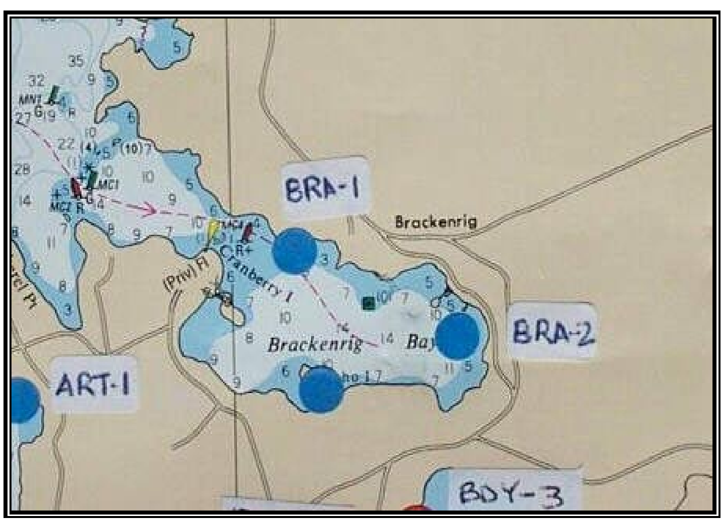
Recommendation

Continue monitoring one or two sites at Beaumaris as part of the long-term monitoring program.

4.2.5 Brackenrig Bay

Brackenrig Bay is isolated from the rest of Lake Rosseau by a narrow channel. It has a dense population of cottage properties. The highest density of residential development is at the narrows. The bay has been classified as "at development capacity" by the District of Muskoka, based on the calculated phosphorus loading. There is a retired agricultural property on the north side of the bay.

Figure 14. Brackenrig Bay (BRA) Testing Sites



BRA-1 was located next to the retired agricultural property (Figure 14). The substrates were muddy, and sloped gently towards the south. The bathymetry was steeper at BRA-2, which lies offshore of a typical residential property. Site BRA-3 was between Echo Island and the south side of the bay in a shallow area surrounded by residential development. Several of the residences in the bay are old, and several have manicured lawns.

Total coliforms, *E. coli* and turbidity were measured at the Brackenrig Bay sites. The results are shown in Table 8. Turbidity and bacteria counts all increased throughout the season. The higher turbidity is partially due to the growth of algae towards the end of the summer. Average bacteria counts for each of the sites show that the nearshore water quality are well below the PWQO.

Table 8. BRA Average Results

Site	TC	EC	Turb.
BRA-1	15	1	2.3
BRA-2	11	1	2.3
BRA-3	23	1	2.1

The total coliform concentration was elevated more often at BRA-3 than the other two sites, on one occasion the measured amount was 109 cfu/100 ml. A count as high as 94 cfu/100 ml was at site BRA-1 on one occasion. Studying how the bacteria trends change over the summer is important in determining the cause of increased bacteria and turbidity. Adding phosphorus and/or chlorophyll *a* would add strength to the investigation of this area.

Recommendation

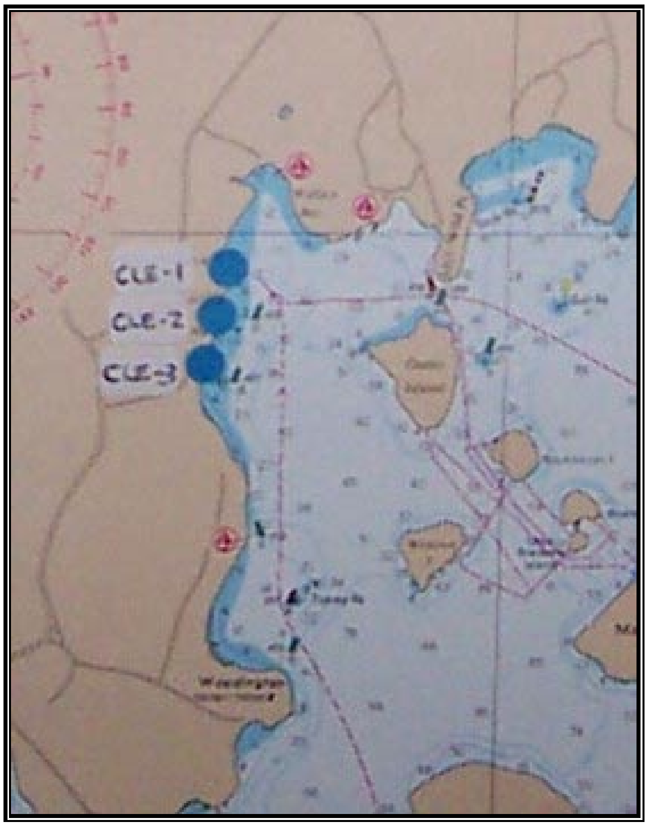
Continue testing at Brackenrig Bay, adding phosphorus and possibly chlorophyll a samples, along with an offshore site, in order to understand seasonal trends in water quality.

4.2.6 Clevelands House

Clevelands House is a resort located in the hamlet of Minett in the south end of Lake Rosseau. The Lake Rosseau Beach Resort and Lakeside Lodge are also close by. This area has been a tourism centre for well over 100 years

The area where the sites are located (see Figure 15) was rocky and shallow, making it difficult to sample the water very close to shore. CLE-1 was located north of the Clevelands House Resort, CLE-2 was located between Clevelands House and Lakeside Lodge, and CLE-3 was located to the south of Lakeside Lodge. Total coliforms, *E. coli* and turbidity were measured at this group of sites.

Figure 15. Clevelands House (CLE) Testing Sites



Clevelands House results are shown in Table 9 and in the appendices. Average *E. coli* counts were <3 (1 ColiPlate cell), suggesting very good water quality. The turbidity increased steadily throughout the season.

Table 9. CLE Average Results

Site	TC	EC	Turb.
CLE-1	8	1	1.2
CLE-2	11	1	1.5
CLE-3	8	1	1.6

The total coliform counts were low at the Clevelands House sites compared with other locations on the lake. This could be a result of the difficulty in accessing the nearshore due to the rocky substrate. The volunteers sampling these sites reported that they often were no closer than fifty feet from shore. More consistent results may be obtained by sampling from the shore in the future. Testing should continue at Clevelands House because it is a mature, densely developed recreational location. Nearshore water quality is very important due to the fact that there are so many people in this area using the water for swimming, boating and other activities.

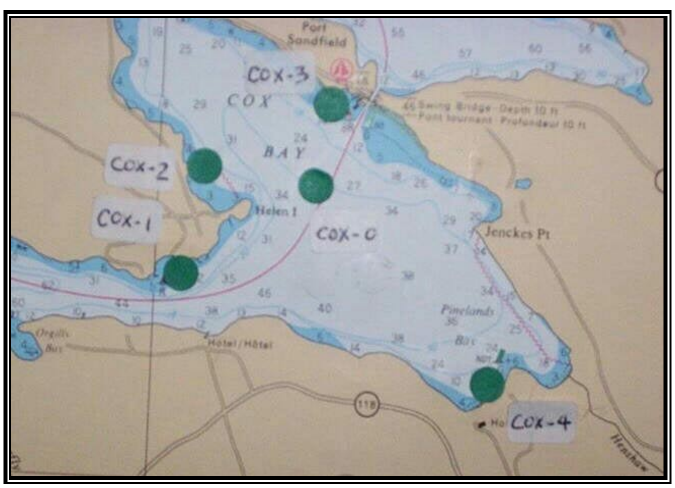
Recommendation

Continue testing at Clevelands House, adding phosphorus samples, along with an offshore site. Ensure that samples are taken as near to shore as possible.

4.2.7 Cox Bay

Cox Bay (including Pinelands Bay) is located at the south end of Lake Joseph. A dredged channel connects the bay to Lake Rosseau at Port Sandfield. At the south end of Pinelands Bay, Pinelands Resort sits adjacent to sandy beaches and open lawn. On the west side of Cox Bay is the Lake Joseph Club golf course. The Lake Joseph Club is a relatively recent development, however the land has been occupied for resorts and golf courses for many years. Redevelopment of the property was closely monitored by the Muskoka Lakes Association and the wider community.

Figure 16. Cox Bay (COX) Testing Sites



Site COX-0 was located in the middle of the bay. COX-1 and COX-2 were adjacent to the southern and eastern shores of the Lake Joseph Club, respectively. Both of these sites were close to areas where golf course runoff was expected. COX-3 was located offshore of the very large Port Sandfield Marina, and COX-4 offshore of the Pinelands Resort. At COX-4 the substrate was very sandy and sloped very gently, making it difficult to approach the shoreline.

Total coliforms, *E. coli*, total phosphorus and turbidity were measured at all of the Cox Bay sites.

Table 10 shows average Cox Bay results. More detailed results showing seasonal trends and group averages are shown in the appendices.

Table 10. COX Average Results

Site	TC	EC	Turb.	TP
COX-0	10	1	0.8	3.5
COX-1	8	1	0.8	2.9
COX-2	17	1	0.8	2.9
COX-3	8	1	0.8	3.2
COX-4	7	1	0.8	3.1

It was expected that Cox Bay would have relatively poor nearshore water quality since it is heavily developed including an urban area, two major resorts and a large golf course. The results show that the area is one of the cleanest on the lake system. The total phosphorus results indicate that the water in Cox Bay is not nutrient enriched, despite the amount of development on its shores. Phosphorus concentrations declined over the summer, which is typical of freshwater systems in Muskoka. The total coliform levels increased slightly over the season at all testing locations, while *E. coli* readings remained relatively constant.

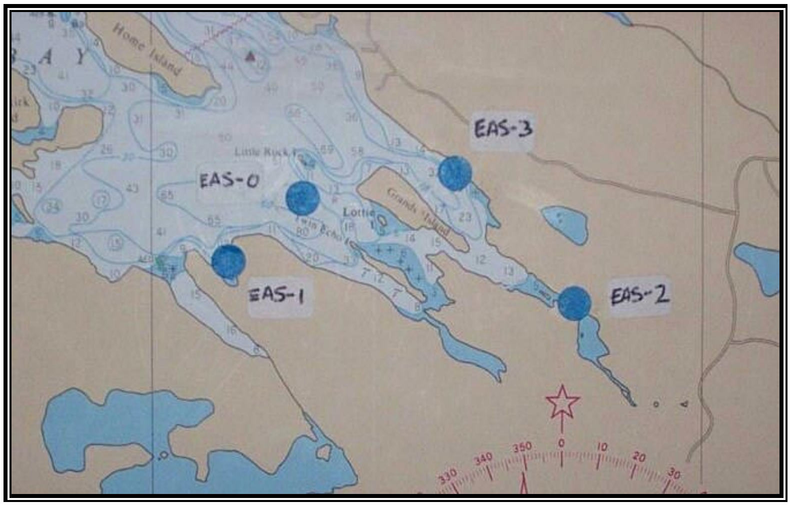
Recommendation

Continue testing at Cox Bay, carefully considering the Lake Joseph Club golf course and other shoreline development in order to determine what physical characteristics or management practices have an effect on nearshore water quality.

4.2.8 East Bay

East Bay was selected as a testing location because it is one of the few undeveloped locations on the Muskoka Lakes. A few newer cottages exist on the northwestern shore of the bay. Otherwise, the bay and adjacent wetland are undisturbed - protected partially by Hardy Lake Provincial Park. This undeveloped area should may illustrate how nearshore water quality differs from offshore water quality, when free from anthropogenic influences.

Figure 17. East Bay (EAS) Testing Sites



EAS-0 was the offshore reference site. EAS-1 was in a small enclosed embayment to the west of the two small islands in the bay. EAS-2 was located in a narrow, shallow channel near the mouth of a large wetland. Finally, EAS-3 was located in the northwest area of the bay, closer to cottage develpments. These sites provided good coverage of the entire bay, and provided contrasting shoreline types (wetland, rock, enclosed bay) to determine the response of nearshore water quality. Total coliforms, *E. coli*, total phosphorus and turbidity have been measured at East Bay since 2001.

Results for East Bay are shown in Table 11 and the appendices. The offshore location, EAS-0 had lower phosphorus and turbidity levels than any of the other three sites, and lower *E. coli* counts than two of the other three sites.

Table 11. EAS Average Results

Site	TC	EC	Turb.	TP
EAS-0	22	2	0.9	3.9
EAS-1	27	2	1.0	4.6
EAS-2	16	4	1.1	7.4
EAS-3	24	4	1.0	10.0

The East Bay was expected to feature relatively good water quality, with minimal difference between nearshore and offshore zones, except where influenced by the wetland. The water quality was less than what was expected for an area that was almost completely undisturbed. The high phosphorus value for site EAS-3, reported in Table 8 is skewed by on value above 30 µg/L recorded in late July. Higher bacteria and phosphorus levels are typically associated with areas influenced by wetlands. Although the phosphorus concentration was elevated compared to EAS-0 and EAS-1 the total coliform counts were the lower on average than at the other sites.

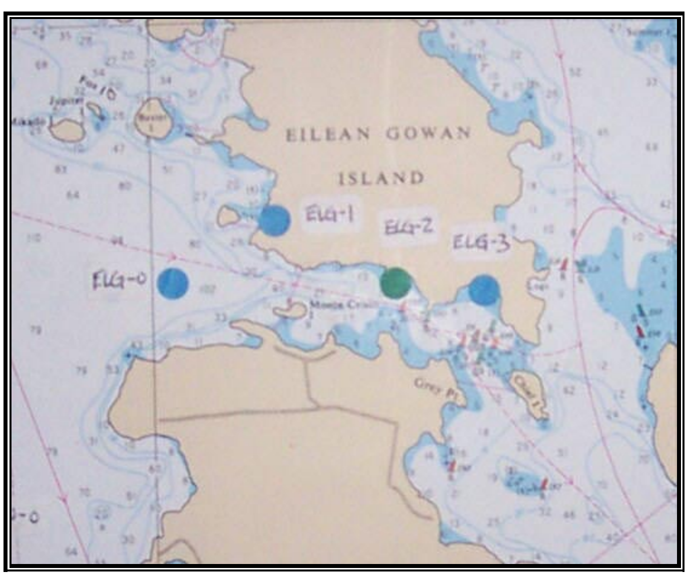
Recommendation

Continue testing East Bay in order to maintain database benchmark. Further study may be focussed on what is impacting the nearshore water quality at EAS-3.

4.2.9 Eilean Gowan Island

Figure 18 shows the testing site locations at Eilean Gowan Island. The shorelines adjacent to this area of Lake Muskoka are dominated by cottage development. ELG-0 was an offshore deep-water reference site. ELG-1 was located in a very small bay near the southwest corner of the island where several large residences and boathouses provided dense development. ELG-2 was adjacent to residential development along the south shore of the island, and ELG-3 was located in the nearshore next to a public park. The park features some deciduous trees, but has been cleared in the past. There were a few picnic tables, but no evidence of on-site sewage facilities.

Figure 18. Eilean Gowan Island (ELG) Testing Sites



Total coliforms, *E. coli*, total phosphorus and turbidity have been measured at Eilean Gowan Island since 2001.

Table 12. ELG Average Results

Site	TC	EC	Turb.	TP
ELG-0	12	1	1.1	5.2
ELG-1	21	2	1.1	6.2
ELG-2	34	4	1.1	7.3
ELG-3	41	1	1.3	6.8

ELG-1 had the best water quality of the three nearshore sites. Given the dense development in this small bay, it was expected that results would show higher bacteria counts and phosphorus levels. Conversely, the park at site ELG-3 yielded the highest total coliform counts and the highest turbidity. Further study would have to be done on this area in order to draw definite conclusions about the reasons for the differences.

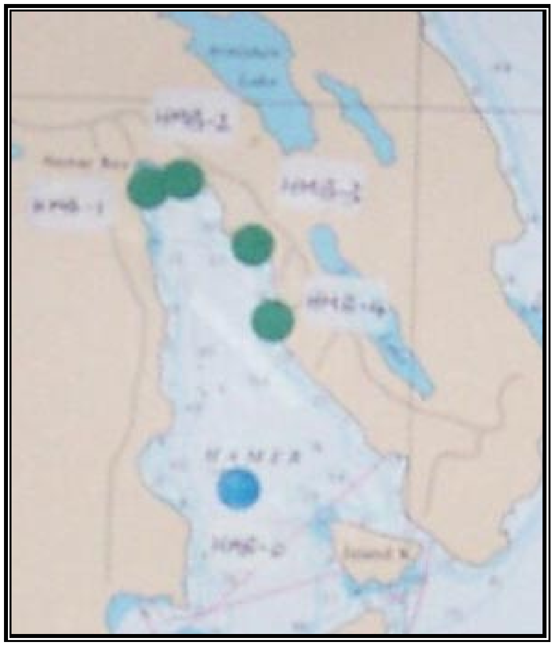
Recommendation

Continue monitoring one or two sites at Eilean Gowan Island in the interest of long-term temporal changes.

4.2.10 Hamer Bay

Hamer Bay, at the north end of Lake Joseph, is one of the more remote areas on the Muskoka Lakes. Residential development on the west side of the bay is accessible from Highway 69, but land on the east side has only been made accessible recently. In this area, lot sizes are larger due to strict modern planning by-laws. At the head of the bay, there is a large marina (Hamer Bay Marine) and a large resort and golf course development (Delta Rocky Crest Resort). In the summer of 2001 an algal bloom was reported in the bay and confirmed to be blue-green algae, an indicator of enrichment. Local residents (The Lake Joseph North Association) are concerned about the relationship between the resort and golf course and enrichment of Hamer Bay and have undertaken an independent monitoring program. They requested that the MLA include Hamer Bay in the nearshore water quality program to help them interpret changes in the bay. The 2002 program was designed to monitor the effects of the marina, resort and golf course.

Figure 19. Hamer Bay (HMB) Testing Sites



Site HMB-0 was a deep water reference site. HMB-1 was located adjacent to a small creek that drains the Rocky Crest Golf Course. HMB-2 was located in the nearshore zone between the marina and resort. HMB-3 was located where a small creek draining the grounds of the resort enters Hamer Bay, and HMB-4 was located adjacent to a large residential building several hundred metres south of the resort.

Total coliforms, *E. coli*, total phosphorus and turbidity have been measured at Hamer Bay since 2001. Further testing of the creeks which drain the resort is undertaken by the Lake Joseph North Association, and ClubLink Rocky Crest Resort.

Table 13. HMB Average Results

Site	TC	EC	Turb.	TP
HMB-0	2	1	0.7	2.9
HMB-1	30	1	1.2	7.3
HMB-2	25	1	0.9	4.4
HMB-3	18	1	0.9	5.6
HMB-4	4	1	0.7	3.6

Hamer Bay is among the areas with the best offshore water quality in the entire lake system. However, there were large differences between nearshore and offshore results, and between different nearshore results. HMB-4, near the low density residential development also showed extremely low turbidity, phosphorus and total coliforms. Water quality at HMB-1 was more enriched than anywhere else in Hamer Bay. More study should be done in order to understand the sources of these effects. The elevated bacteria at site HMB-2, could be an artifact of the enrichment at HMB-1 dispersing along shore or a separate impact from the marina or resort.

Both the Hamer Bay and Cox Bay sites feature golf courses and resorts (managed by the same company). The Cox Bay results show very good water quality, whereas Hamer Bay results show poorer water quality. This area should be continued for detailed testing in the future. Results of monitoring carried out by the Lake Joseph North Association showed significant enrichment of runoff in the tributary entering Hamer Bay adjacent to site HMB-1 by phosphorus and nitrogen. Enrichment was recorded in 2001 and 2002, but not in 1999 and 2000, prior to full resort operation and when sampling frequency was lower. Although some natural enrichment occurs in Precambrian Shield wetland drainage in mid summer the Hamer Bay drainage is also influenced by the discharge of treated sewage from the Rocky Crest Resort, potentially enriched runoff from the golf course operations and from maintenance activities (Gartner Lee Limited 2003).

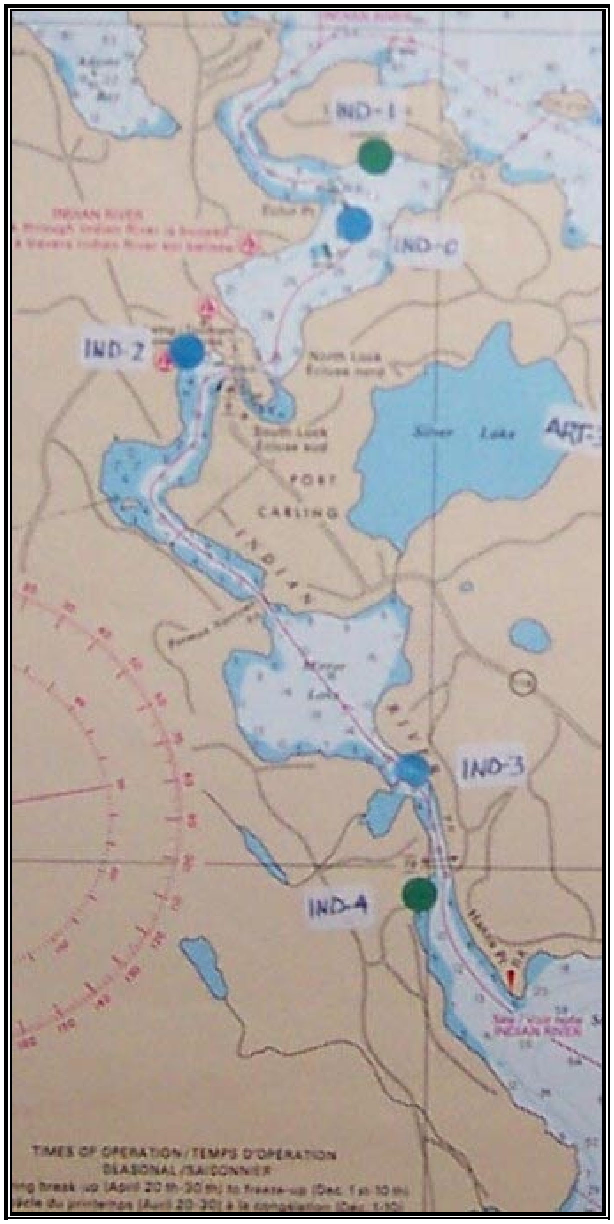
Recommendation

Continue detailed testing at Hamer Bay. Study the influence of physical orientation and management practices of the facilities on-site on nearshore water quality. Continue to co-operate with the Lake Joseph North Association.

4.2.11 Indian River

The Indian River connects Lake Rosseau and Lake Muskoka. The community of Port Carling situated on the river, is a busy urban centre during the summer months. The river features older cottage development both upstream and downstream of the locks at Port Carling, often densely packed. The area is considered ‘urban’ according to the Township of Muskoka Lakes Official Plan, so development regulations (such as building setbacks and lot coverage) are not as strict compared to ‘waterfront’ zoning. The river system is unique to the MLA program, as it incorporates a variety of land uses along its shores which were incorporated into the study design.

Figure 20. Indian River (IND) Testing Sites



The offshore site, IND-0, was located near the centre of Minihaha Bay (the widening of the river upstream of the locks.) The IND-0 site was chosen to be upstream of the urban area to be free from any large-scale effects of urban runoff. Site IND-1 also acted as a reference site, as it was upstream of Port Carling. IND-2 was adjacent to the urban area of Port Carling, in amongst several commercial docks. This area was susceptible to urban runoff after rain events. Site IND-3 was downstream of Mirror Lake (a widening in the river downstream of town), in the nearshore zone of a trailer-park development. This park hosts several mobile-home type trailers, some of which are within a few metres of the shoreline. IND-4 was located adjacent to a historic farming property in the lower reaches of the Indian River. The property is no longer farmed commercially, but some cattle are kept as a hobby. In the past, these cattle have often been seen in the lake.

Total coliform, *E. coli*, total phosphorus and turbidity have been measured in the Indian River since 2001.

Table 14. IND Average Results

Site	TC	EC	Turb.	TP
IND-0	16	1	1.1	3.8
IND-1	16	1	1.1	3.9
IND-2	56	4	1.4	6.2
IND-3	69	6	1.8	8
IND-4	33	2	1.4	6.5

The sites upstream of Port Carling are very different from those downstream. The water quality at the offshore (IND-0) and the nearshore (IND-1) upstream sites was good and similar for all four parameters. The most degraded site in this group was adjacent to the trailer park development (IND-3). At this site, total coliform and *E. coli* counts were elevated, but still well below Provincial Water Quality Objectives from body contact (MOE, 1994). Bacterial counts at both IND-3 and IND-2 were among the highest on the entire lake system. Where IND-4 was higher in total coliforms, phosphorus and turbidity than the upstream sites, it was lower than the sites directly downstream of Port Carling.

Some pollutants (bacteria and phosphorus) undoubtedly originated in the urban area and travelled downstream to sites IND-3 and IND-4. However, it is also possible that additional pollutants were added to the water column at or near the trailer park, since readings at IND-3 were higher than at IND-2. Runoff from both the urban area (IND-2) and the trailer park (IND-3) is of concern, because both of these areas have little or no riparian vegetation (buffer zones), and support dense development. These two sites must be studied further in order to achieve a full understanding of processes effecting nearshore water quality.

Water quality at IND-4 was noticeably better than at IND-2 and IND-3. This may reflect an altering of mixing processes as the river widens above site IND-4. As well, there appeared to be a limited effect of the hobby farm on nearshore water quality.

The Indian River is one of the most interesting locations to study nearshore water quality in the Muskoka Lakes, due to the intense land use and urban development. This area will remain important for understanding how land uses and land-based activities effect water quality in general.

Recommendation

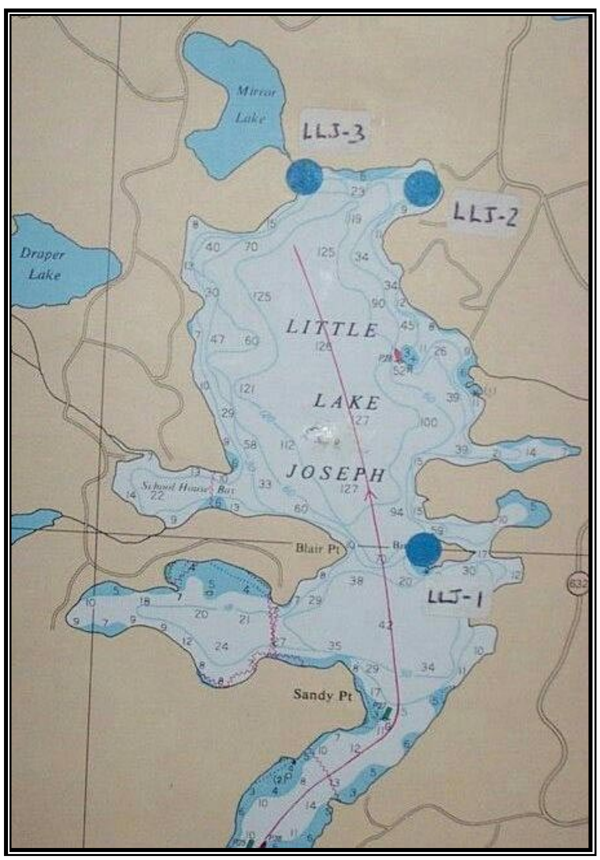
Continue detailed testing at the Indian River. Quantify runoff from the urban area and trailer park, and attempt to understand how pollutants move through the river. Consider adding more testing sites to the river.

4.2.11.1 Little Lake Joseph

Little Lake Joseph is located on the east side of Lake Joseph. It is separated from the main watermass by a very narrow channel at the south end. The area's cottage development has increased slowly over many years, and is currently nearing capacity. This area of the lake is also identified as 'at development capacity' by the Township of Seguin. Little Lake Joseph is sensitive to phosphorus loading and other contaminants, because of it's small watershed, and slow flushing rate.

Total coliforms, *E. coli* and turbidity were tested at three nearshore sites in Little Lake Joseph as part of the 2002 MLA water quality testing program.

Figure 21. Little Lake Joseph (LLJ) Testing Sites



Site LLJ-1 was located at the southeast end of the lake, on the west side of a small island. There was no development in the immediate vicinity of LLJ-1, making it useful as a reference location. LLJ-2 was located adjacent to residential development in the north end of the lake. LLJ-3 was also located in the north end of the water body, at the Mirror Lake outlet to Little Lake Joseph.

Table 15. LLJ Average Results

Site	TC	EC	Turb
LLJ-1	10	1	0.8
LLJ-2	12	1	0.8
LLJ-3	8	1	0.8

The results from Little Lake Joseph are summarized in Table 15. The results for all three sites are similar, with the exception of slightly lower total coliform counts at LLJ-3. The average total coliform concentrations presented above are skewed by higher counts at all three sites on the last sample date.

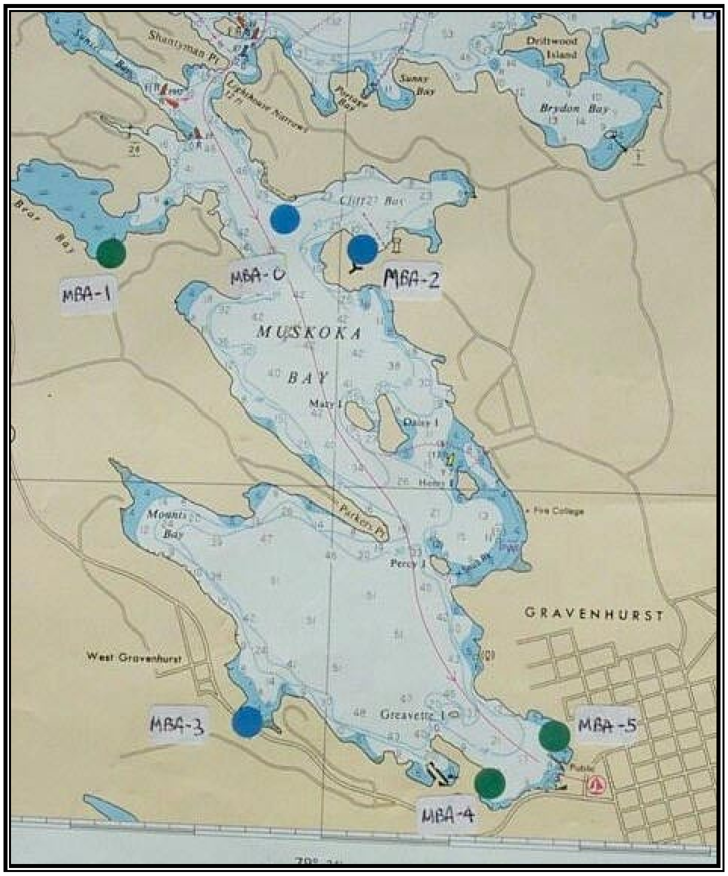
Recommendation

Continue monitoring one or two sites on Little Lake Joseph for the purpose of identifying long-term trends. Add phosphorus measurements and an offshore testing location in order to see how this isolated bay compares to the larger Lake Joseph.

4.2.12 Muskoka Bay

Muskoka Bay is an historically important and well-studied section of the Muskoka Lakes. The Town of Gravenhurst is located on the bay, and has been one of the most important urban centres of the area for the last 150 years. Gravenhurst was the original Muskoka destination for the stagecoach and railway, welcoming the areas first tourists and fulfilling the role of timber and transportation hub. Gravenhurst's treated sewage effluent was discharged into the bay until 1994 and added phosphorus loading. Currently, sewage is treated to a very high standard, and effluent is disposed of in the main body of Lake Muskoka. Muskoka Bay is also very sensitive to contaminants because it is very isolated from the main part of the lake giving a slow flushing rate. Traditionally the bay has been very high in nutrients, but monitorng by the District Municipality of Muskoka, MOE and the Muskoka Bay Association showed that nutrient levels have decreased since the STP outfall was relocated outside the bay.

Figure 22. Muskoka Bay (MBA) Testing Sites



Total coliform, *E. coli*, total phosphorus and turbidity were tested at one offshore and five nearshore sites in Muskoka Bay. In addition, the Muskoka Bay Association and the District of Muskoka continue to monitor phosphorus levels and water clarity.

MBA-0 was located in deep water at the north end of the bay, far away from influences from Gravenhurst. Site MBA-1 was located at the mouth of the Bear Bay wetland, in order to examine natural influences on nearshore water quality in the bay. MBA-2 was located adjacent to the Muskoka Centre property. The property was used historically by institutions such as hospitals and schools. Currently, it serves as a police training facility and has onsite sewage treatment, which discharges to Muskoka Bay. Site MBA-3 was located in Loon Bay, where a small stream that drains a suburban area of town flows into the bay. MBA-4 was located in the nearshore adjacent to a brownfields site that was formerly the location of a wooden boat manufacturer. Site MBA-5 was located adjacent to the large steamship wharf at Sagamo Park. The area of sites MBA-4 and MBA-5 is scheduled for redevelopment in the next few years as the Muskoka Wharf Project. Water quality data will be important as a baseline for this development.

Table 16. MBA Average Results

Site	TC	EC	Turb.	TP
MBA-0	24	2	1.0	7.8
MBA-1	19	1	3.4	16.0
MBA-2	25	1	1.1	10.2
MBA-3	41	3	1.3	20.3
MBA-4	55	6	1.2	9.5
MBA-5	91	2	1.2	12.8

The results summary (Table 16) showed that phosphorus levels were higher in Muskoka Bay than in other portions of Lake Muskoka. The entire bay, except for the offshore site, exceeded 9 µg/L of phosphorus. These were the highest levels of phosphorus encountered on the entire lake system. The phosphorus concentration declined at all sites over the season. The southern part of the bay (known as Gravenhurst Bay) experienced higher levels of bacteria compared to the north part of the bay. The sites closer to sources of urban runoff showed a higher levels than the sites located further from Gravenhurst.

Further studies on stormwater practices in and around Gravenhurst may uncover the source of the elevated bacteria levels. The increased activities resulting from the Muskoka Wharf Project suggest that continued monitoring is important, to track changes and reveal any need for improved stormwater management.

Recommendation

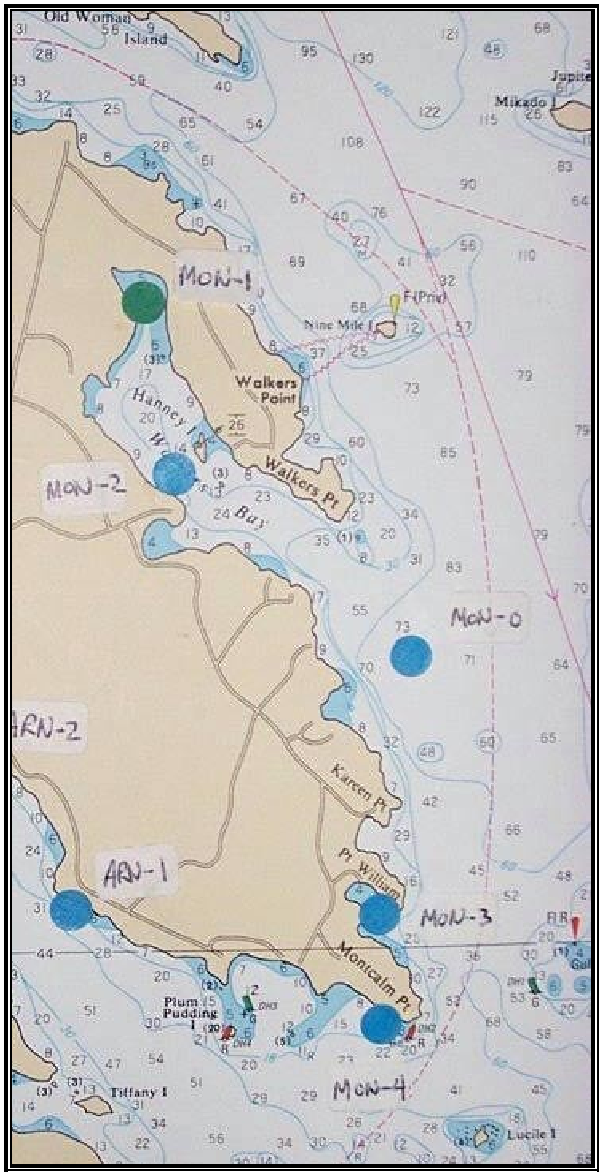
Continue detailed study of Muskoka Bay, focussing on urban areas.

4.2.13 Montcalm Point

Montcalm Point is located on the west side of southern Lake Muskoka. The testing area includes Montcalm Point, Walker's Point and Walker's Bay. Walker's Bay and Walker's Point represent small-lot residential development that occurred in Muskoka during the mid 1900's. The development is dense compared with most other areas on the lakes. The cottages on Walker's Bay are particularly close together, and many have manicured lawns and hardened shorelines. Total coliform, *E. coli*, total phosphorus and turbidity were tested at one offshore and four nearshore sites near Montcalm Point.

MON-0 was located offshore from Walker's Point, in a very exposed area. MON-1 was located at the north end of Walker's Bay, adjacent to several residences with manicured lawns and hardened shorelines. Site MON-2 was located adjacent to a less dense residential area on the western side of Walker's Bay. MON-3 was located in a small bay to the north of Montcalm Point, and MON-4 on the south side of Montcalm Point. The latter two sites were chosen to show the difference in effects on water quality between very densely developed residential areas and those areas that are less dense.

Figure 23. Montcalm Point (MON) Testing Sites



A summary of the results for Montcalm Point is shown in Table 17. The nearshore sites were grouped by dense (MON-1 and MON-2) and less dense (MON-3 and MON-4) development. All four parameters indicate that the densely developed areas had lower water quality than the less dense. Phosphorus concentrations declined over the season at all sites.

Table 17. MON Average Results

Site	TC	EC	Turb.	TP
MON-0	17	1	0.9	4.4
MON-1	47	8	1.5	11.4
MON-2	41	3	1.1	8.6
MON-3	29	2	0.9	6.5
MON-4	34	2	0.9	6.1

Recommendation

Continue detailed study at Montcalm Point. Concentrate on the differences between Walker's Bay and nearby areas which are more exposed and have less-dense development.

4.2.14 Muskoka Sands

The Muskoka Sands sample area was located at the south end of Lake Muskoka, near the mouth of the Hoc Roc River. The Muskoka Sands Resort, Taboo Golf Course and the Hoc Roc River drainage were located close by. The sites were selected to study the effects of a large resort and golf course and river drainage on the nearshore water quality. The area is very exposed and receives westerly winds sweeping over 5-6 km of open water. Total coliform, *E. coli*, total phosphorus and turbidity were tested at three nearshore sites (Figure 24).

Site MSN-1 was located adjacent to one of the main docks at the resort, at the centre of the busy resort waterfront. MSN-2 was located at the mouth of the Hoc Roc River, which receives natural drainage as well as that from the Taboo Golf Course. MSN-2 was adjacent to Muskoka Beach, and was also tested for bacteria by the Muskoka-Parry Sound Health Unit. MSN-3 was located to the south of the river, in a quiet bay with only a few cottages.

Figure 24. Muskoka Sands (MSN) Testing Sites

There are contrasting results from the two sites closer to the resort (MSN-1 and MSN-2), compared to the site located further away (MSN-3). The results are summarized in Table 18. The intense land use associated with the resort, beach and golf course appear to be impacting the nearshore water quality but natural drainage from the Hoc Roc River cannot be excluded as a factor. A more detailed study of this area is suggested to better understand influences on water quality.

Table 18. MSN Average Results

Site	TC	EC	Turb.	TP
MSN-1	57	4	1.3	7.4
MSN-2	47	5	1.5	8.7
MSN-3	31	2	1.5	7.0

Recommendation

Continue detailed study at Muskoka Sands. Separate the natural drainage of the Hoc Roc River from any effects of development in the area. Request monitoring data from the Taboo golf course development to assess any potential influence on water quality.

4.2.14.1 Royal Muskoka Island

Royal Muskoka Island is located on the west side of Lake Rosseau. Is was formerly the site of the Royal Muskoka Hotel and was subdivided and redeveloped during the 1950s into small cottage lots. This area was chosen for testing to determine the effects of dense residential development on enclosed embayments. Total coliform, *E. coli* and turbidity were tested at three nearshore sites (Figure 25).

Site RMI-1 was located close to residential development, behind Highlands Island. RMI-2 and RMI-3 were also proximate to residential development within the small embayment on the south side of Royal Muskoka Island. A summary of the 2002 results is presented in Table 19. The biweekly results are provided in Appendix C.

Figure 25. Royal Muskoka Island (RMI) Testing Sites

All three sites in this area studied the same land use. No large differences were observed between the sites. There was one sample collected from site RMI-2 in early September with a total coliform count over 100 cfu/100 mL.

Table 19. RMI Average Results

Site	TC	EC	Turb.
RMI-1	14	2	0.8
RMI-2	11	2	1.1
RMI-3	11	2	1.0

Recommendation

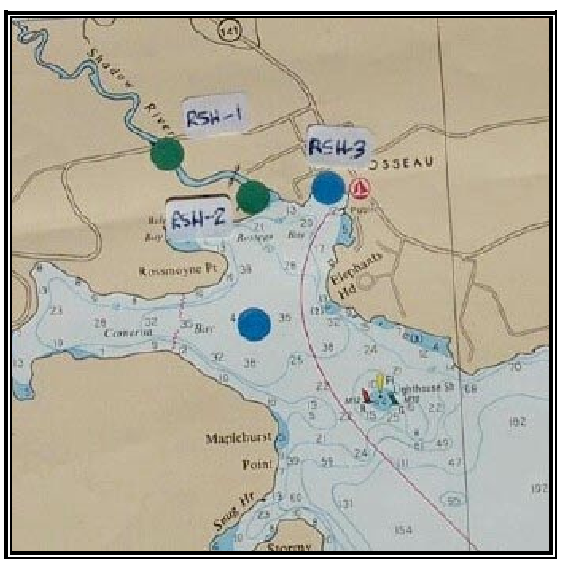
Continue monitoring one or two nearshore sites at Royal Muskoka Island for the purpose of monitoring the impacts of residential development. Add an offshore site for comparison.

4.2.14.2 Rosseau/Shadow River

Rosseau and the Shadow River are located at the north end of Lake Rosseau. The first resort (Pratt's) on the Muskoka Lakes was in the Village of Rosseau. There are currently plans to revitalize the village through Federal Heritage Ministry funding. A large marina dominates the waterfront. Outside Rosseau, there are several cottages constructed at low density.

The Shadow River drains land that was historically agricultural but is now fallow. Large residences have been built along the lower reaches of the river, and a subdivision has been constructed further upstream. Recent water quality concerns on the Shadow River, have been handled by the Shadow River Land Trust. The river is darkly stained by dissolved organic carbon from wetlands in the catchment nature. Total coliform, *E. coli*, total phosphorus and turbidity were tested at one offshore site, one nearshore site at the Village of Rosseau, and two nearshore sites on the Shadow River.

Figure 26. Rosseau / Shadow River (RSH) Testing Sites



Site RSH-0 was located in deep water offshore of Rossmoyne Point. RSH-1 was located on the Shadow River downstream of CR 632, RSH-2 at the mouth of the river, and RSH-3 in the nearshore adjacent to the Lakes of Muskoka Marine. The resultsx summary is shown in Table 20.

Table 20. RSH Average Results

Site	TC	EC	Turb.	TP
RSH-0	13	1	0.9	5.1
RSH-1	89	34	3.0	20.6
RSH-2	33	5	1.5	12.5
RSH-3	15	3	1.3	5.4

These results indicate that the urban area of Rosseau has a relatively small impact on the local water quality, compared to the Shadow River. An additional site further east of the marina may intercept the village's stormwater runoff. The data in Table 20 also show that there is a distinct difference between the water quality of Lake Rosseau and that of the Shadow River. This difference between lakes and their tributaries is common and results from the immediate interaction of these tributaries with wetlands in the catchment. The results indicate a dilution of nutrients as the waters mix at the mouth of the river and assimilative processes such as settling of particulate matter in the lake which reduces the loading introduced from the watershed upstream.

Recommendation

Continue detailed monitoring of the area, as per the interests of local residents and the development plans of the village.

4.3 Summary

Overall, water quality in the nearshore zones of the Muskoka Lakes is excellent. With few exceptions, the results for the 2002 program were in compliance with the Provincial Water Quality Objectives (MOE, 1994) for total phosphorus and *E. coli* , as well as the more stringent criteria suggested by Shiefer (2001). The detailed study of specific areas has provided further insight into the effects of land use on nearshore water quality. Further study will help to clarify these relationships. The 2002 water quality testing program has been instrumental in identifying what types of field work need to be added or repeated in 2003.

5. Effects of Nearshore Land Use on Water Quality

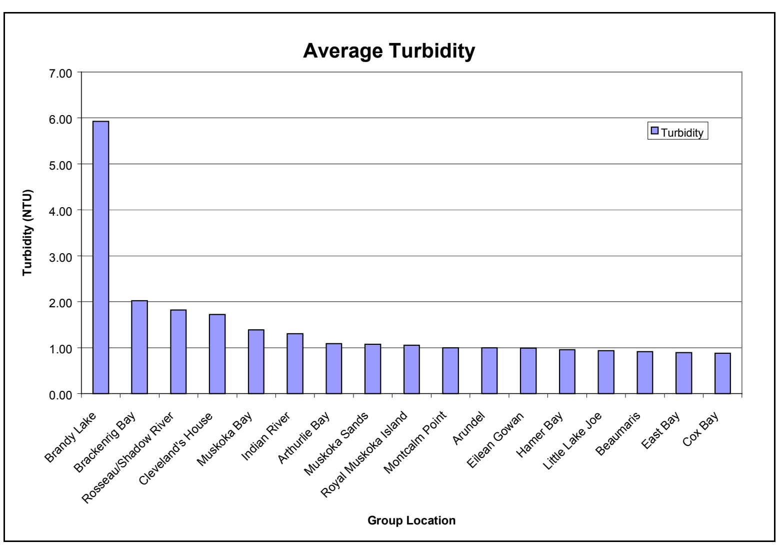
The results provided in Section 4.2 provide specific water quality at points of interest to the Muskoka Lakes Association, in support of the long term monitoring objectives of the MLA. They also show that nearshore water quality is not as good as that measured offshore in conventional monitoring programs and that water quality may vary in response to different land uses. In this section of the report, these results are used to search for common responses of water quality to land use across the entire study area.

5.1 Turbidity

The turbidity of every lake sample was measured for the last five sample periods.

Figure 27 shows the average turbidity of all 17 testing groups. The average turbidity was calculated as the arithmetic mean for all measurements taken over the season in each group. The figure shows that, apart from the Brandy Lake group, turbidity was very low. It ranged from 0.9 to 2.0 NTU, indicating excellent water clarity and high aesthetic quality of the water. These readings are typical of turbidity in clear lakes like Lakes Joseph, Lake Rosseau and Lake Muskoka, which receive most of their carbon from internal sources such as photosynthesis by algae ("autochthonous nutrition"). Brandy Lake, however, receives most of its carbon from external sources, such as the wetlands in its catchment ("allochthonous nutrition"). It is tea-coloured, with high levels of dissolved organic carbon and naturally high turbidity. The elevated turbidity readings are due to the dissolved carbon and associated nutrients originating in its watershed (Clark, 2002).

Figure 27. Average Turbidity by Group



Turbidity showed a trend of increase at the nearshore sites, but did not reveal compelling evidence of land use effects on water clarity. The collection of turbidity data was not resource intensive, nor did it add any further workload to the role of the volunteers. Collection of these data should continue in the future as part of a long-term monitoring effort. Effort should made to focus on between-site comparisons during rain events, when nearshore runoff is active and turbidity problems more likely.

5.2 Total Coliforms

Seasonal results for total coliforms at each test site and each group were summarized by calculating a geometric mean. The geometric mean was used because it provides a better estimate of the average concentration by decreasing the influence of extreme values. Bacteriological data can be highly variable because the organisms naturally occur in clumps or agglomerations. The Ontario Ministry of Health, as well as other public health agencies use the geometric mean when calculating bacteria levels in surface water.

The total coliform counts averaged by group are shown in Figure 28. Group averages ranged from 10 to 47 counts/100 mL. Recreational water quality standards laid out by the Ontario Ministry of Health state that water with less than 1000 counts/100 mL total coliforms is safe for body contact (swimming etc.) Schiefer, in his work for the Georgian Bay Association (2001) suggested a standard of 100 counts/100 mL would be more appropriate, reflecting the naturally higher water quality for recreational-use lakes in the area. His suggestion was based on the recognition that the lower the total coliform count, the safer the water is for recreational purposes. Moreover, Schiefer also recognized that a higher standard of water quality as an objective, would be more effective in protecting lakes in the area that currently have excellent water quality. Promotion of a higher standard for bacterial water quality fits well within the mandate of the MLA. Total coliform counts were well within the standard of 100 counts/100 mL and confirm that water quality is very high in the Muskoka Lakes.

Figure 28. Average Total Coliforms By Group

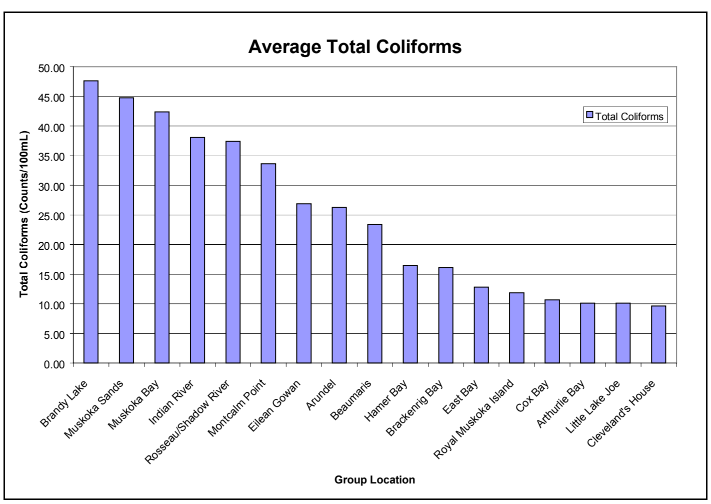
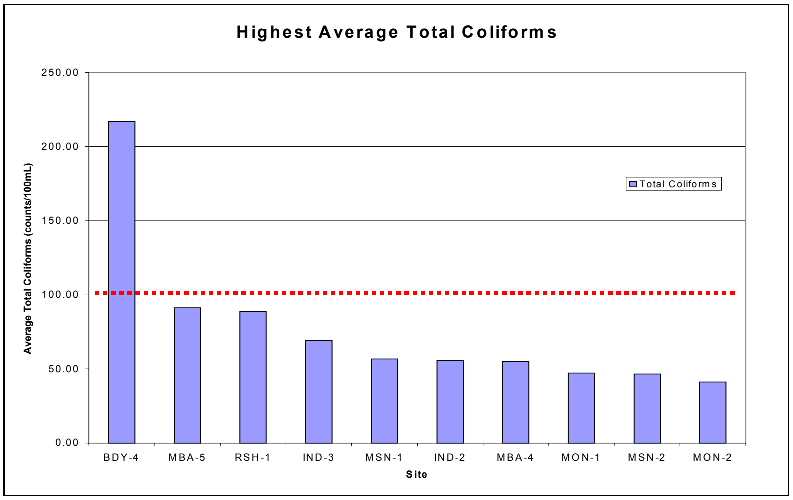


Figure 29. Ten Highest Average Total Coliform Results By Site



Note: Dotted red line indicates criteria suggested by Schiefer (2001).

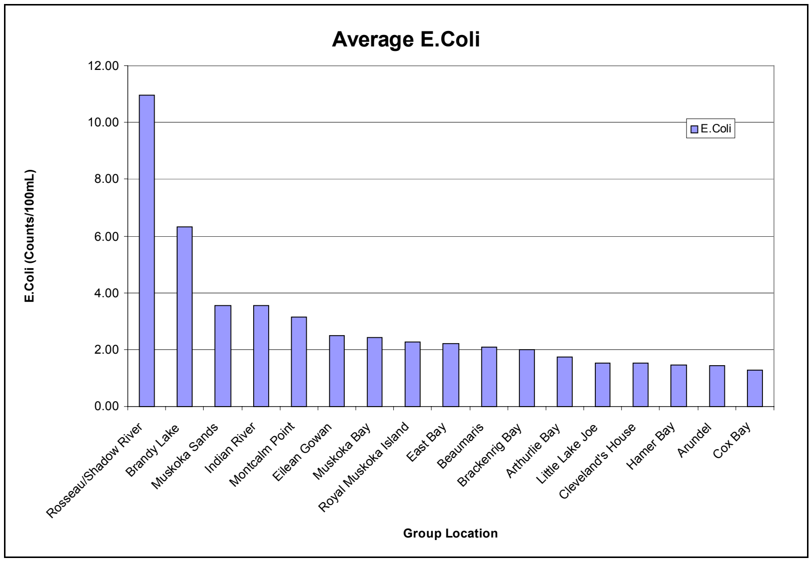
It is important to recognize that Figure 28 shows group-wide averages, and that some individual sites had higher total coliform results. Figure 29 shows the ten highest individual site results. Even the highest average seasonal results did not approach the Provincial Water Quality Objective. Only one site (BDY-4) exceeded the higher standards suggested by Schiefer (denoted by the dotted line). This area also had elevated levels of total coliforms in 1974 (MOE, Cockburn, 1975) but represents drainage form the upstream catchment, with agriculture and wetlands to a greater extent than in-lake water quality.

5.3 Escherichia Coli

The *E. coli* results were summarized in the same way as the total coliform results, using the geometric mean. Figure 30 shows the *E. coli* results, averaged by group.

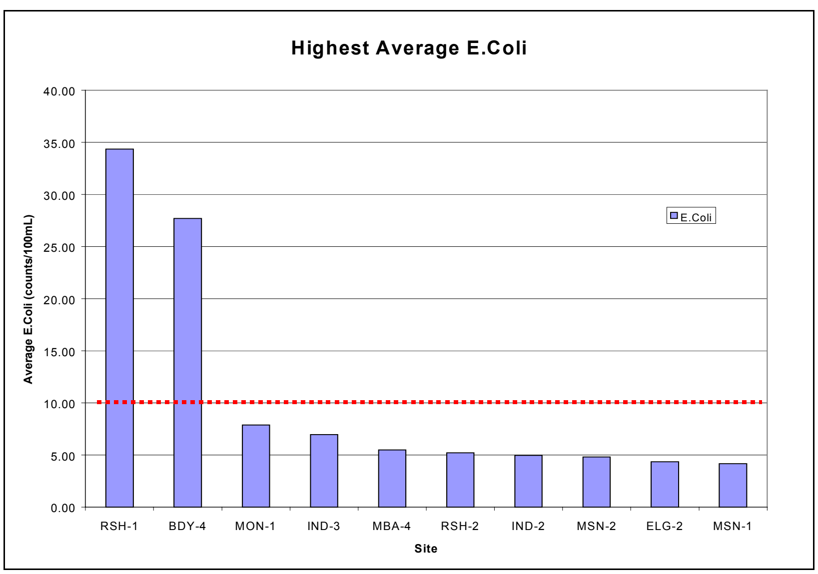
The Ontario Ministry of Health stipulates that for recreational purposes, water must have less than 100 counts/100mL of *E. coli* (calculated as the geomean of five samples). Schiefer (2001) suggested a lower limit of 10 counts/100 mL for high quality recreational waters. Figure 31 shows the ten sites with the highest *E. coli* readings.

Figure 30. Average *E. coli* By Group



Note: Dotted red line indicates criteria suggested by Schiefer (2001).

Figure 31. Ten Highest Average *E. coli* Results By Site



Note: Dotted red line indicates criteria suggested by Schiefer (2001).

The average *E. coli* concentration was well below the criteria for recreational water in Ontario. Likewise, only two sites (RSH-1 and BDY-4) failed to meet the water quality standard suggested by Schiefer (represented by the dotted line on Figure 31) and both of these represented river influence (Brandy Creek and the Shadow River).

Both measures of bacteria were consistent in identifying areas of degraded water quality within the lakes. These include the south end of Muskoka Bay, near the Muskoka Sands resort, the Shadow River and the Indian River downstream of Port Carling. In future years, these sites may warrant further investigation of bacterial sources. Nevertheless, bacterial results support an interpretation of very good water quality throughout the Muskoka Lakes.

5.4 Phosphorus

Average total phosphorus for the sampling season was calculated for individual sites as well as groups. Group averages are shown in Figure 32. Figure 33 shows the ten sites with the highest total phosphorus concentrations in 2002.

The PWQO for total phosphorus (MOE, 1994) is tiered, in recognition of the natural variability of phosphorus concentration in Ontario. The PWQO for nutrient poor, oligotrophic lakes is 10 µg/L TP. Lakes with a TP concentration between 10 µg/L and 20 µg/L are considered mesotrophic, indicating that they are showing signs of nutrient enrichment from either natural or human sources. For these lakes, the PWQO is 20 µg/L. Finally, lakes with a phosphorus concentration over 20 µg/L are considered eutrophic, indicating that they are in the more advanced stages of natural ageing (often catalysed by anthropogenic sources of nutrients).

Figure 32. Average Phosphorus Concentration By Group

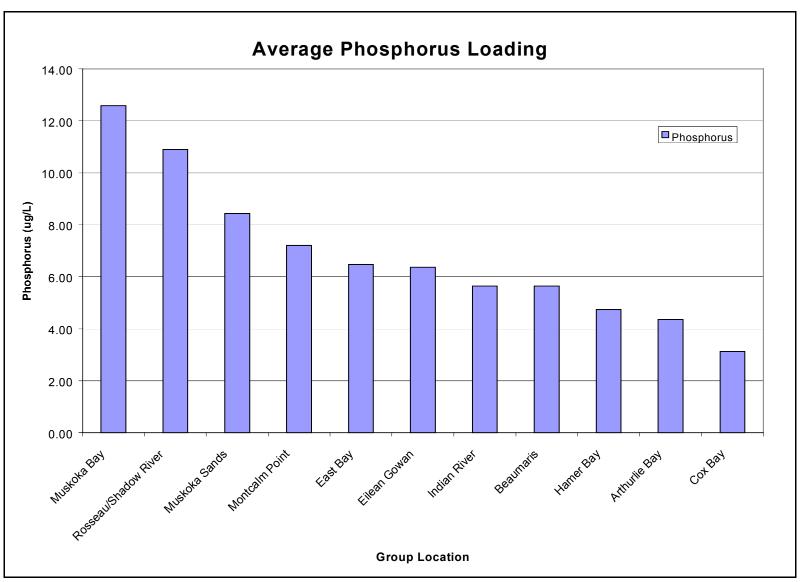
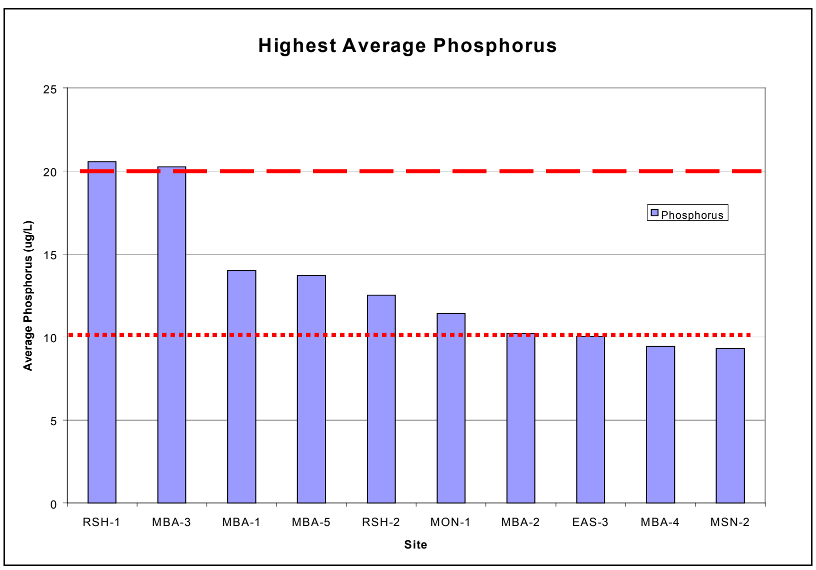


Figure 32 indicates that, on average, the most nutrient-enriched areas on the Muskoka Lakes were Muskoka Bay at the south end of Lake Muskoka and the Shadow River in and around the town of Rosseau at the north end of Lake Rosseau. Higher phosphorus levels were measured at individual sites (Figure 33). Two sites (RSH-1 and MBA-3) are at the MOE's Provincial Water Quality Objective (PWQO) for phosphorus in lakes (20 µg/L, MOE 1994). The Shadow River site represents the river's influence and the PWQO for rivers is 30 µg/L. The Muskoka Bay site indicates reduced flushing, urban runoff, some release of phosphorus from sediments and recovery from historic discharges of treated sewage. We also note that the PWQO is set for the open water areas of lakes and not for nearshore waters. The MLA results represent nearshore waters. They indicate land use effects and are not directly interpretable against the PWQO, but do indicate areas of potential concern. Future programs should continue to focus on phosphorus enrichment at these sites.

The area with the lowest average phosphorus concentration was Cox Bay. The land use in this area includes major resorts, old resorts, marinas, a large number of shoreline residences and the Lake Joseph Club Golf Course. As a result, one might expect Cox Bay to show a high level of enrichment. In spite of this, the overall results and results for individual sites indicate very little alteration of water quality. This may reflect good management of phosphorus runoff or good exposure of Cox Bay to winds and mixing, such that runoff is assimilated and diluted rapidly.

Figure 33. Ten Highest Average Phosphorus Loading Results By Site



Note: Provincial Water Quality Objectives for total phosphorus are enclosed by the dashed and the dotted red lines.

5.5 Algae

The goals of the algae program were:

a) to determine if periphyton abundance can be measured reliably;

b) to establish if measurements were related to adjacent land use activities; and

c) to determine if algae abundance was related to phosphorus concentrations in the nearshore areas.

Algal growth is a function of many factors and it is difficult to determine cause and effect directly with a limited data set. The hypothesis guiding the 2002 program was that algal growth in the nearshore area would be influenced by enhanced nutrient runoff from different land use activities. Nevertheless, the interpretation must also be guided by the response of algal growth to ambient light levels, the physical effect of wave action on algal growth and dispersion of nutrients in the water and the effects of grazing activities from snails and other invertebrates in reducing algal growth. The study design incorporated standard depths of water at the algal sites and standard southern exposure to limit variance due to depth and sunlight (See Section 3). Two assumptions must still be applied: first, that the effects of grazers and, second, the effects of wave action were equal at all sites. The 2003 program should include steps to evaluate the impacts of each.

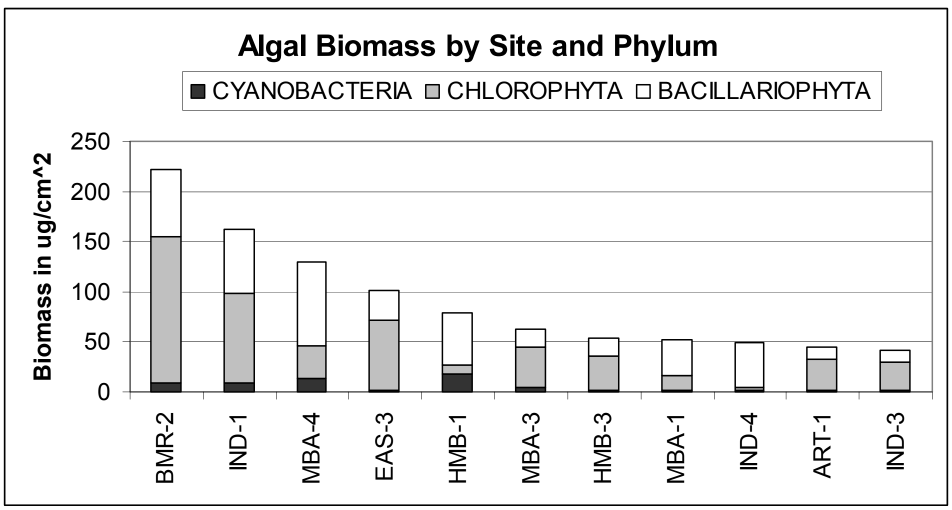
The algal tiles were retrieved from 10 of the 11 sites where they were deployed. The tiles were lost from site IND-3 and so chlorophyll analysis was not possible and the taxonomic analysis was performed on samples taken off a rock collected at the site. At the ten other sites the tiles were collected intact and were successfully colonized over the full surface area. At each location, the coverage of the two tiles, assessed visually, was similar. Because one tile was used for chlorophyll analysis and the other for taxonomic analysis, it is not possible to compare within site variation using the same parameter between tiles. Regression analyses of biomass versus chlorophyll and density versus chlorophyll yielded a positive but weak relationship for both analyses ($r^2 = 0.17$ and $r^2 = 0.57$). The biomass – chlorophyll relationship was skewed by a high chlorophyll concentration at site BMR-2.

An important goal of the algae program was to determine if the difference between sites was related to adjacent land uses. The sites were classified by land use as described in Table 21. The growth of attached algae ("periphyton") in nearshore waters was expected to be enhanced near golf courses, resorts and areas of urban influence in comparison with other more natural sites.

Table 21. Land Use Classification of Site with Algal Plates

Site	Classification
ART-1	➢ Grassland, retired farm land
BMR-2	➢ Golf Course (#2)
EAS-3	➢ Undisturbed, reference site
HMB-1	➢ Golf Course (#1)
HMB-3	➢ Resort
IND-1	➢ Residential
IND-3	➢ Trailer Park
IND-4	➢ Livestock
MBA-1	➢ Wetland
MBA-3	➢ Urban 1
MBA-4	➢ Urban 2

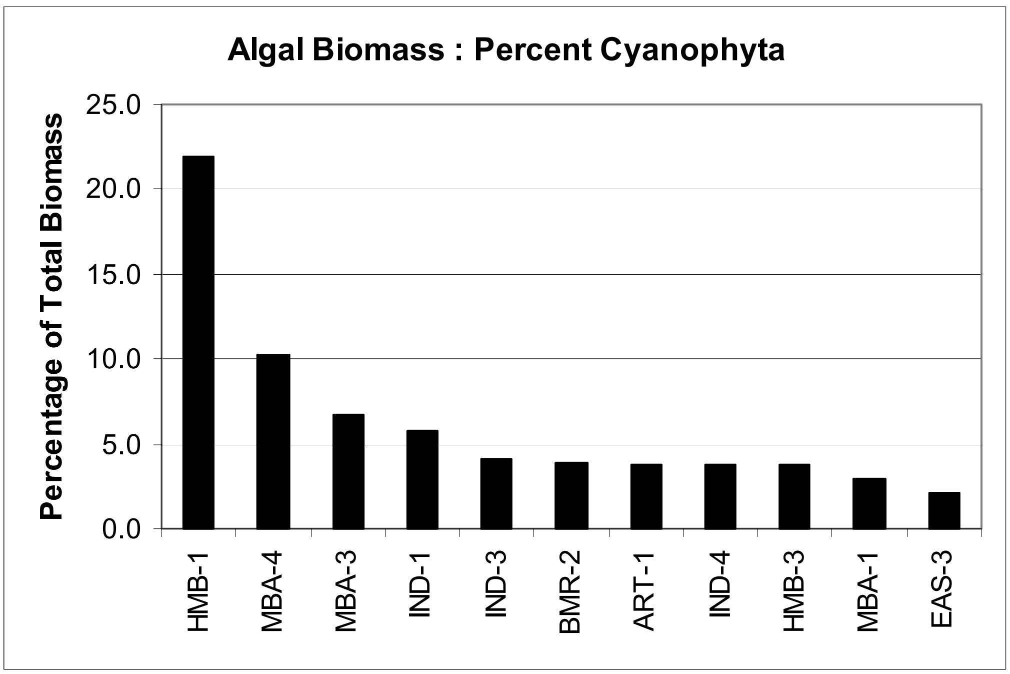
Figure 34. Biomass of Three Main Algal Taxa at Each Site



Three algal groups or phyla dominated the community at each of the sites (Figure 34): blue-green algae (cyanobacteria), green algae (chlorophytes) and diatoms (bacillariophytes). There were no strong associations between biomass of periphyton and land use. Areas of low intensity uses such as the Indian River upstream of Port Carling (IND-1), Beaumaris (BMR-2) or the reference site in East Bay (EAS-3) were among the areas with the highest algal biomass while the Muskoka Bay wetland area (MBA-1) and two areas of high disturbance in the Indian River (IND-2,3) had the lowest biomass levels.

Although land use did not have a strong effect on the biomass of algae, it influenced the proportion of biomass made up by the different algal phyla. The percent of cyanobacteria (blue-green algae) is expected to increase with increases in environmental disturbance, especially as a result of nutrient and organic enrichment and exposure to toxic substances (Steinman *et al.* 1991; Leland, 1995). The proportion of the total biomass represented by cyanobacteria was the highest of all sites studied at the location in Hamer Bay adjacent to the golf course drainage tributary (GC1, Figure 35), confirming some degree of enrichment at the site. Cyanobacterial dominance was also higher at sites in the relatively enriched Muskoka Bay and at the Indian River sites near Port Carling.

Figure 35. Percentage of Algal Biomass Made Up by Cyanophyta at Each Site



The number of algal taxa (~species) varied across the sites but showed no consistent relationship to disturbance. Number of taxa ranged from 56 at MBA-4 (urban) to 31 at IND-3. Low numbers of taxa were seen at the Indian River and MBA-1 sites, and also at HMB-1 (Table 22).

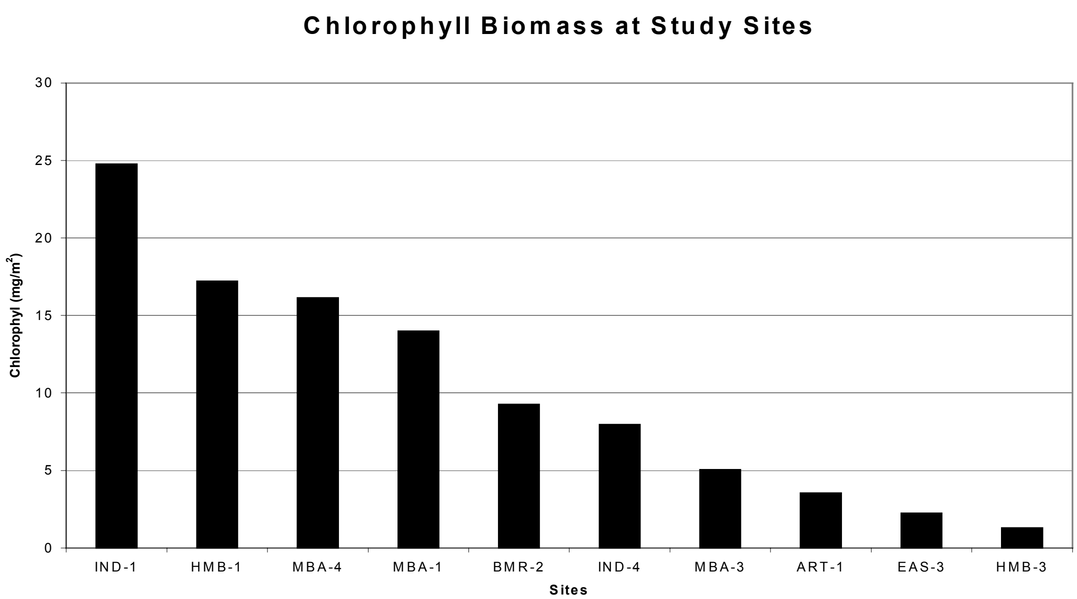
Table 22. Number of Algal Taxa at Each Study Site

Site	Total Algal Taxa
MBA-4	56
IND-1	55
EAS-3	41
HMB-3	39
BMR-2	38
MBA-3	38
ART-1	36
HMB-1	36
MBA-1	35
IND-4	32
IND-3	31

Chlorophyll a

Chlorophyll *a* is a plant pigment that uses light for photosynthesis. The amount of the pigment measured on the clay tiles (expressed as mg per square meter of tile) can also be used as an indicator of algal biomass. The three highest chlorophyll concentrations were found at the IND-1, HMB-1 and MBA-4, sites. These sites were adjacent to residential, golf course and urban land uses, respectively. (Figure 36).

Figure 36. Chlorophyll *a* Concentration at Site with Algal Tiles



5.6 Summary

Each of the metrics showed a response to differences between the study sites. Although each metric did not show the expected response to land use there was some degree of consistency across all sites and all forms of measurements. Responses at the Indian River and Muskoka Bay sites, and one Hamer Bay site (HMB-1) were consistently ranked as higher, more enriched or more indicative of some form of stress than were the other sites. These responses will be further explored in the next section

5.7 Principal Component (Ordination) Analysis

The purpose of Principal Components Analysis (PCA) is to determine factors (i.e., principal components) that explain as much of the total variation in the data as possible with as few of these factors as possible. This demonstrates correlation between environmental responses and similarity between sites which responded in a similar manner. The PCA was applied to the MLA data in an attempt to summarize land use effects on water quality.

5.7.1 Algal Data

The first principal component (PC1) is that weighted linear combination of the variables (in this case algal genera) which accounts for the largest amount of the total variation in the data. It is normally represented along the x-axis with the second principal component (PC2) along the y-axis. With respect to the algal data, the PCA assists in illustrating the variation of algal species between the various sites or land uses. That is, sites that tend to have similar species assemblages will separate graphically from those with different assemblages.

The first ordination analysis was performed on the density data grouped into phylum. The second ordination analysis incorporated the biomass data grouped by phylum. Cyanobacteria (blue-green algae), Chlorophyta (green algae), Euglenophyta, Chrysophyta, Bacillariophyta (diatoms), Haptophyta, Cryptophyta and Pyrrophyta were used where available to evaluate station similarities. The density data was standardized by taking the natural logarithm prior to applying the analysis.

Figures 37 and 38 show the ordination results for the density and biomass data sets. The number in brackets beside each axis title represents the percentage of variation in the data explained by that principal component. For example, PC1 (82.8%) indicates that 82.8 percent of the variation between stations, for the algal groups mentioned above, is represented by the orientation of points along that axis.

Figure 37. Principal Components Analysis of Algal Sites by Phylum Density

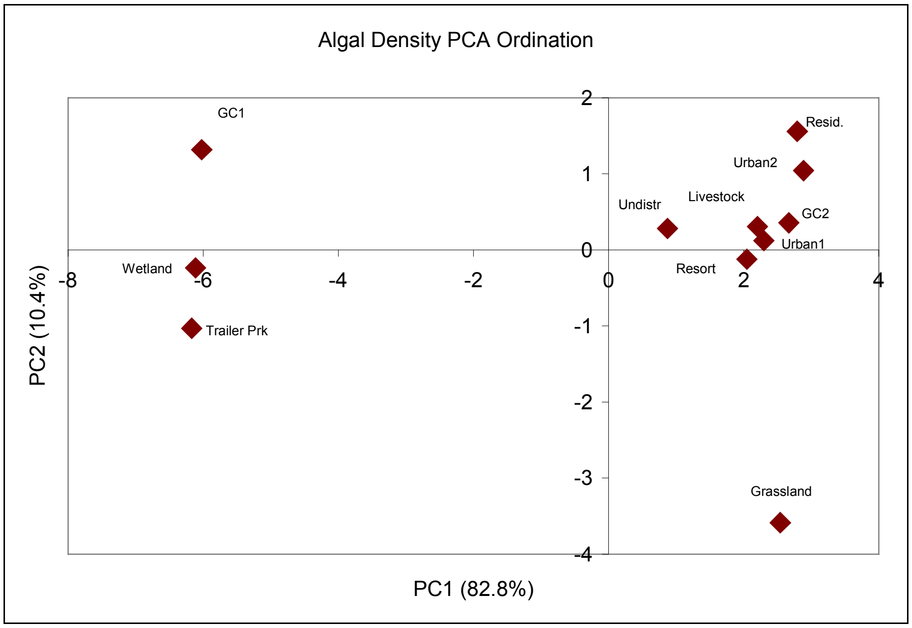
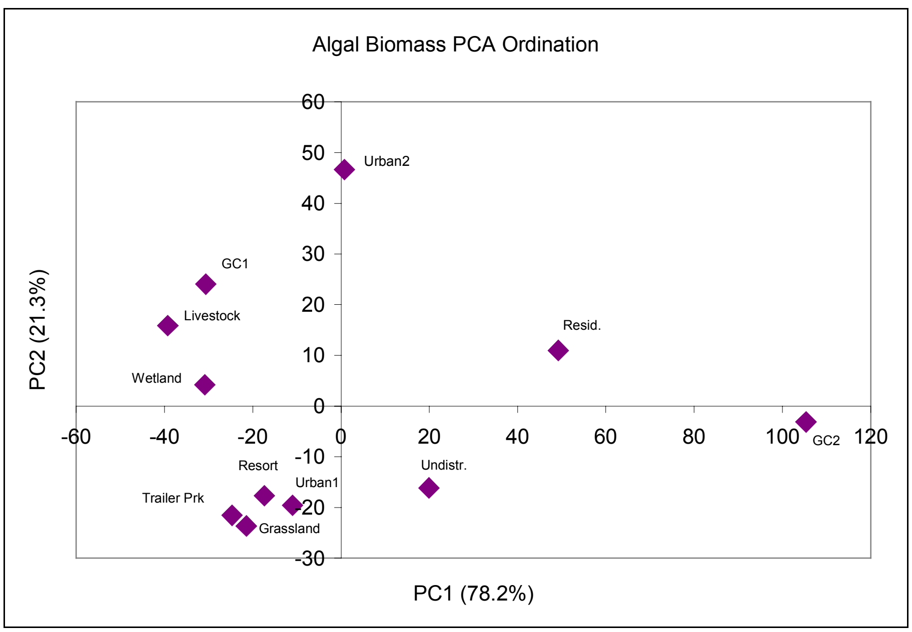


Figure 38. Principal Components Analysis of Algal Sites by Phylum Biomass



The data points in both the density and biomass PCA plots are separated mostly by their relative composition of cyanobacteria, green algae, chrysophytes and diatoms. In Figure 37 the chrysophyte composition strongly influences the separation of the sites along the x-axis. The three stations to the left side of the graph (HMB-1(GC1), IND-3 (Trailer Park) and MBA-3 (wetland)) did not record any chrysophytes. The y-axis is most influenced by the diatom and cyanobacterial communities. In Figure 38, the biomass ordination, the horizontal separation is most strongly influenced by the abundance of green algae. The vertical axis is most strongly influenced by diatom abundance.

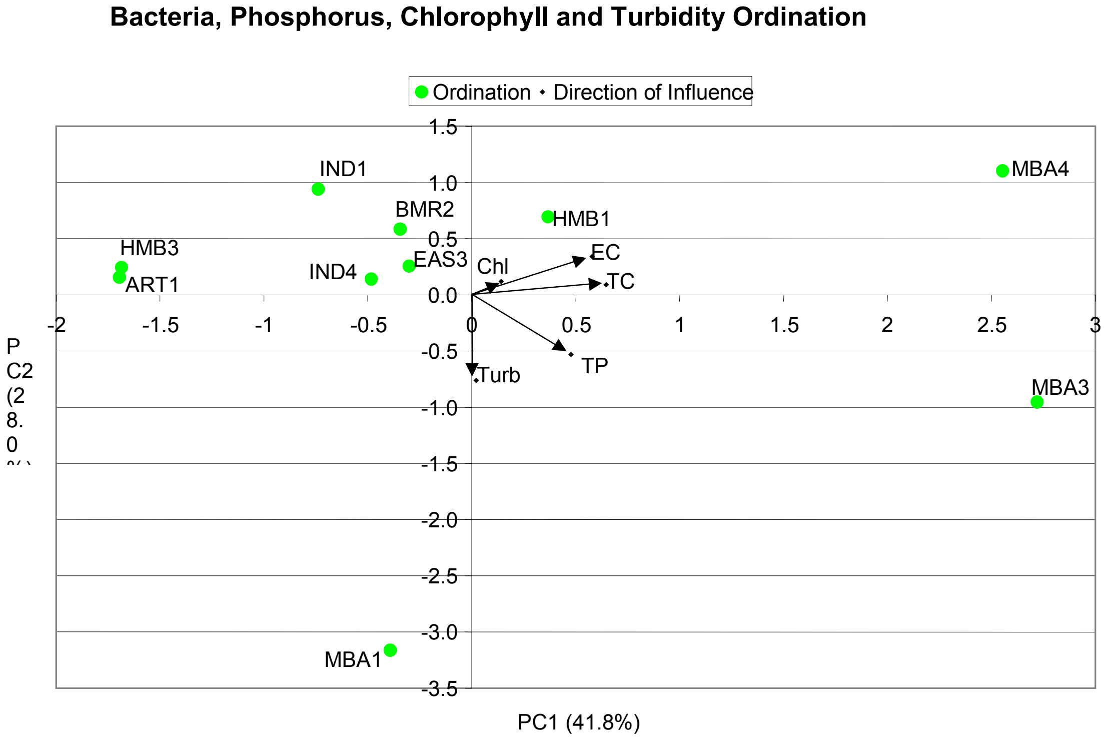
Both the density and biomass plots illustrate a horizontal grouping of the tributary draining Rocky Crest Golf Course (HMB-1/GC1), the trailer park on the Indian River (IND-3) and the natural wetland in Bear Bay (MBA-3). This separation is much more pronounced in the density plot (Figure 37). The large difference between the two golf course sites, HMB-1 and BMR-2 may reflect differences in management practices on the site or exposure of the nearshore area to wind and waves which could disperse runoff more easily at one site.

In summary – the algal ordinations demonstrate that land use is an important factor structuring the algal community in the Muskoka Lakes and that wetlands, golf course runoff and urban runoff may have varying effects on the algal community.

5.7.2 Water Quality Data

When total coliform, *E. coli*, total phosphorus, turbidity and chlorophyll *a we*re used in the same multi-variate statistical analysis used for the algal data the result was the separation of sites shown in Figure 39. The analysis was applied to all sites with complete data sets for the parameters listed. The strongest separation of the data was with respect to the urban sites in Muskoka Bay. Their separation was strongly influenced by higher bacteria concentrations. The wetland site in Muskoka Bay stands alone. The reason for the separation is higher turbidity levels, which are commonly attributed to dissolved organic carbon export from wetlands. The sites to the far left of Figure 38, ART-1 and HMB-3, ranked among the lowest for total coliform, *E. coli* and chlorophyll *a*. The Hamer Bay golf course site (HMB-1) was associated with slightly higher bacteria, phosphorus and chlorophyll levels.

Figure 39. Principal Components Analysis of Sites by Bacteria, Turbidity and Phosphorus Data

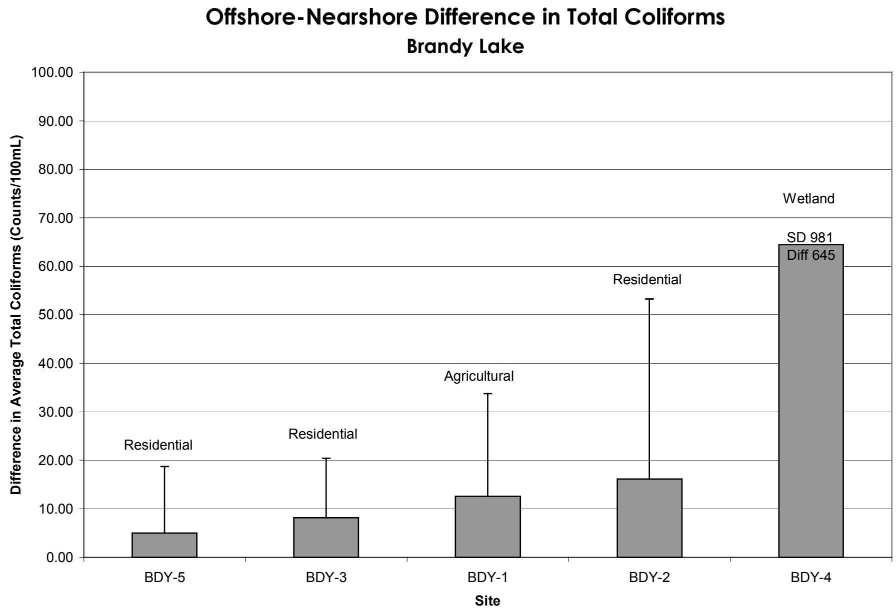


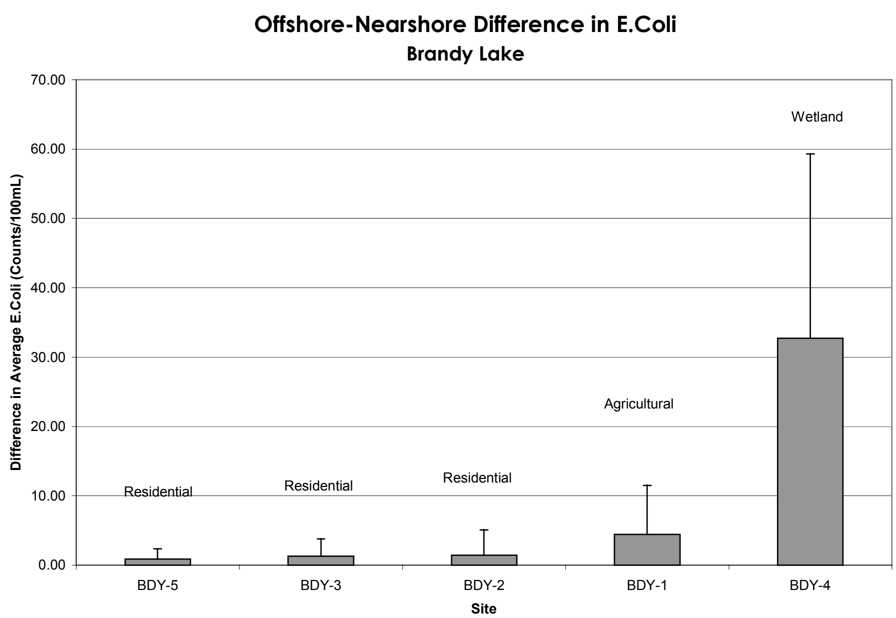
6. Land use Effects

Land use effects were illustrated by comparing the difference between nearshore and offshore water quality for each lake. The following graphs provide summaries for each lake. The columns on each graph have been sorted so that the smallest average difference between nearshore and offshore water quality for each lake appears on the left, and the greatest difference at the right. These were intended to summarize differences in nearshore and offshore water quality as a function of land use. If there were correlations between various land uses with nearshore water quality then columns representing similar land uses (noted as text on each figure) should appear together after being sorted. Theoretically, similar land uses will have similar effects on nearshore water quality.

One drawback to this method is that some lakes, especially Lake Joseph and Brandy Lake, had fewer testing sites and therefore offer less information and interpretation.

Figure 40. Differences Between Nearshore and Offshore Levels of Total Coliform (Top) and *E. coli* (Bottom) in Brandy Lake



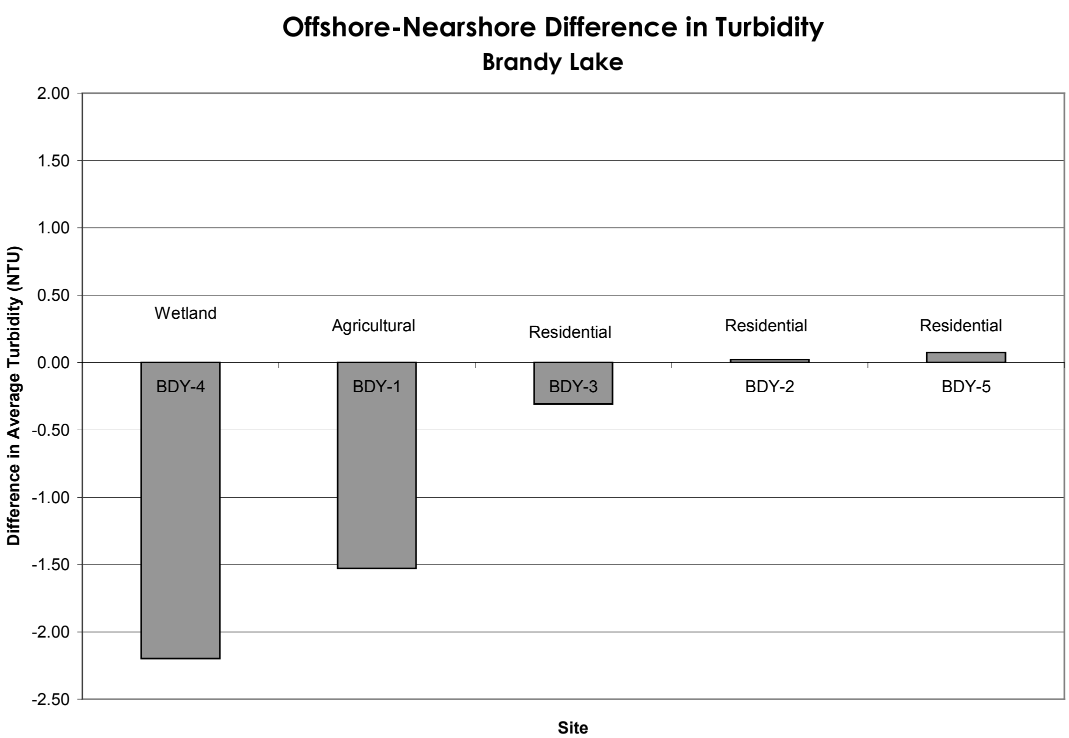


6.1 Brandy Lake

The most visible distinction among sites in Brandy Lake was with respect to bacteria concentrations (Figure 40) at the west inflow from Brandy Creek (BDY-4). Towards mid-summer, the total coliform levels at site BDY-4 were two orders of magnitude higher than at the other sites. *E. coli* levels followed a similar trend, they were always highest at BDY-4. Increased bacteria levels are often higher in wetland systems, although the water quality at this wetland site (BDY-4) may also be impacted by agricultural activity further up the creek. There were few other between-site differences in Brandy Lake and it is clear that the higher bacteria levels from BDY-4 do not persist in the lake itself.

The turbidity results showed the opposite trend compared to the bacteria data (Figure 40). The turbidity at the wetland site remained fairly constant over the summer, but increased at all of the other sites including offshore. The data indicate that Brandy Lake was experiencing an algal bloom towards the end of the summer that was diluted at site BDY-4 by the water coming in from Brandy Creek. The turbidity at the agricultural site (BDY-1) was also lower than the offshore site.

Figure 41. Differences Between Nearshore and Offshore Turbidity Levels in Brandy Lake



6.2 Lake Joseph

Golf courses on Lake Joseph provided some surprising results. For all four parameters, the site closest to the Rocky Crest Golf Course drainage tributary (HMB-1) showed the greatest difference between nearshore and offshore water quality. By comparison, the sites adjacent to the Lake Joseph Club golf course showed very little water quality response. This suggests either or all of the following factors : between-course differences in stormwater management, the addition of treated sewage effluent as well as runoff at Hamer Bay, or that there are physical differences within the bays (such as mixing by currents or wave climate) that obscure any effects of golf course runoff to Cox Bay.

Residential and urban developments on Lake Joseph were typically in the mid-range of land use effects on water quality (Figures 42-46). It is important to note, however, that only one residential site and one urban site were tested on Lake Joseph. In addition, the site denoted as 'urban' was adjacent to the small hamlet of Port Sandfield, which would intuitively have less effect on water quality than a larger community like Port Carling or Gravenhurst.

While resort development was recognized as influencing nearshore water quality, there were also distinct differences between the two resorts tested. Again, the Rocky Crest Resort in Hamer Bay consistently has a greater effect on water quality than the Pinelands resort in Cox Bay, particularly with respect to turbidity and phosphorus.

Overall, it appears that anthropogenic effects on nearshore water quality are much more important in Hamer Bay than they are in Cox Bay and other areas of Lake Joseph. This likely reflects the more enclosed and sheltered nature of Hamer Bay, compared to the other sites. This would tend to reduce mixing and dispersion of runoff, wetland drainage and treated sewage from the Rocky Crest site. With so few test sites on the lake, it is difficult to draw conclusions about general land uses but the Hamer Bay site does stand apart as an obvious departure from other sites.

Figure 42. Differences Between Nearshore and Offshore Total Coliform Levels in Lake Joseph

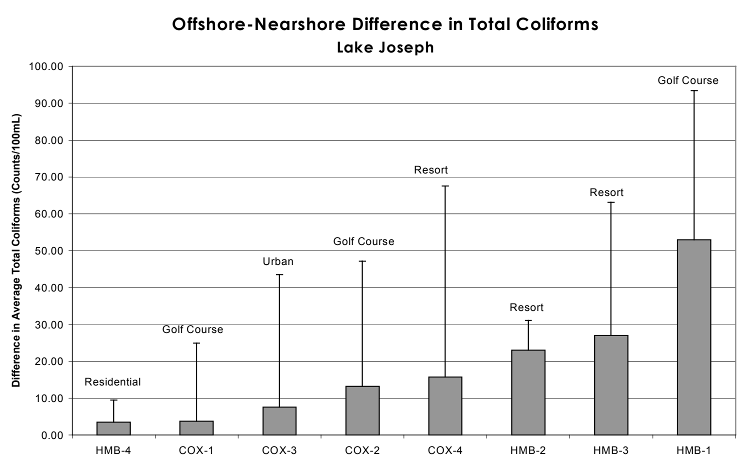


Figure 43. Differences Between Nearshore and Offshore *E. coli* Levels in Lake Joseph

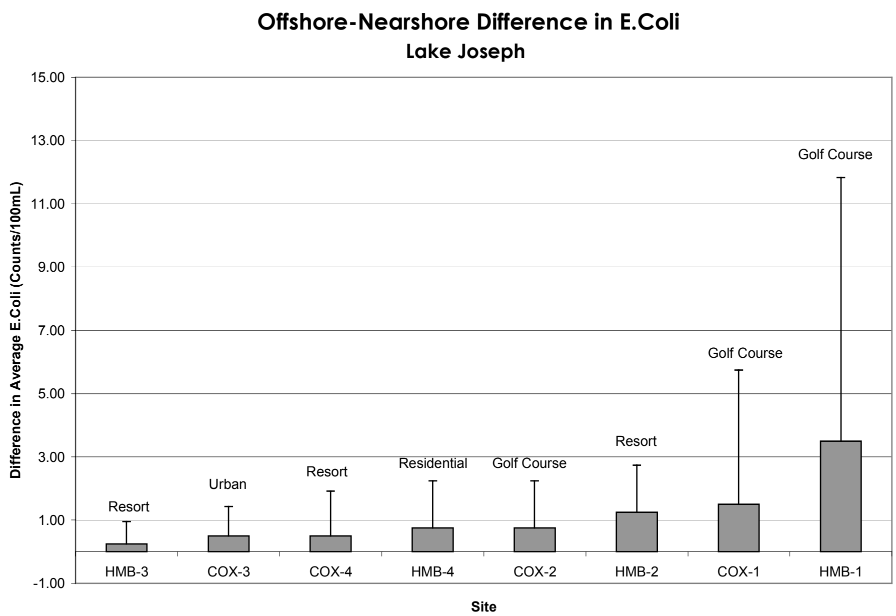


Figure 44. Differences Between Nearshore and Offshore Total Phosphorus Levels in Lake Joseph

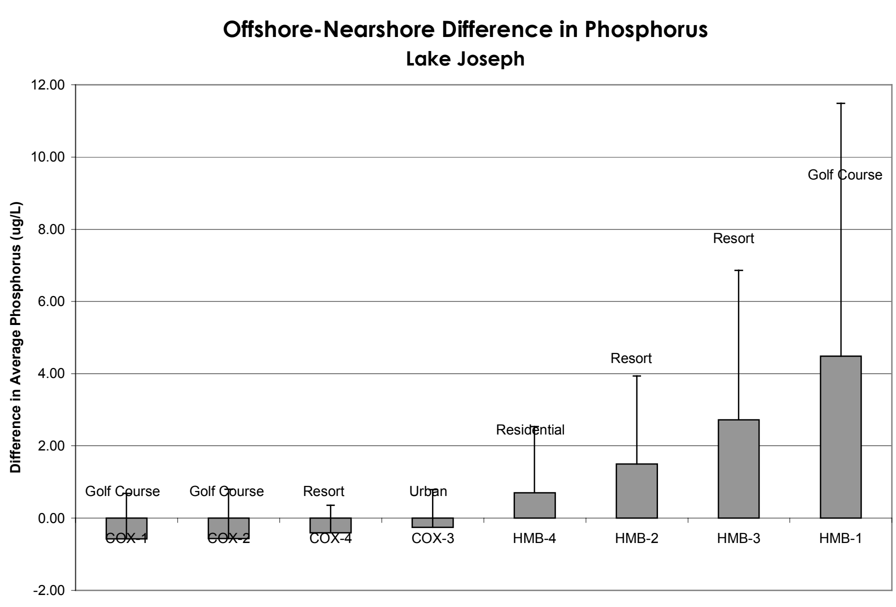
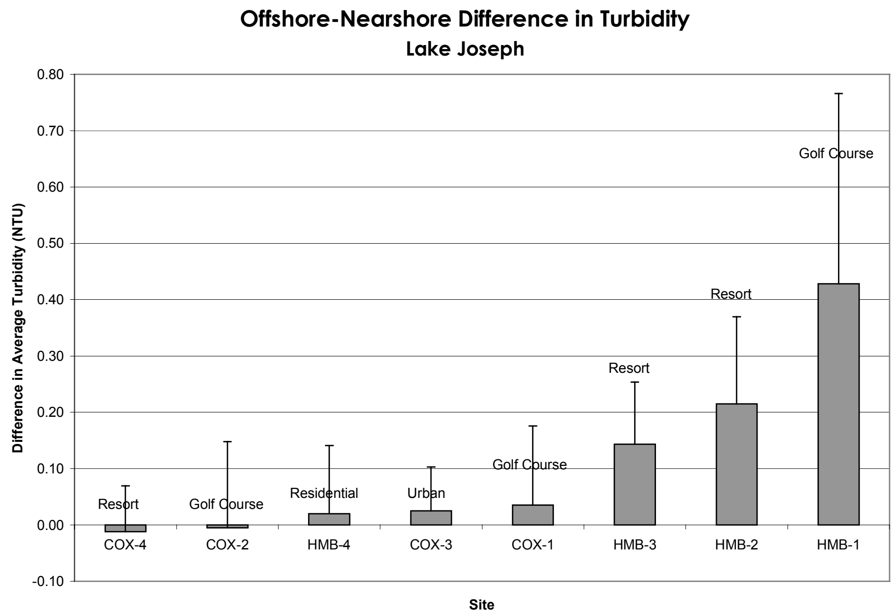


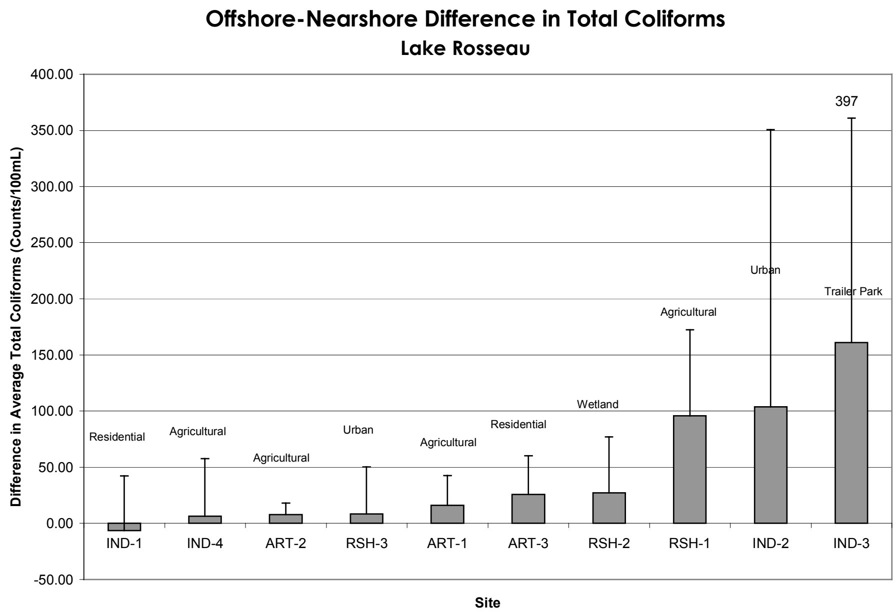
Figure 45. Differences Between Nearshore and Offshore Turbidity Levels in Lake Joseph

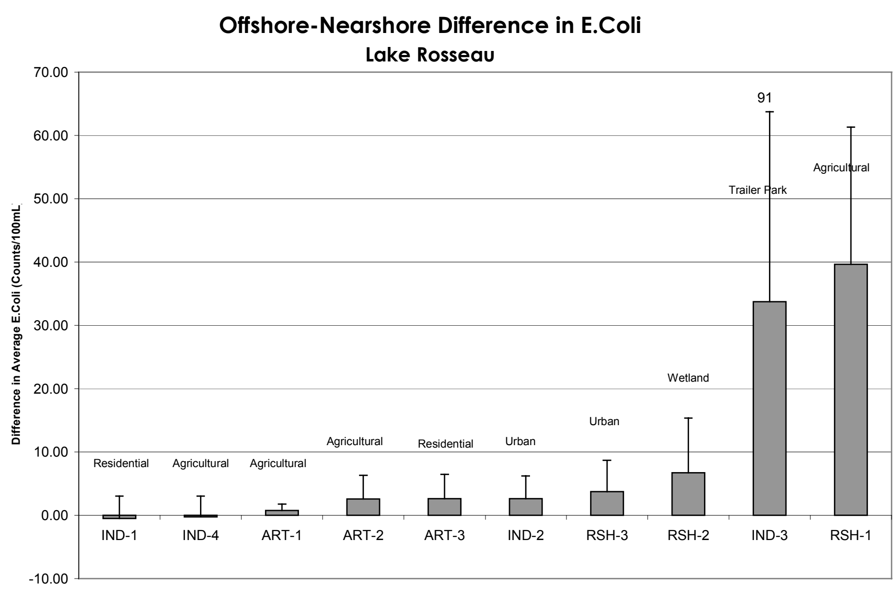


6.3 Lake Rosseau

The overall water quality of Lake Rosseau proper, excluding the Shadow and Indian River sites, was excellent. With respect to total coliforms and *E. coli* there was little difference between adjacent land use and the offshore areas of the lake (Figure 46). The residential, agricultural and urban sites showed minor variation over the season, but no particular land use stood out as more or less detrimental. The results from the Shadow and Indian Rivers were higher on average and had a larger variance than the Lake Rosseau-proper sites.

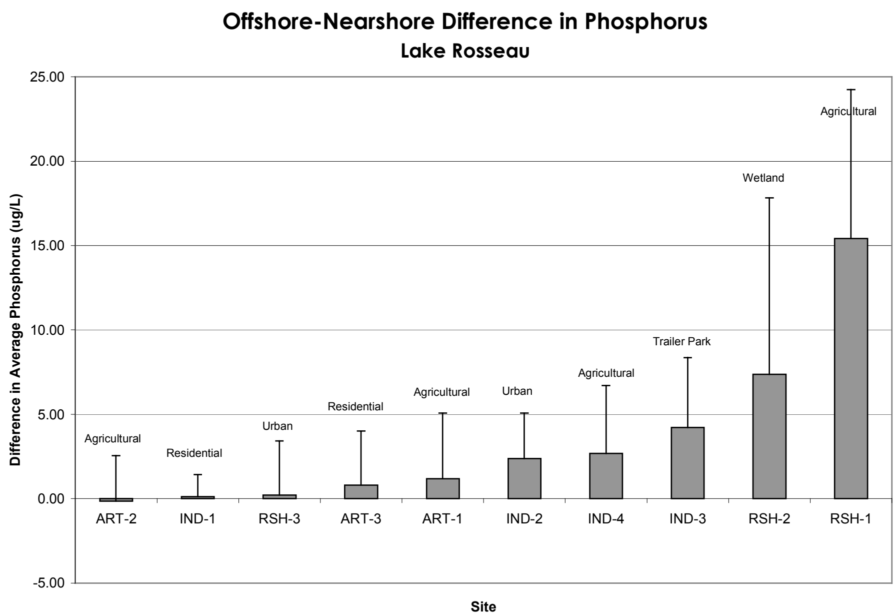
Figure 46. Differences Between Nearshore and Offshore Levels of Total Coliform (Top) and *E. coli* (Bottom) in Lake Rosseau





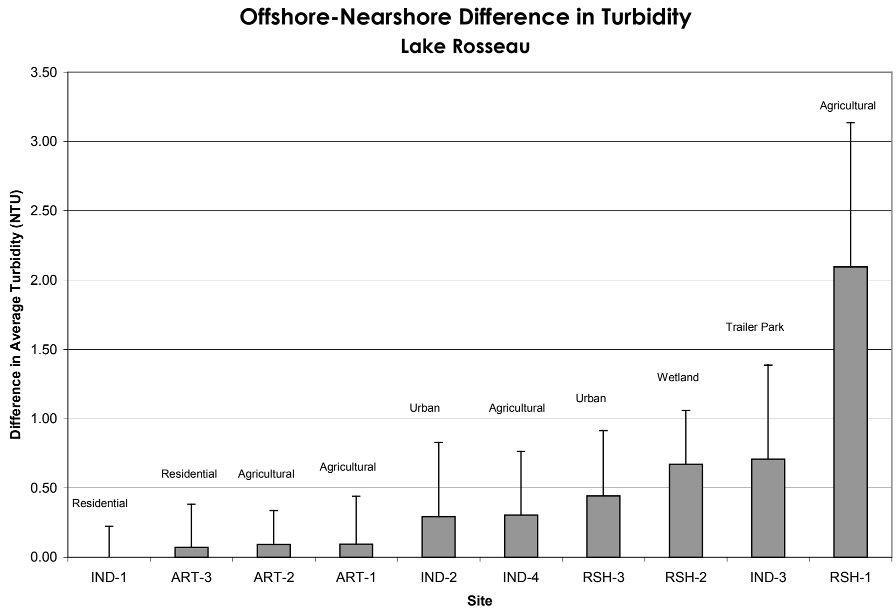
The results from the different residential and urban sites were all very similar with respect to total phosphorus concentration (Figure 47) but all nearshore sites showed enrichment compared to offshore sites. The results from the Shadow and Indian Rivers were higher on average and had a larger variance than the Lake Rosseau-proper sites.

Figure 47. Differences Between Nearshore and Offshore Total Phosphorus Levels in Lake Rosseau



Comparison of turbidity results showed little difference between nearshore and offshore sites in Lake Rosseau-proper with the exception of the marina site near the village of Rosseau (Figure 48). The Shadow River site (RSH-1) had the highest turbidity, attributable to higher concentrations of organic carbon. The higher values at the marina site are most likely a result of the proximity to the mouth of the river.

Figure 48. Differences Between Nearshore and Offshore Turbidity Levels in Lake Rosseau



6.4 Lake Muskoka

The phosphorus concentrations in Lake Muskoka have historically been higher than in Lake Rosseau or Lake Joseph. This can be attributed to the larger urban centres, Bracebridge and Gravenhurst, on Lake Muskoka and its position at the downstream end of a large watershed.

The total phosphorus concentrations in Muskoka Bay, in particular, have been high. This was a result of the discharge of treated sewage in the mid-1900s and the ongoing recovery of the bay from this. The phosphorus results from site MBA-3 were the most elevated of all the lake sites. The seasonal average, 20.3 µg/L was above the Provincial Water Quality Objective for enriched lakes (20 µg/L). The rest of the urban sites in Lake Muskoka (BMR-3, MBA-4, MBA-5) were scattered along the spectrum from most enriched to least enriched with TP. There was no clear evidence of phosphorus enrichment with land use in Lake Muskoka (Figure 49) although nearshore phosphorus was higher than that measured offshore.

Figure 49. Differences Between Nearshore and Offshore Total Phosphorus Levels in Lake Muskoka

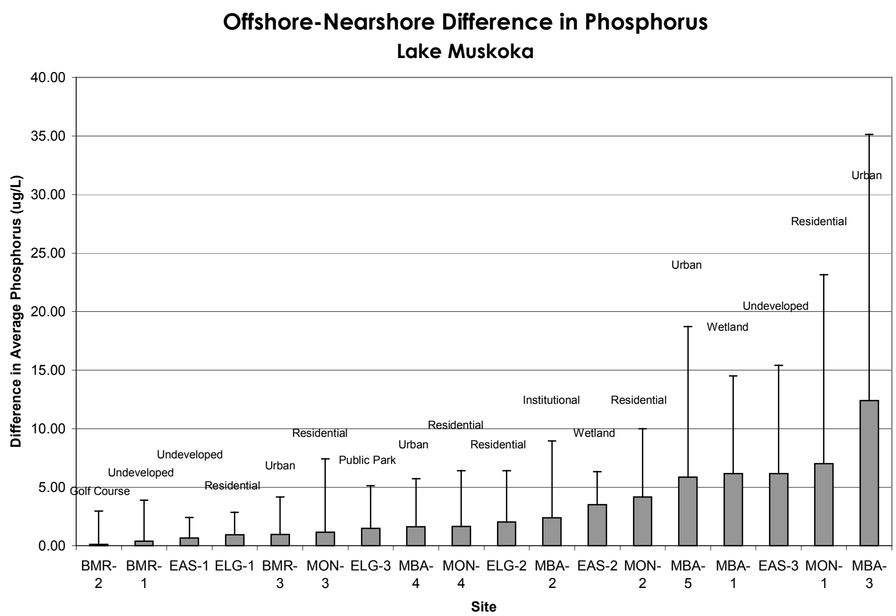
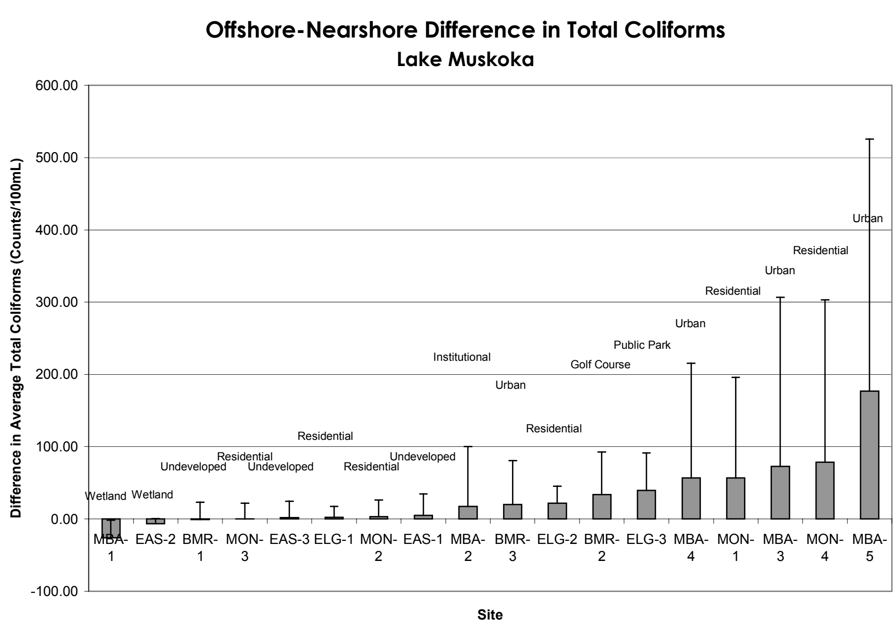
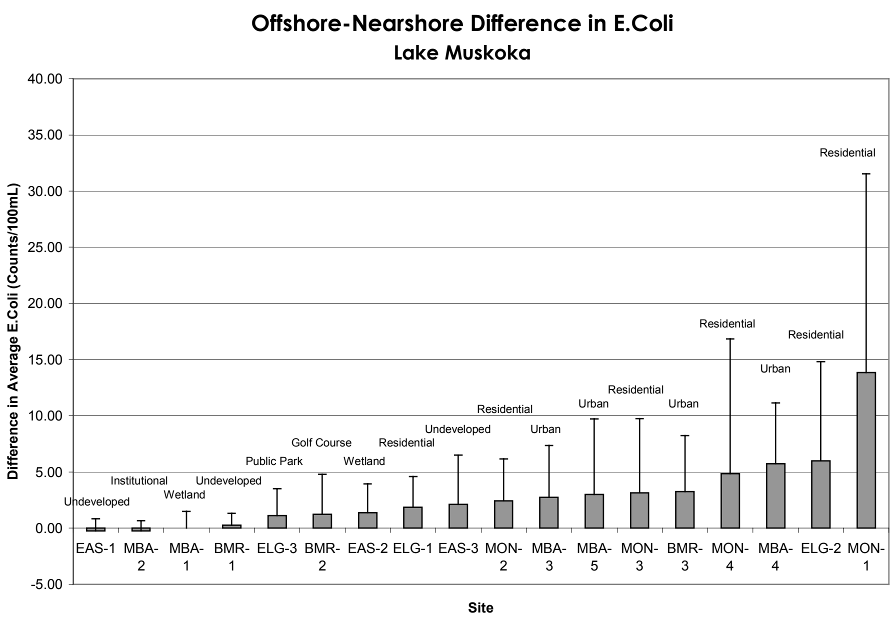


Figure 50. Differences Between Nearshore and Offshore Levels of Total Coliform in Lake Muskoka



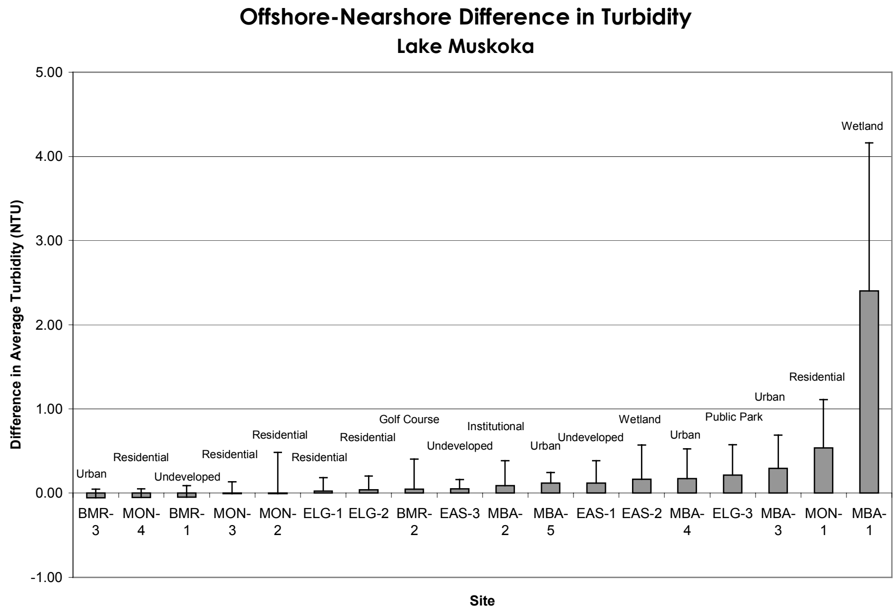
The total coliform data showed a different response than the phosphorus data (Figure 50). The undeveloped and wetland sites were all in the lower half of the sites for total coliform, while the urban sites were all in upper half. The residential sites were scattered throughout. The highest *E. coli* levels were measured at sites influenced by urban or residential land uses. The undeveloped and wetland sites were again in the lower half of the data (Figure 51). This pattern shows a clear trend of bacterial enrichment of urban sites compared to offshore sites in Lake Muskoka.

Figure 51. Differences Between Nearshore and Offshore Levels of *E. coli* in Lake Muskoka



The turbidity results showed no distinctive trend with respect to land use in Lake Muskoka. Residential, urban and undeveloped sites were spread along the spectrum from highest to lowest turbidity (Figure 52). The wetlands were higher up in the order of impacted sites. However this is not a source of concern as wetlands are a natural decompositional environment and will have naturally higher DOC resulting in higher turbidity.

Figure 52. Differences Between Nearshore and Offshore Levels of Turbidity in Lake Muskoka



6.5 Summary

Although trends are not consistent between land use and water quality, there are clearly differences between nearshore and offshore water quality in the three Muskoka Lakes. All four water quality measurements showed evidence of enrichment in nearshore areas, particularly in urban areas such as Muskoka Bay or the Indian River and in Hamer Bay. Wetlands appeared to have as great an effect on water quality as human land use as bacteria, phosphorus and turbidity levels were enriched in study sites receiving wetland drainage. Land use effects could not easily be separated from physical factors in the receiving environment which would influence the mixing and assimilation of runoff with the water mass in the lake.

7. Conclusions and Recommendations

The 2003 water quality program was a success, in terms of:

a) volunteer involvement;
b) program co-ordination;
c) collection of useful data for long-term monitoring;
d) refinement of methods for assessment of nearshore water quality;
e) elaboration of factors influencing nearshore water quality; and
f) communication of results to the MLA, local government and NGOs and the general public.

The monitoring results showed that nearshore water quality differs from that measured offshore, in that it is more enriched with phosphorus and bacteria. As a result :

a) water quality programs which focus on the offshore only do not provide a complete picture of water quality;

b) nearshore water quality is important as it represents the area of the lake which is used for swimming and, occasionally, water supply;

c) nearshore water quality is influenced by the adjacent land use – urban runoff, golf course runoff and wetland drainage were identified as important influences; and

d) the effects of land use on nearshore water quality are modified by the physical aspects of the nearshore, particularly by depth and exposure to wind and wave action.

The program also showed that algal growth, particularly the proportion of blue-green algae, responded to nearshore nutrient enrichment.

The nearshore water quality program was originally conceived as a three year pilot study for the years 2001, 2002 and 2003. We recommend that the study proceed as planned in 2003. Several changes are recommended, however, as adjustments to details which will allow the MLA to better use resources in the coming years.

One major change involves the implementation of one of the original program goals. The original project calls for both a research and monitoring program. The terms may seem to be interchangeable but they serve different functions. To date, most energy has been spent on the research program, including the development of protocols and an administration system. Now that these systems are in place, it is possible to focus more heavily on monitoring using the protocols developed in the first two years of the program. Nevertheless, one objective of the long term research program is to provide information to guide land use planning and stewardship activities. The “research sites” will be most useful in this regard and should be focussed on areas where the program has identified problems with i.e. urban, agricultural or golf course runoff.

Within this context, several areas were identified as having good potential for further study, while others were noted as having less potential. Sites with good potential should be considered for future seasons. The capacity of the program should be defined in terms of financial, human and physical resources. Monitoring a wide range of sites with routine and well understood methods allows the MLA to respond to the needs of members who wish to see a water quality program in their portion of the lakes. Collection of such information over the long term gives the MLA the ability to track long-term changes in the nearshore water quality and to provide information to the membership by way of their database and web site. Additional resources could be spent on expanding the monitoring program to areas with strong community interest which may or may not show strong potential as a research site. In addition, the MLA should take advantage of interest in the water quality testing program from community members outside of the ‘big 3’ Muskoka Lakes to involve these stakeholders in the Association.

Considering the experience from the 2002 Water Quality Testing Program, several recommendations for the future program are presented:

a) Consider narrowing the research program to fewer areas with more intense sampling within the selected areas.

b) Launch a monitoring program to coincide with development of the online database available to all MLA members.

c) Monitor as many sites as financial and human resources will allow, focussing on areas of public and scientific significance. Candidate areas identified to the MLA by members includes:
   - Windermere, to address concerns with golf course and resort runoff,
   - Bala Bay, to address concerns with intense levels of old cottage development
   - Town of Bala, to address concerns with urban runoff and older residential development,
   - The Muskoka River, to assess upstream development, and
   - Little Joseph River, to assess a major outflow from Lake Joseph.

d) Involve members of the community from outside of the ‘Big 3’ Muskoka Lakes. The following lake associations have expressed interest in the monitoring program:
   - Brandy Lake;
   - Sucker Lake;
   - Gull and Silver Lakes; and
   - Leonard Lake.

e) Continue using volunteers in the Water Quality Testing Program. This is especially useful for lake associations outside of "the Big 3" which cannot be easily sampled by the volunteers from the large lakes.

f) Ensure everyone who wants to help with the Water Quality Testing Program is included and is thoroughly trained. A larger corps of volunteers increases the need for thorough and repeated training to ensure program integrity and consistency,

g) Carefully instruct the volunteers regarding data sheets and duplicate/blank samples.

h) Add *estimated distance from shore* and *water depth* parameters to data sheet.

i) Record *wave height* as either "rough" or "calm".

j) Include an offshore reference site with all groups of sites.

k) Include offshore sites representative of the whole lake. These can be done by accessing data from the program of the District Municipality of Muskoka but their program does not sample all sites every year. We therefore recommend that the MLA collect their own offshore samples representative of the large lake mass with consideration of the DMM sample sites.

l) Visit EBPI to consult with Dr. Karl Schiefer in order to discuss interpretation of ColiPlate results.

m) Emphasize the importance of sterilization in order to minimize bacterial contamination.

n) Compare bacteria duplicate variability with data from the Muskoka-Parry Sound Health Unit's public beaches program to determine natural ranges of within site bacterial variability for samples taken on the same day and to establish if MLA variability is within an acceptable range.

o) Compare phosphorus duplicate variability to other phosphorus data tested this season at the Trent University Environmental Science Centre in order to determine if variability is within an acceptable range.

p) Add several sampling runs in response to rain events as pollutants are most likely to be mobilized in response to rain.

q) Continue to work with the Lake Joseph North Association to interpret results from Hamer Bay.

Report Prepared By:	**Report Reviewed By:**
Sean A. Miller, M.Sc. Aquatic Ecologist	Neil J. Hutchinson, Ph.D. Senior Aquatic Scientist Principal

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Appendices

Appendix A

2002 Program Volunteers

Appendix A

Muskoka Lakes Association – 2002 Quality Program Volunteers

Paul Aggett
Doug Applegath
Bill Boughner
John Carr
Jim Cormack
Harold Cormick
Tim Cormick
Margot Cummings-Hodgins
John Curran
Liz Curran
John Duncan
Diane Faught
Beth Guy
Stan Harper
Gary Innanen
Terry Johnson
Jeremy Johnston
Elaine Logan
Inglis MacDonald
John Magee
Bev Manchee
Joe Moher
Lori Morrisey
Keith Shantz
Dirk Soutendijk
Anne Stanway
Ian Taylor
Peter Ward

MLA Staff:

Amy Brown
Andrea Clark
Cheryl Hollows
Shannon Jennings
Michael Logan
Cheryl Watt

Many thanks to all for a job well done !!

Appendix B

Sample Event Data Sheet)

Appendix B

2002 Sample Event Data Sheet

General Information

Group Code: EAS   Date: 3 June 2002

Sampler:____________________________________   Time:___________

Weather conditions:__________________________________   (Air) Temperature:__________

Rainfall in last 48 hours (heavy, moderate, light, none):__________________________________

Direction wind is coming from (or “calm”):_____________________________

Site Specific Information

Site Code: EAS-0   (Water) Temperature: _______________

Wave Height: ❑ None ❑ < 5 cm ❑ > 5 cm ❑ Breaking   Direction: _______________

Site Code: EAS-1   (Water) Temperature: _______________

Wave Height: ❑ None ❑ < 5 cm ❑ > 5 cm ❑ Breaking   Direction: _______________

Site Code: EAS-2   (Water) Temperature: _______________

Wave Height: ❑ None ❑ < 5 cm ❑ > 5 cm ❑ Breaking   Direction: _______________

Site Code: EAS-3   (Water) Temperature: _______________

Wave Height: ❑ None ❑ < 5 cm ❑ > 5 cm ❑ Breaking   Direction: _______________

Appendix C

Raw Data

Appendix C

Raw Data

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data

Sample Date 1	May 27, June 03, 2002
Sample Date 2	June 10, June 17, 2003
Sample Date 3	June 24, July 1, 2002
Sample Date 4	July 8, July 15, 2002
Sample Date 5	July 22, July 29, 2002
Sample Date 6	August 5, August 12, 2002
Sample Date 7	August 19, August 26, 2002
Sample Date 8	September 2, September 9, 2002

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 1			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	3	<3	4	
	HMB-1	102	3	22	
	HMB-2	22	<3	5	
	HMB-3	72	3	13	
	HMB-4	11	3	4	
Little Lake Joe	LLJ-1	13	<3		
	LLJ-2	16	<3		
	LLJ-3	8	<3		
Cox Bay	COX-0	5	<3	5	
	COX-1	33	13	4	
	COX-2	3	<3	6	
	COX-3	<3	<3	5	
	COX-4	<3	<3	4	
Rosseau/Shadow River	RSH-0	52	3	9	
	RSH-1	194	43	23	
	RSH-2	136	22	21	
	RSH-3	114	11	11	
Royal Muskoka Island	RMI-1	13	3		
	RMI-2	11	3		
	RMI-3	13	3		
Cleveland's House	CLE-1	11	<3		
	CLE-2	22	<3		
	CLE-3	52	<3		
Brackenrig Bay	BRA-1	5	3		
	BRA-2	3	<3		
	BRA-3	3	3		
Arthurlie Bay	ART-0	<3	<3	6	
	ART-1	83	<3	6	
	ART-2			7	
	ART-3	22	3	7	
Indian River	IND-0	5	<3	5	
	IND-1	8	<3	5	
	IND-2	16	5	10	
	IND-3	16	5	9	
	IND-4	19	<3	8	

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 1			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0				
	BDY-1				
	BDY-2				
	BDY-3				
	BDY-4				
	BDY-5				
Beaumaris	BMR-0	<3	<3	5	
	BMR-1	3	<3	5	
	BMR-2	8	<3	9	
	BMR-3	5	<3	6	
East Bay	EAS-0	3	<3	6	
	EAS-1	<3	<3		
	EAS-2	13	5	10	
	EAS-3	<3	<3	7	
Montcalm Point	MON-0				
	MON-1				
	MON-2				
	MON-3				
	MON-4				
Arundel	ARN-1				
	ARN-2				
	ARN-3				
Eilean Gowan	ELG-0	3	<3	8	
	ELG-1	13	8	7	
	ELG-2	30	8	12	
	ELG-3	5	3	14	
Muskoka Sands	MSN-1	22	11		
	MSN-2	109	36		
	MSN-3	52			
Muskoka Bay	MBA-0	13	3	10	
	MBA-1	8	<3	17	
	MBA-2	49	3	25	
	MBA-3	16	8	11	
	MBA-4	25	16	16	
	MBA-5	39	3	12	

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 2			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	<3	<3	4	
	HMB-1	52	<3	7	
	HMB-2	19	<3	5	
	HMB-3	102	<3	10	
	HMB-4	<3	<3	6	
Little Lake Joe	LLJ-1	5	<3		
	LLJ-2	3	<3		
	LLJ-3	<3	<3		
Cox Bay	COX-0	<3	<3	4	
	COX-1	19	<3	3	
	COX-2	8	<3	3	
	COX-3	11	<3	3	
	COX-4	<3	<3	4	
Rosseau/Shadow River	RSH-0	5	<3	7	
	RSH-1	146	65	30	
	RSH-2	52	<3	16	
	RSH-3	5	5	9	
Royal Muskoka Island	RMI-1	19	<3		
	RMI-2	<3	<3		
	RMI-3	13	<3		
Cleveland's House	CLE-1	3	<3		
	CLE-2	22	<3		
	CLE-3	11	3		
Brackenrig Bay	BRA-1	11	<3		
	BRA-2	16	5		
	BRA-3	11	<3		
Arthurlie Bay	ART-0	3	<3	7	
	ART-1	28	<3	14	
	ART-2	8	5	9	
	ART-3	106	<3	11	
Indian River	IND-0	8	<3	5	
	IND-1	8	<3	5	
	IND-2	740	8	10	
	IND-3	30	3	15	
	IND-4	25	<3	6	

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 2			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	19	<3		
	BDY-1	65	19		
	BDY-2	109	3		
	BDY-3	36	8		
	BDY-4	98	52		
	BDY-5	43	5		
Beaumaris	BMR-0	13	5	12	
	BMR-1	25	3	5	
	BMR-2	36	5	9	
	BMR-3	39	16	7	
East Bay	EAS-0	13	3	4	
	EAS-1	13	3	5	
	EAS-2	13	5	6	
	EAS-3	13	8	15	
Montcalm Point	MON-0	19	<3	8	
	MON-1	403	52	48	
	MON-2	49	11	7	
	MON-3	55	3	7	
	MON-4	619	33	6	
Arundel	ARN-1	39	8		
	ARN-2	83	13		
	ARN-3	25	<3		
Eilean Gowan	ELG-0	8	3	6	
	ELG-1	19	5	9	
	ELG-2	55	28	6	
	ELG-3	22	<3	8	
Muskoka Sands	MSN-1	11	5		
	MSN-2	8	<3		
	MSN-3	25	3		
Muskoka Bay	MBA-0	25	<3	12	
	MBA-1	16	5	29	
	MBA-2	8	3	12	
	MBA-3	28	13	20	
	MBA-4	25	<3	13	
	MBA-5	619	19	42	

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 3			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	<3	<3	3	0.9
	HMB-1	49	<3	5	1.58
	HMB-2	36	3	5	0.8
	HMB-3	8	<3	4	0.7
	HMB-4	8	<3	6	0.73
Little Lake Joe	LLJ-1	13	8		0.62
	LLJ-2	36	16		0.55
	LLJ-3	25	3		0.69
Cox Bay	COX-0	11	<3	9	0.74
	COX-1	11	<3	4	0.6
	COX-2	33	5	3	0.64
	COX-3	5	<3	4	0.76
	COX-4	8	<3	4	0.66
Rosseau/Shadow River	RSH-0	36	3	9	0.91
	RSH-1	141	72	33	1.26
	RSH-2	65	22	23	1.21
	RSH-3	39	<3	6	0.78
Royal Muskoka Island	RMI-1	16	3		0.68
	RMI-2	25	5		0.73
	RMI-3	11	3		0.64
Cleveland's House	CLE-1	3	<3		0.59
	CLE-2	36	11		0.72
	CLE-3	5	3		0.67
Brackenrig Bay	BRA-1	11	5		0.99
	BRA-2	5	<3		0.81
	BRA-3	36	3		0.88
Arthurlie Bay	ART-0	13	<3	5	0.9
	ART-1	5	<3	4	0.64
	ART-2	28	11	3	0.62
	ART-3	11	3	4	0.97
Indian River	IND-0	3	<3	3	0.63
	IND-1	13	<3	6	0.69
	IND-2	13	<3	4	0.7
	IND-3	52	11	5	0.89
	IND-4	33	11	4	0.7

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 3			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	8	5		3.16
	BDY-1	16	8		1.49
	BDY-2	28	11		1.72
	BDY-3	33	<3		3.02
	BDY-4	156	28		4.79
	BDY-5	3	<3		1.78
Beaumaris	BMR-0	5	3	5	1.15
	BMR-1	5	3	8	1.08
	BMR-2	8	<3	4	1.63
	BMR-3	22	8	5	1.04
East Bay	EAS-0	5	5	5	1.18
	EAS-1	3	<3	7	1.52
	EAS-2	22	5	12	1.86
	EAS-3	11	<3	7	1.1
Montcalm Point	MON-0	3	<3	6	0.99
	MON-1	69	8	11	1.24
	MON-2	33	3	6	1.25
	MON-3	36	19	19	0.94
	MON-4	13	<3		1
Arundel	ARN-1	19	3		0.93
	ARN-2	19	<3		1.12
	ARN-3	13	<3		1.21
Eilean Gowan	ELG-0	5	<3	4	1.08
	ELG-1	22	5	7	1.16
	ELG-2	25	8	5	0.94
	ELG-3	39	<3	7	1.66
Muskoka Sands	MSN-1	49	<3	11	1.4
	MSN-2	30	<3	11	1.23
	MSN-3	11	<3	11	1.17
Muskoka Bay	MBA-0	3	3	10	1.17
	MBA-1	11	<3	21	5.03
	MBA-2	3	<3	13	1.55
	MBA-3	16	8	25	1.86
	MBA-4	11	5	13	1.87
	MBA-5	25	<3	12	1.28

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 4			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	5	<3	6	0.7
	HMB-1	49	<3	14	
	HMB-2	30	<3	9	1
	HMB-3	11	<3	6	1.01
	HMB-4	8	<3	4	0.93
Little Lake Joe	LLJ-1	8	3		0.9
	LLJ-2	11	5		0.81
	LLJ-3	19	<3		0.77
Cox Bay	COX-0	11	<3	3	0.79
	COX-1	<3	<3	5	0.77
	COX-2	8	<3	3	0.72
	COX-3	11	3	4	0.73
	COX-4	3	<3	3	0.89
Rosseau/Shadow River	RSH-0	3	<3	5	1.01
	RSH-1	72	30	24	3.45
	RSH-2	22	5	27	1.6
	RSH-3	<3	<3	6	0.99
Royal Muskoka Island	RMI-1	5	<3		0.9
	RMI-2	13	3		1.32
	RMI-3	8	3		1.06
Cleveland's House	CLE-1	19	<3		1.31
	CLE-2	<3	<3		1.1
	CLE-3	5	<3		1.05
Brackenrig Bay	BRA-1	13	<3		2.45
	BRA-2	13	<3		2.5
	BRA-3	22	<3		2.45
Arthurlie Bay	ART-0	<3	<3	6	1.04
	ART-1	13	3	6	0.85
	ART-2	13	<3	4	1.14
	ART-3	19	<3	3	0.8
Indian River	IND-0	8	<3	5	0.99
	IND-1	3	3	4	0.97
	IND-2	36	5	8	0.95
	IND-3	30	5	14	1.44
	IND-4	16	3	16	1.2

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 4			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	11	<3		1.56
	BDY-1	11	<3		1.22
	BDY-2	3	3		2
	BDY-3	19	3		1.14
	BDY-4	72	19		1.43
	BDY-5	3	<3		1.6
Beaumaris	BMR-0	16	<3	7	1.26
	BMR-1	13	3	5	0.77
	BMR-2	3	3	3	1.41
	BMR-3	5	5	13	1.06
East Bay	EAS-0	11	<3	3	0.98
	EAS-1	3	<3	6	1.01
	EAS-2	5	<3	6	0.81
	EAS-3	<3	<3	9	0.88
Montcalm Point	MON-0	5	<3	4	1.09
	MON-1	11	<3	5	2.43
	MON-2	22	5	21	1.02
	MON-3	11	3	0	1.17
	MON-4	8	<3	3	0.88
Arundel	ARN-1	11	<3		1.11
	ARN-2	3	<3		1.5
	ARN-3	3	<3		0.87
Eilean Gowan	ELG-0	3	3	6	1.1
	ELG-1	19	5	8	1
	ELG-2	5	<3	3	0.89
	ELG-3	39	8	4	0.85
Muskoka Sands	MSN-1	22	5	11	1.05
	MSN-2	25	<3	11	1.84
	MSN-3	22	<3	8	1.21
Muskoka Bay	MBA-0	5	<3	8	0.94
	MBA-1	3	<3	12	0.9
	MBA-2	<3	<3	7	0.75
	MBA-3	5	3	74	0.89
	MBA-4	22	3	8	1.22
	MBA-5	33	<3	7	1.1

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 5			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	3	<3	2	0.85
	HMB-1	119	25	5	1.11
	HMB-2	36	<3	3	0.95
	HMB-3	22	<3	2	0.93
	HMB-4	19	5	2	0.77
Little Lake Joe	LLJ-1	11	<3		0.82
	LLJ-2	11	3		0.71
	LLJ-3	16	<3		0.79
Cox Bay	COX-0	19	<3	3	0.9
	COX-1	39	<3	2	0.88
	COX-2	79	3	2	0.93
	COX-3	16	<3	3	0.94
	COX-4	119	5	3	0.85
Rosseau/Shadow River	RSH-0	90	<3	2	0.93
	RSH-1	109	46	13	2.99
	RSH-2	16	5	3	1.62
	RSH-3	83	11	3	1.3
Royal Muskoka Island	RMI-1	52	8		1.12
	RMI-2	39	5		1.09
	RMI-3	59	13		1.1
Cleveland's House	CLE-1	62	13		1.37
	CLE-2	16	3		2.25
	CLE-3	8	<3		1.11
Brackenrig Bay	BRA-1	33	13		3.67
	BRA-2	11	8		2.62
	BRA-3	8	3		2.63
Arthurlie Bay	ART-0	5	<3	1	0.82
	ART-1	11	3	4	1.07
	ART-2	25	5	1	1.27
	ART-3	19	8	3	0.89
Indian River	IND-0	52	3	3	0.97
	IND-1	72	11	3	1.15
	IND-2	166	11	4	1.25
	IND-3	1174	263	5	2.79
	IND-4	72	3	5	1.3

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 5			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	3	<3		2.26
	BDY-1	28	11		3.8
	BDY-2	3	<3		2.35
	BDY-3	11	3		2.26
	BDY-4	2424	25		2.15
	BDY-5	13	3		3.33
Beaumaris	BMR-0	25	<3	2	0.91
	BMR-1	30	<3	3	0.97
	BMR-2	161	11	3	0.96
	BMR-3	22	3	7	1.04
East Bay	EAS-0	8	5	3	0.76
	EAS-1	11	3	3	1.05
	EAS-2	11	8	6	0.8
	EAS-3	28	13	31	0.88
Montcalm Point	MON-0	8	<3	3	0.75
	MON-1	19	3	3	1.06
	MON-2	39	3	9	1.04
	MON-3	13	<3	2	0.76
	MON-4	16	<3	16	0.71
Arundel	ARN-1	13	<3		0.83
	ARN-2	8	<3		0.98
	ARN-3	11	<3		1.05
Eilean Gowan	ELG-0	16	<3	3	1.24
	ELG-1	11	<3	3	1.28
	ELG-2	46	<3	16	1.32
	ELG-3	141	<3	3	1.25
Muskoka Sands	MSN-1	2424	16	5	1.72
	MSN-2	388	30	7	2.6
	MSN-3	90	8	4	2.49
Muskoka Bay	MBA-0	30	3	4	1.17
	MBA-1	30	<3	11	5.35
	MBA-2	62	<3	7	1.38
	MBA-3	22	<3	4	1.64
	MBA-4	87	13	4	1.14
	MBA-5	938	11		1.19

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 6			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	<3	<3	<1	0.57
	HMB-1	<3	<3	1	1.01
	HMB-2	28	3	2	0.78
	HMB-3	13	<3	<1	0.9
	HMB-4	<3	<3	<1	0.55
Little Lake Joe	LLJ-1	3	<3		0.73
	LLJ-2	5	<3		0.9
	LLJ-3	5	<3		0.89
Cox Bay	COX-0	11	<3	1	0.77
	COX-1	<3	<3	2	0.97
	COX-2	16	<3	<1	0.82
	COX-3	<3	<3	<1	0.83
	COX-4	8	<3	<1	0.76
Rosseau/Shadow River	RSH-0	5	<3	3	0.83
	RSH-1	8	8	19	3.75
	RSH-2	5	3	3	1.13
	RSH-3	5	<3	2	1.35
Royal Muskoka Island	RMI-1	8	8		0.78
	RMI-2	5	<3		1.03
	RMI-3	<3	<3		1
Cleveland's House	CLE-1	8	<3		1.22
	CLE-2	8	<3		1.64
	CLE-3	<3	<3		1.62
Brackenrig Bay	BRA-1	8	<3		2.23
	BRA-2	13	3		2.23
	BRA-3	109	<3		2.63
Arthurlie Bay	ART-0	<3	<3	2	1.1
	ART-1	3	<3	2	1.08
	ART-2	3	<3	2	1.28
	ART-3	<3	<3	<1	0.87
Indian River	IND-0	28	19	3	1.2
	IND-1	8	5	2	1.06
	IND-2	19	11	5	1.73
	IND-3	39	5	4	1.45
	IND-4	16	3	3	1.38

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 6			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	13	<3		3.25
	BDY-1	5	<3		2.96
	BDY-2	13	<3		2.9
	BDY-3	11	3		3.1
	BDY-4	1696	87		2.47
	BDY-5	22	3		2.87
Beaumaris	BMR-0	28	<3	3	0.85
	BMR-1	36	<3	13	1.05
	BMR-2	119	<3	3	0.94
	BMR-3	30	<3	3	0.99
East Bay	EAS-0	30	<3	4	1.01
	EAS-1	62	3	5	0.89
	EAS-2	16	3	4	0.96
	EAS-3	39	5	4	0.84
Montcalm Point	MON-0	28	<3	4	1.04
	MON-1	36	5	5	1.9
	MON-2	72	<3	4	0.84
	MON-3	36	<3	6	0.83
	MON-4	16	<3	4	0.84
Arundel	ARN-1	43	<3		1.06
	ARN-2	146	<3		0.96
	ARN-3	46	<3		0.95
Eilean Gowan	ELG-0	25	<3	5	0.92
	ELG-1	59	<3	6	1.08
	ELG-2	83	3	7	1.12
	ELG-3	141	3	5	1.62
Muskoka Sands	MSN-1	69	5	6	1.33
	MSN-2	36	11	7	1.05
	MSN-3	16	<3	8	1.23
Muskoka Bay	MBA-0	25	<3	7	0.86
	MBA-1	46	<3	0	2.84
	MBA-2	240	<3	8	0.98
	MBA-3	94	<3	9	1.08
	MBA-4	489	11	8	0.97
	MBA-5	76	<3	8	1

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 7			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	11	<3	0	0.67
	HMB-1	11	<3	2	0.69
	HMB-2	28	5	3	0.88
	HMB-3	5	<3	3	0.86
	HMB-4	5	<3	2	0.73
Little Lake Joe	LLJ-1	5	<3		1.12
	LLJ-2	3	<3		0.98
	LLJ-3	3	<3		1.03
Cox Bay	COX-0	19	<3	2	0.75
	COX-1	3	<3	2	0.97
	COX-2	8	<3	2	0.68
	COX-3	46	3	2	0.87
	COX-4	8	<3	3	0.79
Rosseau/Shadow River	RSH-0	3	<3	3	0.76
	RSH-1	62	19	16	4.05
	RSH-2	16	3	3	1.45
	RSH-3	19	11	3	2.16
Royal Muskoka Island	RMI-1	5	<3		0.88
	RMI-2	3	<3		1.04
	RMI-3	8	<3		1.04
Cleveland's House	CLE-1	<3	<3		10.5
	CLE-2	5	<3		1.82
	CLE-3	8	<3		3.06
Brackenrig Bay	BRA-1	11	<3		2.3
	BRA-2	16	3		3.07
	BRA-3	36	<3		2.25
Arthurlie Bay	ART-0	<3	<3	3	1.28
	ART-1	5	<3	3	1.33
	ART-2	3	<3	2	1.18
	ART-3	11	<3	3	1.55
Indian River	IND-0	16	<3	4	1.51
	IND-1	22	<3	4	1.34
	IND-2	43	5	5	2.18
	IND-3	79	<3	6	1.8
	IND-4	30	3	7	2.11

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 7			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	11	<3		7.7
	BDY-1	36	<3		6.54
	BDY-2	13	<3		7.1
	BDY-3	25	<3		6.87
	BDY-4	109	13		3.95
	BDY-5	19	<3		9.3
Beaumaris	BMR-0	102	<3	4	1.15
	BMR-1	52	<3	3	1.14
	BMR-2	90	<3	9	0.76
	BMR-3	98	3	4	0.79
East Bay	EAS-0	62	<3	4	0.7
	EAS-1	52	<3	3	0.78
	EAS-2	19	<3	9	1.11
	EAS-3	30	<3	3	1.07
Montcalm Point	MON-0	69	<3	4	0.89
	MON-1	55	16	4	1.13
	MON-2	49	<3	4	1.38
	MON-3	69	<3	3	0.89
	MON-4	83	3	3	0.86
Arundel	ARN-1	83	3		0.88
	ARN-2	65	<3		1.24
	ARN-3	79	<3		0.88
Eilean Gowan	ELG-0	69	<3	4	0.87
	ELG-1	22	<3	4	0.81
	ELG-2	39	3	4	1.22
	ELG-3	52	3	4	0.84
Muskoka Sands	MSN-1				
	MSN-2				
	MSN-3				
Muskoka Bay	MBA-0	182	<3	6	0.95
	MBA-1	36	<3	12	4.33
	MBA-2	146	<3	5	0.97
	MBA-3	141	<3	8	0.98
	MBA-4	102	3	6	0.87
	MBA-5	52	<3	7	1.04

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 8			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Hamer Bay	HMB-0	3	<3	1	0.63
	HMB-1	69	3	3	1.35
	HMB-2	13	3	2	1.2
	HMB-3	11	<3	2	0.78
	HMB-4	3	<3	2	0.73
Little Lake Joe	LLJ-1	83	<3		0.75
	LLJ-2	98	<3		0.78
	LLJ-3	43	<3		0.77
Cox Bay	COX-0	59	<3	1	0.9
	COX-1	59	<3	2	0.87
	COX-2	87	<3	2	1.03
	COX-3	106	<3	2	0.87
	COX-4	114	<3	2	0.83
Rosseau/Shadow River	RSH-0	19	<3	4	0.77
	RSH-1	247	46	7	2.28
	RSH-2	119	5	4	2.22
	RSH-3	13	<3	3	1.28
Royal Muskoka Island	RMI-1	28	<3		0.91
	RMI-2	114	3		1.53
	RMI-3	28	3		1.26
Cleveland's House	CLE-1	30	5		1.34
	CLE-2	43	<3		1.32
	CLE-3	22	<3		1.85
Brackenrig Bay	BRA-1	94	<3		2.12
	BRA-2	28	<3		2.65
	BRA-3	90	8		1.73
Arthurlie Bay	ART-0	13	<3	2	0.89
	ART-1	19	3	3	1.62
	ART-2	8	<3	3	1.09
	ART-3	55	11	3	1.38
Indian River	IND-0	206	<3	2	1.1
	IND-1	141	<3	3	1.19
	IND-2	123	3	4	1.35
	IND-3	194	5	7	2.28
	IND-4	166	<3	4	1.53

Table C.1 - 2002 MLA Water Quality Research and Monitoring Programme Data (continued)

Location	Site	Sample 8			
		Total Coliforms	E.Coli	Phosphorus	Turbidity
Brandy Lake	BDY-0	16	<3		25.5
	BDY-1	8	<3		18.25
	BDY-2	25	<3		27.5
	BDY-3	3	<3		25.2
	BDY-4	46	16		15.45
	BDY-5	13	3		25
Beaumaris	BMR-0	52	<3	5	0.87
	BMR-1	72	3	3	0.9
	BMR-2	87	<3	4	0.77
	BMR-3	182	3	6	0.94
East Bay	EAS-0	46	<3	3	0.77
	EAS-1	72	3	3	0.88
	EAS-2	28	<3	7	0.86
	EAS-3	69	5	5	0.94
Montcalm Point	MON-0	109	<3	3	0.8
	MON-1	46	19	4	1.03
	MON-2			11	0
	MON-3	22	<3	2	0.94
	MON-4	36	<3	5	0.96
Arundel	ARN-1	43	<3		0.78
	ARN-2	49	<3		1.02
	ARN-3	46	<3		1.2
Eilean Gowan	ELG-0	39	<3	6	1.07
	ELG-1	22	<3	6	1.1
	ELG-2	59	8	6	1.03
	ELG-3	46	<3	9	1.36
Muskoka Sands	MSN-1	43	<3		1
	MSN-2	52	5		0.83
	MSN-3	62	<3		1.15
Muskoka Bay	MBA-0	151	<3	7	1.09
	MBA-1	76	3	11	2.15
	MBA-2	62	<3	6	1.09
	MBA-3	694	<3	10	1.5
	MBA-4	127	8	7	1.15
	MBA-5	65	<3	8	1.3