Muskoka Lakes Association Water Quality Initiative:

2005 Annual Technical Report

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Executive Summary

2005 marks the fifth year of the Muskoka Lakes Association's long-term commitment on behalf of the community to monitoring, protecting and enhancing the environmental resources of the Muskoka Lakes area. Scientific protocols and analytical procedures used during the 2005 program were developed during the 3-year pilot project and remained unchanged from those used in 2004. Protocols and procedures may evolve in the future if necessary.

Research had two foci in 2005. The first research project focused on the effects of golf course landscapes on nearshore water quality (specifically, total phosphorus concentration). Data collected strongly suggested a difference between nearshore and offshore water quality, with statistical significance being evident at around 35% of sites monitored. This implies that the developed landscape has a significant impact on water quality. We recommend the golf course landscape study be continued in 2006, and expanded in scope to include: (1) a thorough literature review of best environmental management practices for golf course operators; and (2) the collection of fertilizer and pesticide application schedules, rainfall statistics and local hydrologic information. This information can then form the basis of a more thorough study of the effects of golf course landscapes on nearshore water quality.

The second research project compared offshore total phosphorus concentration measurements collected by the District Municipality of Muskoka to those collected by the Muskoka Lakes Association. The best conversion formula relating the data collected by the two groups has been calculated in Section 4.2.2 as:

$$[TP_{so}] = 0.67\ [TP_{epi}] + 2.77$$

This conversion formula is based on a small amount of data, and therefore should continually be updated and calibrated in the coming years, in order to best integrate Muskoka Lakes Association total epilimnetic phosphorus concentration ($[TP_{epi}]$) data with District Municipality of Muskoka total spring turnover phosphorus concentration ($[TP_{so}]$) data and with the District of Muskoka's Lake System Health Program and Muskoka Water Quality Model.

Three new partner associations (the Clear Lake Association, the Bass Lake Association and the Moon River Property Owners' Association) were added to the program in 2005. Monitoring efforts grew to 152 sites monitored by over 80 volunteers. Results of the monitoring program are once again available online at http://www.mla.on.ca.

Several recommendations are made for consideration in 2006 including a continuation and expansion of the public education campaign associated with the water quality initiative to include several workshops around the Muskoka area, embracing the Muskoka Watershed Council's protocol for benthic community monitoring and the use of volunteers to analyze bacteria samples. More consultant and coordinator time should be devoted to advancing the program's long-term goals, workshops and volunteer training.

Overall, the 2005 monitoring season was successful as the database of water quality statistics grew, the community was effectively engaged in the analysis and understanding of the results, and significant advances in research were realized. The MLA should build on these successes in order to involve a wider community in the initiative, further develop knowledge based on the scientific research, and support, promote and facilitate responsible environmental stewardship in 2006.

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1.0 Introduction

The Muskoka Lakes Association (MLA) is a non-profit organization that represents the interests of lakefront residents in the Muskoka Lakes area of Central Ontario. While the MLA has always recognized the urgency of protecting and enhancing the local environment, a formal scientifically-based ecological monitoring and lake water quality research program was introduced in 2001. The pilot water quality initiative spanned the 2001 to 2003 seasons and was overseen by Dr. Neil Hutchinson of Gartner Lee Ltd. The 2005 program represents the second year of ongoing commitment by the MLA Board of Directors to the initiative; a response to the program's scientific and social significance.

In 2004, the initiative matured into a sustainable monitoring and research program that is both financially and logistically feasible as long as MLA members are interested in its continuation. For 2005, the program remained funded entirely by MLA internal revenue streams and continues to be successful because of the hard work of MLA volunteers. Lura Consulting, a firm specializing in community engagement and collaborative processes, provided strategic advice to the MLA on the initiative's design, implementation and ongoing monitoring. Mike Logan, of Lura has been involved in the initiative since 2002, and served as the 2005 program advisor and was responsible for the coordination of day-to-day operations.

The 3-year pilot project established that there are two main functions of the MLA's Water Quality Initiative: monitoring and research. These functions reflect how the results of the program are reported and used; they do not substantially affect data collection or project cost. The scientific details of the 2005 program and the results of the research function of the program are presented here.

1.1 Monitoring Function Report

For simplicity and data access considerations, the detailed results of the monitoring function of the MLA program have been published online. This allows the average reader to easily access the specific results they are most interested in, without having to review all the technical information produced for all data collection sites. These online results can be viewed at the MLA's website (http://www.mla.on.ca), where easy-to-read instructions and a tutorial for accessing the data are also published. MLA members can also obtain a copy of the *Summary Report of 2005 Monitoring Program including instructions for accessing data via the Internet* from the MLA office in Port Carling. This report should be widely distributed among MLA members.

2.0 Background

With over 250,000 lakes in Ontario (Globe and Mail, 2004), provincial and local government resources are insufficient to protect and thoroughly monitor the state of all of Ontario's aquatic ecosystems. The traditional approach to planning for lakeside development in Ontario is embodied in mathematical models that simplify the process. The models equate lake health with total phosphorus concentration, and predict phosphorus concentration in each lake based on empirical observation and development records around the lake. These models were developed in part by the District of Muskoka (DMM), and to keep them appropriately calibrated, DMM monitors spring turnover total phosphorus concentration ([TP_{so}]) in approximately 150 lakes within the district on a rotational basis (Planning and Economic Development Department, 2003). While this rational approach has been generally successful in predicting lakeshore capacity and limiting development (and in fact has been made more accurate by the latest iteration of the Lake System Health Program released in 2005), it inevitably cannot provide a "correct" solution to the management of sustainable landscape change. Environmental planning and resource management must instead be responsive to public opinion while integrating dynamic scientific knowledge (Logan, 2003).

The provincial Ministry of the Environment (MOE) also monitors lakes in several ways. The Lake Partner Program is an attempt to engage the public in the collection of scientific information and therefore in environmental management. The goal of this program is to “protect the quality of Ontario's inland lakes by involving citizens in a volunteer-based water quality monitoring program” (MOE, 2004). Volunteers involved in this program collect [TP_{so}] samples and make monthly water clarity observations on their lakes. This information is intended to facilitate the “early detection of changes in the nutrient status of the lake due to the impacts of shoreline development, climate change and other stresses.” (MOE, 2004) Two of the main limitations of the Lake Partner Program are samples are collected infrequently (thus requiring several years’ data to be scientifically valid) and volunteers mail the samples into a central analysis location (while the usefulness of volunteer efforts to the MOE is apparent, meaningful engagement of the public and human capacity-building in protecting and enhancing the local environment is somewhat less obvious, as all information transfer is unidirectional).

Responding to MLA member interest, the Association began to thoroughly and systematically study water quality in both the offshore and nearshore zones in 2001. Since then, the initiative has grown spatially (even to include several lakes outside of the MLA’s traditional scope of interest) and evolved into a marquis program of the MLA.

2.1 Long-term Objectives

The long-term objectives originally set out by Gartner Lee Ltd.’s (GLL) *Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau* are as follows (GLL, 2001):

a) **Review of existing information** on water quality in Lakes Muskoka, Joseph and Rosseau
b) **An opinion on the water quality stresses of most significance** to the Muskoka Lakes and the MLA and rationale for that opinion, with particular emphasis on acid rain, nutrient enrichment and bacterial contamination
c) **Development of a research and monitoring program** to document conditions of nutrient runoff, bacterial contamination and algal growth in the near-shore waters as they are influenced by bottom substrate, development density and shoreline vegetation
d) **Liaison with other management initiatives** (District of Muskoka, MOE, non-governmental organizations (NGOs))
e) **Advise on future stewardship initiatives** for the MLA.

As the water quality initiative matures and evolves from year to year new objectives have been and will be identified. In addition to the original objectives outlined above, the 2004 Annual Report identified additional long-term goals:

f) Build on community relationships and **work more closely with the Muskoka Watershed Council** to adopt protocols that are already used for various water quality indicators
g) Continue and formalize the **public education campaign and workshops** that have been ongoing since 2002
h) Attain **external funding** for the program, now that the initiative has a positive track record
i) Support the Muskoka Watershed Council's **benthic monitoring program** by promoting the protocol to volunteers and the MLA membership
j) **Build human-capacity** by utilizing volunteers to analyze bacteria samples using ColiPlates and incubators
k) Designate an external consultant as the **manager of the water quality initiative** in order to lessen the burden on office staff and volunteers
l) **Build relationships** with other residents' groups and associations in the vicinity of the Muskoka Lakes.

2.2 Technical Objectives

Several technical recommendations that will develop the scientific reputation of the initiative were also identified in 2004:

a) Focus total phosphorus research on areas adjacent to golf course or resort development
b) Include offshore sites representative of the whole lake. These sites should coincide with District Municipality of Muskoka sampling sites, but follow protocols established by the MLA
c) Compare bacteria duplicate variability with data from the Simcoe-Muskoka District Health Unit's public beaches monitoring program to determine natural ranges of within-site bacterial variability. If possible, replicate Health Unit monitoring and compare CoilPlate results with laboratory results
d) Produce a co-ordinator's manual in order to ease the transition between program co-ordinators

2.3 Achievements

Over the past three years all of the initial long-term objectives (A through E) have been achieved. Objectives A and B were accomplished in the inaugural year (2001) and are detailed in Gartner Lee Limited, 2001. Objectives C, D, and E were the focus of the 2002 and 2003 seasons and once again are detailed in Hutchinson, 2003 and Logan, 2004. Significant achievements in new partnerships have also been made in 2005.

2.3.1 Partnerships

Community groups on lakes in the vicinity of Lakes Muskoka, Joseph, and Rosseau have been very interested in the MLA's water quality initiative and the credibility that potential partnerships with the MLA could provide to their own water quality monitoring efforts. Three additional community groups joined the MLA on the water quality initiative for the 2005 season: the Bass Lake Association (Foot's Bay), the Clear Lake Association (Torrence) and the Moon River Property Owners' Association (Bala) all initiated monitoring programs on their water bodies. The Sucker Lake Association, although interested, did not participate in the initiative due to financial constraints. As a result the MLA had a total of nine community groups in partnership with the MLA's Water Quality Initiative for the 2005 season:

- Bass Lake Association
- Brandy Lake Association
- Clear Lake Association
- Friends of Long Lake
- Gull and Silver Lakes Residents' Association (Gravenhurst)
- Moon River Property Owners' Association
- North Lake Joseph Association
- Silver Lake Association (Township of Muskoka Lakes)
- South Muskoka Lake Community Association

Local media coverage, scientific credibility of the initiative, and a presentation on the initiative as part of the Muskoka Lakes Museum's autumn lecture series has sparked interest from community groups near Lakes Muskoka, Joseph and Rosseau. Four more local community groups, including : the Black Lake Association (Torrence), the Skeleton Lake Association (Rosseau), Three Mile Lake Association (Windermere) and the Clear Lake Association (Parry Sound) have expressed interest in becoming involved with the initiative in 2006. The North Lake Joseph Association has also expressed interest in expanding the monitoring program in the vicinity of North Lake Joseph to include Portage Lake. The MLA should begin now to develop relationships with the executive of each of these associations to facilitate early involvement of these organizations in the 2006 water quality initiative.

Substantial effort has been made by the MLA and MLA's legal counsel over the summer of 2005 to legally formalize the relationship of the MLA to these other associations. Legal arrangements include the ownership of data collected, and protection against liability associated with the initiative. Serious implications associated with the sharing of data also necessitated the creation of a detailed disclaimer for use on the MLA website, protecting the MLA and other involved associations from misuse of the shared data by any third party.

2.4 Future Considerations

Progress on many of the long-term goals such as developing working relationships with the Muskoka Watershed Council, the development of workshops, the acquisition of external funding and supporting the Watershed Council's benthic monitoring program, has been slow. In order to make significant progress in these areas, more resources will need to be devoted to them. It is recommended that more consultant time be designated to these objectives, and less to the day-to-day management of the program. Day-to-day tasks (including distribution of sampling kits, picking up samples at drop-off locations etc.) might be designated to part time staff hired by the advising consultant, to be selected from the pool of MLA part-time staff (e.g. MLA Marine Patrol or summer office support).

3.0 Methods

3.1 Volunteers

During the 2005 season over 80 volunteers participated in the water quality initiative. The volunteers were divided into 30 teams that sampled at specific areas across 17 lakes and rivers in Muskoka. Each team consisted of between 1 and 9 volunteers. The large number of volunteers working on the initiative this year increased the number of individuals per team and provided more flexibility and reliability which in turn ensured that the required sampling was completed on each sampling day. Below is a list of the 30 teams responsible for sampling 152 sites every two weeks:

Lake Joseph

Hamer Bay	*Cox Bay*	*Joseph River*
Terry Johnson	Gord Ross	Heather Wilson Irons
Sean Sutton	Fred Morrison	
	Marion Riach	

Little Lake Joseph
Dirk Soutendijk
Mark Johnstone

Foot's Bay
John Maas
Morag Fitzgerald

Stanley Bay
Bob Hunter
Fred Sims
Mary Sims

Gordon Bay
Tony Taylor

Lake Rosseau

Rosseau/Shadow River
Linda White
Christie White
Lorie White
Steve White

Windermere
John Duncan
Bev Manchee
Stephen Duncan
Charles Simmonds
Morgan Simmonds

Minnett
Bill Boughner
Keith Shantz

Royal Muskoka Island
Doug Applegath
John Curran

Indian River
Bill Jennings

Brackenrig Bay
Ian Wallace

Lake Muskoka

North Bay
Doug Wilson
David Barker

Bala
Bill Sloan
Len Wait
Arch Nordstrum
Ian Baker

Muskoka River
John Wood

Beaumaris
Louise Cragg
Chris Cragg
Mimi DeGruy

East Bay
Ron Manto

Eilean Gowan Island
Doug Turner
Sandy Turner
John Carr

Walker's Point
Mary Wiley
Peter Wiley
Alex Tilley

Muskoka Sands
Anne Stanway
Al Ward

Willow Beach
Liz Denyar

Muskoka Bay
Brian Yeates
Diane Yeates
John Soutar
Doug McKenzie
Stu Wilson

Affiliate Associations

Bass Lake
Jon Sykes
Joanna Davey

Gull & Silver
Jim Davis
Gord Lee

Brandy Lake
Jim Cormack
Jerry Fisher

Silver Lake (Port Carling)
Perry Bowker
Doug Lisso

Long Lake
Cheryl Watt
Bob Watt
Ellen Edwards

Moon River
Patricia Arney
Carol Ball
Doug Ball
Brian McDonald
Marion McDonald
Sherri Hopkins
Steve Burdick
Anna Mallin
Peter Hemming

Clear Lake
John Frame
Keith Villamere

3.2 Sites

Sampling sites were originally chosen to focus on specific land uses in 2002. Sites have been added each year since 2002. In some cases, specific sites have not been selected for sampling in some years due to either a change in the focus of research, or a lack of significant bacteria results. Each site, including maps and photos, is documented along with its related results in the database displayed on the MLA website (http://www.mla.on.ca).

Total phosphorus concentration sites for the research program are typically selected first. Given the research focus (e.g. golf course developments in 2005), nearshore sites are selected in the vicinity of the land use that research is focusing on. Sites will be selected in order to capture the effects of the land use on the nearshore water quality (e.g. overland runoff). In these cases, sites are grouped in such a way as to compare an offshore measurement (considered to be the control) with multiple nearshore measurements. A statistical comparison of the results comprises the analysis of the research function.

Bacteria monitoring sites are also selected. In these cases, sites are identified in heavily used bays and inlets because a) bacteria is usually highest in heavily-used areas and b) bacteria is of most concern in heavily used areas. Bacteria count results therefore give a conservative estimate of the average bacteria level in an area, since sites are placed where bacteria levels are estimated to be highest.

In 2005, the measurement of total phosphorus concentration ([TP]) at nearshore sites in residential areas was discontinued in accordance with the recommendation put forward in the 2004 Annual Report (Logan, 2004). This was due to the conclusion that most often, nearshore [TP] is not significantly different than deep water [TP] in residential areas. This means that the MLA program can sufficiently monitor [TP] in residential areas by simply taking samples offshore. To minimize program costs, monitoring of bacteria at most offshore sites was discontinued given that bacteria have been shown to be typically lowest in the deep water. Bacteria monitoring was maintained at the nearshore sites as most recreational interaction with the water occurs in this area.

Eleven additional phosphorus monitoring sites were added in nearshore areas adjacent to golf course developments (e.g. Beaumaris and Minett). A comparison of the results from these nearshore sites and their corresponding offshore site will form the basis of the research results of the program, as detailed in Section 4.2.

As previously mentioned, the monitoring program expanded as recommended (Logan, 2004) to include 152 sites (an increase from 136 in 2004). These sites were monitored biweekly throughout the summer (23 May 2005 to 5 September 2005). All sites were analysed for temperature and turbidity and 118 sites were analysed for bacterial contamination. Total phosphorus was measured at 71 sites.

As in previous years, the sites were divided into two groups to facilitate the load of sample analysis and volunteer management. Approximately half of the sites (the northern-most sites) were sampled on one week, and the other half (the southern-most sites) were sampled the following week. Table 3.1 shows when each sample was taken. Table 3.2 shows which parameters were analysed for each site, and lists the targeted land use (or control) for each site.

Table 3.1 - Sampling Groups

Sample Number	Group 1	Group 2
	Lake Joseph, Lake Rosseau, Brandy Lake	Lake Muskoka, Long Lake, Gull & Silver Lakes, Bass Lake, Muskoka River, Moon River, Clear Lake, Silver Lake
1	May 23, 2005	May 30, 2005
2	June 6, 2005	June 13, 2005
3	June 20, 2005	June 27, 2005
4	July 4, 2005	July 11, 2005
5	July 18, 2005	July 25, 2005
6	August 1, 2005	August 8, 2005
7	August 15, 2005	August 22, 2005
8	August 29, 2005	September 5, 2005

Table 3.2 - Monitoring program sites (▲ indicates measurement of parameter)

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Bala Bay (Lake Muskoka)	BAL-0	Offshore		▲	▲	▲
	BAL-1	Residential	▲		▲	▲
	BAL-2	Town Site	▲		▲	▲
	BAL-3	Residential	▲		▲	▲
	BAL-4	Residential	▲		▲	▲
	BAL-5	Residential	▲		▲	▲
	BAL-6	Residential	▲		▲	▲
Bass Lake	BAS-0	Offshore		▲	▲	▲
	BAS-1	Residential		▲	▲	▲
	BAS-2	Residential	▲		▲	▲
	BAS-3	Residential	▲		▲	▲
Brandy Lake	BDY-0	Offshore	▲	▲	▲	▲
	BDY-1	Wetland	▲		▲	▲
	BDY-2	Residential	▲		▲	▲
	BDY-3	Residential	▲		▲	▲
	BDY-5	Residential	▲		▲	▲

Table 3.2 - Monitoring program sites (▲ indicates measurement of parameter) (continued)

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Beaumaris	BMR-0	Offshore		▲	▲	▲
(Lake Muskoka)	BMR-2	Golf Course (BYC)	▲	▲	▲	▲
	BMR-3	Town (Beaumaris)	▲		▲	▲
	BMR-4	Golf Course (BYC)	▲	▲	▲	▲
	BMR-5	Golf Course (BYC)	▲	▲	▲	▲
	BMR-6	Golf Course (BYC)	▲	▲	▲	▲
Brackenrig Bay	BRA-0	Offshore		▲	▲	▲
(Lake Rosseau)	BRA-1	Residential	▲		▲	▲
	BRA-2	Residential	▲		▲	▲
	BRA-3	Residential	▲		▲	▲
Clear Lake	CLR-1	Residential	▲		▲	▲
	CLR-2	Residential	▲		▲	▲
	CLR-3	Residential	▲		▲	▲
Cox Bay	COX-0	Offshore		▲	▲	▲
(Lake Joseph)	COX-1	Golf Course (Lake Joe)	▲	▲	▲	▲
	COX-2	Golf Course (Lake Joe)	▲	▲	▲	▲
	COX-3	Town (Port Sandfield)	▲	▲	▲	▲
	COX-4	Resort (Pinelands)	▲	▲	▲	▲
East Bay	EAS-0	Offshore		▲	▲	▲
(Lake Muskoka)	EAS-1	Undeveloped	▲	▲	▲	▲
	EAS-2	Undeveloped	▲	▲	▲	▲
	EAS-3	Undeveloped	▲	▲	▲	▲
Eilean Gowan	ELG-0	Offshore		▲	▲	▲
(Lake Muskoka)	ELG-1	Residential	▲		▲	▲
	ELG-2	Residential	▲		▲	▲
	ELG-3	Residential	▲		▲	▲
Foot's Bay	FTB-3	Offshore	▲		▲	▲
(Lake Joseph)	STI-0	Offshore		▲	▲	▲
	STI-2	Golf Course (Still's Bay)	▲	▲	▲	▲
Gordon Bay	GNB-0	Offshore		▲	▲	▲
(Lake Joseph)	GNB-1	Marina/Highway	▲		▲	▲
	GNB-2	Residential	▲		▲	▲
	GNB-3	Residential	▲		▲	▲
	GNB-4	Residential	▲		▲	▲
Gull Lake	GUL-0	Offshore	▲	▲	▲	▲
	GUL-1	Hoc Roc	▲		▲	▲
	GUL-2	Residential	▲		▲	▲
	GUL-3	Residential	▲		▲	▲
	GUL-4	Park	▲		▲	▲
Hamer Bay	HMB-0	Offshore		▲	▲	▲
(Lake Joseph)	HMB-1	Golf Course (Rocky Crest)	▲	▲	▲	▲
	HMB-2	Resort (Rocky Crest)	▲	▲	▲	▲
	HMB-3	Resort (Rocky Crest)	▲	▲	▲	▲
	HMB-4	Residential	▲	▲	▲	▲
Indian River	IND-0	Offshore		▲	▲	▲
	IND-2	Town (Port Carling)	▲		▲	▲
	IND-3	Trailer Park	▲	▲	▲	▲
	IND-5	Residential	▲		▲	▲
	IND-6	Residential	▲		▲	▲

Table 3.2 - Monitoring program sites (▲ indicates measurement of parameter) (continued)

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Joseph River	JOR-0	Offshore		▲	▲	▲
	JOR-1	Residential	▲		▲	▲
	JOR-2	Residential	▲		▲	▲
	JOR-3	Residential	▲		▲	▲
	JOR-4	Residential	▲		▲	▲
Little Lake Joseph	LLJ-0	Offshore		▲	▲	▲
	LLJ-1	Residential	▲		▲	▲
	LLJ-2	Residential	▲		▲	▲
	LLJ-3	Residential	▲		▲	▲
Long Lake	LOL-0	Offshore		▲	▲	▲
	LOL-1	Residential	▲		▲	▲
	LOL-2	Residential	▲		▲	▲
	LOL-3	Residential	▲		▲	▲
	LOL-4	Residential	▲		▲	▲
	LOL-5	Residential	▲		▲	▲
Mid Lake Joseph	JOS-1	Deep Water		▲		
Mid Lake Muskoka	MUS-1	Deep Water		▲		
	MUS-2	Deep Water		▲		
	MUS-3	Deep Water		▲		
Mid Lake Rosseau	ROS-1	Deep Water		▲		
	ROS-2	Deep Water		▲		
	ROS-3	Deep Water		▲		
Minett (Lake Rosseau)	MIN-0	Offshore		▲	▲	▲
	MIN-1	Resort (Cleveland's House)	▲	▲	▲	▲
	MIN-2	Resort (Cleveland's House)		▲	▲	▲
	MIN-4	Golf Course (The Rock)	▲	▲	▲	▲
	MIN-5	Golf Course (The Rock)		▲	▲	▲
Moon River	MOO-1	Lake Muskoka	▲	▲	▲	▲
	MOO-2	Bala STP Outfall	▲	▲	▲	▲
	MOO-3	Residential	▲		▲	▲
	MOO-4	Residential	▲		▲	▲
	MOO-5	Residential	▲		▲	▲
	MOO-6	Residential	▲		▲	▲
	MOO-7	Camping	▲		▲	▲
Muskoka Bay (Lake Muskoka)	MBA-0	Offshore		▲	▲	▲
	MBA-3	Residential	▲		▲	▲
	MBA-4	Town (Gravenhurst)	▲		▲	▲
	MBA-5	Town (Gravenhurst)	▲		▲	▲
	MBA-6	Residential	▲		▲	▲
Muskoka River	MRV-1	Mouth	▲		▲	▲
	MRV-2	Santa's Village	▲		▲	▲
	MRV-3	South Branch	▲		▲	▲
	MRV-4	North Branch	▲	▲	▲	▲
Muskoka Sands (Lake Muskoka)	MSN-0	Offshore	▲	▲	▲	▲
	MSN-1	Resort (Muskoka Sands)	▲	▲	▲	▲
	MSN-2	Golf Course (Taboo)	▲	▲	▲	▲
	MSN-3	Residential	▲		▲	▲
	MSN-4	Golf Course (Taboo)	▲	▲	▲	▲

Table 3.2 - Monitoring program sites (▲ indicates measurement of parameter) (continued)

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
North Bay (Lake Muskoka)	NRT-0	Offshore		▲	▲	▲
	NRT-1	Residential	▲		▲	▲
	NRT-2	Transfer Station	▲		▲	▲
	NRT-3	Transfer Station	▲		▲	▲
Royal Muskoka Island (Lake Rosseau)	RMI-0	Offshore		▲	▲	▲
	RMI-1	Residential	▲		▲	▲
	RMI-4	Residential	▲		▲	▲
	RMI-5	Residential	▲		▲	▲
Rosseau/Shadow River (Lake Rosseau)	RSH-0	Offshore		▲	▲	▲
	RSH-1	Wetland	▲		▲	▲
	RSH-2	Wetland	▲		▲	▲
	RSH-3	Town (Rosseau)	▲		▲	▲
	RSH-4	Town (Rosseau)	▲		▲	▲
	RSH-5	Camp (Muskoka Woods)	▲		▲	▲
Silver Lake (Gravenhurst)	SVR-0	Offshore	▲	▲	▲	▲
	SVR-1	Residential	▲		▲	▲
	SVR-2	Jevins Lake	▲		▲	▲
Silver Lake (Muskoka Lakes)	SPC-0	Offshore	▲	▲	▲	▲
	SPC-1	Residential	▲		▲	▲
	SPC-2	Residential	▲		▲	▲
	SPC-3	Residential	▲		▲	▲
Stanley Bay (Lake Joseph)	STN-0	Offshore		▲	▲	▲
	STN-1	Residential	▲		▲	▲
	STN-2	Residential	▲		▲	▲
	STN-3	Residential	▲		▲	▲
Walker's Point (Lake Muskoka)	WAK-0	Offshore		▲	▲	▲
	WAK-1	Residential	▲	▲	▲	▲
	WAK-2	Residential	▲	▲	▲	▲
	WAK-3	Residential	▲		▲	▲
	WAK-4	Residential	▲		▲	▲
Windermere (Lake Rosseau)	WIN-0	Offshore		▲	▲	▲
	WIN-1	Dee River	▲		▲	▲
	WIN-2	Residential	▲	▲	▲	▲
	WIN-3	Golf Course (Windermere)	▲	▲	▲	▲
	WIN-4	Resort (Windermere House)	▲	▲	▲	▲
Willow Beach (Lake Muskoka)	WLB-0	Offshore		▲	▲	▲
	WLB-1	Resort	▲	▲	▲	▲
	WLB-2	Resort	▲	▲	▲	▲
	WLB-3	Golf Course (Kirie Glen)	▲	▲	▲	▲

3.3 Phosphorus

Total phosphorus concentration ([TP]) was measured at sites indicated in Table 3.2. Digest tubes were filled directly from surface water and analyzed by the

Trent University Environmental Science Centre in Dorset as described in Section 3.7 of the 2002 Annual Report (Hutchinson, 2003).

3.4 Total Coliform

Bacteria samples were collected and analyzed at each site as noted in Table 3.2. Protocols have remained unchanged since 2002 (Hutchinson, 2003; Logan, 2004), including the use of ColiPlate technology to internally determine both total coliform and *E.Coli* levels. The detection limits of the ColiPlates was handled by assigning all readings of “less than three” counts of coliform/100mL sample as an absolute value of 1 count/100mL. This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

3.5 Escherichia Coli

Sampling and analytical procedure for *Escherichia coli (E.Coli)* remained unchanged from 2002 and 2003. A detailed explanation of protocols is found in the 2002 Annual Report (Hutchinson, 2003). Readings of “less than three” counts *E.Coli*/100mL are recorded as 1 count/100mL, again as a conservative estimate.

3.6 Turbidity

Sampling and analytical procedure for turbidity remained unchanged from 2004. Water from bacteria sampling bottles, or water collected separately for sites where bacteria was not analyzed, was measured for turbidity using a HACH 2100P turbidimeter. A more detailed explanation of protocols is found in Section 3.6 of the 2004 Annual Report (Logan, 2004).

3.7 Temperature

The sampling and analytical procedure for temperature remained unchanged from 2004. Volunteers hung a pool thermometer into the water, near the surface of the lake from their boat while they performed the other sampling protocols, and read the temperature when they were finished (as explained in Section 3.7 of the 2004 Annual Report (Logan, 2004)).

3.8 Duplicates and Blanks

Sound scientific procedures give the knowledge generated by the MLA water quality initiative its credibility. This credibility is particularly important since the program is volunteer-based. As in 2002, 2003 and 2004, random duplicate measures and blank samples were used throughout the 2005 season. Sampling protocols are detailed in the 2002 Annual Report (Hutchinson, 2003). Five percent of phosphorus samples were duplicated and analyzed by Trent University, five percent of bacteria samples were duplicated and analyzed internally and a further five percent of bacteria samples were duplicated and analyzed by a laboratory accredited by the Ontario government (Central Ontario Analytical Laboratory). Field blank measurements using commercially available purified drinking water were also taken alongside of five percent of bacteria samples and analyzed for bacterial contamination internally. Turbidity was measured for all of the duplicate and field blank samples analyzed internally.

4.0 Results

The two functions of the MLA water quality initiative – research and monitoring – have been well-defined over the past three sampling seasons. The following results focus on the results of the research program as well as the quality control and quality assurance measures necessary to ensure scientific credibility. A summary of the monitoring results and instructions for using the interactive online database that displays all monitoring results is available separately in the *Summary Report of 2005 Monitoring Program*.

4.1 Duplicates and Blanks

No scientific program of study can claim to use or produce information that is absolutely 'correct.' Instead, scientific information helps people to understand how the physical environment works (in this case, how the lake ecosystem works) by collecting information through procedures that can be replicated. When analyzed and shared appropriately, this information is transformed into knowledge that helps people interact with their physical environment (Logan, 2003). There is usually great variability in information, especially when environmental parameters are being measured in the field. Nevertheless, it is the goal of programs like the MLA's to reduce environmental variables as much as possible in order to create knowledge through scientific procedures that are both scientifically sound and replicable.

Using volunteers who are not professionally trained in field protocol nor who receive any sort of compensation for efforts further complicates a scientific research program. Volunteers may not understand or bother to follow all protocols thus increasing variability in information collected. For this reason, quality control and quality assurance protocols that aim to identify procedural error is of utmost importance in the MLA program.

4.1.1 Bacteria Blanks

Bacteria blanks are important to the MLA's water quality initiative as they provide an indication of bacteriological contamination in the samples. Possible sources of contamination include improper sterilization of collection bottles, the breaking of seals on the bottles after sterilization and contamination of the samples by volunteers. New bottle caps were used throughout the 2005 season, thus eliminating a suspected source of contamination identified in both 2003 and 2004.

Table 4.1 - Blank sample results

Site	Sample Number	EC Blank	TC Blank	Turb Blank	Sampler
BAS-2	1	1	1	0.19	
BMR-4	2	1	1	0.32	Cragg
BRA-1	2	1	8	0.46	Wallace
COX-4	2	1	1	0.43	Ross
EAS-3	2	1	1	0.61	Manto
ELG-3	2	1	1	0.55	D.Turner
MOO-3	2	1	1	0.61	Burdick
WAK-4	2	1	1	0.26	P.Wiley
FTB-3	3	3	79	1.32	Maas
GNB-1	3	16	90	1.09	Taylor
HMB-1	3	1	49	0.66	Sutton
RSH-1	3	1	1	0.36	E.Logan
STN-1	3	1	1	0.33	F. Sims
BAL-2	4	1	1	0.18	Sloan
BDY-1	4	1	1	0.21	Fisher
EAS-1	4	1	1	0.24	
LOL-1	4	1	1		Watt
MBA-3	4	1	1	0.17	
MOO-6	4	1	1	0.1	Ball
MRV-1	5	1	1	0.16	Wood
NRT-1	5	1	1	0.21	Barker
COX-2	6	1	1	0.17	Ross
IND-6	6	5	247	1	Jennings
LLJ-3	6	1	1	0.15	Johnstone
MOO-4	6	1	1	0.17	Hopkins
NRT-2	6	1	1	0.16	Barker
SPC-1	6	1	22	1.08	Lisso
SVR-1	6	1	3	0.15	Lee
WIN-2	6	1	11	0.22	Duncan
WLB-1	6	1	1	0.38	Denyar
CLR-3	7	1	1	0.28	Frame
LOL-4	7	1	1	0.2	Watt
RSH-3	7	1	1	0.22	C.White
WIN-3	7	1	1	0.32	Duncan
COX-1	8	1	1	0.2	M.Riach
EAS-1	8	1	1		Manto
ELG-2	8	1	1	0.32	Carr
GNB-3	8	1	1	0.25	Taylor
GUL-2	8	1	5	0.23	Lee
HMB-2	8	1	1	0.39	Sutton
MIN-4	8	1	1	0.34	E.Logan
MOO-5	8	1	1	0.17	D.Ball
RSH-2	8	1	1	0.53	S.White
STI-2	8	1	21	0.61	Maas

Table 4.1 shows the results of blanks (readings of total coliform, *E.Coli* and turbidity), sorted by sampling date. Note that as previously mentioned all samples analyzed using the ColiPlate technology and recorded as being contaminated with 1 bacteria count/100mL actually had a result of <3 bacteria counts/100mL (the detection limit of the technology). A reading of one count therefore does not necessarily represent contamination in the blank sample, but is a conservative estimate of an uncontaminated reading. Ten of 44 blanks samples (22.7%) therefore showed contamination. This level of contamination is much higher than in previous years.

Since "blank" samples should be uniform in properties to a reasonable extent (all "blank" water tested was commercially available Aquafina bottled drinking water), turbidity should be similar with a narrow range of variability. Varying turbidity would most likely suggest either a problem with the turbidimeter or water other than the designated "blank" sample being present.

The results show that four of the samples had a turbidity that exceeded twice the standard deviation above the average of all readings (highlighted in red). All four of these blank samples also showed bacteriological contamination. These two observations suggest that it is likely these samples actually contained lake water rather than previously treated "blank" water. Since 10% of all blank samples likely contained lake water, volunteer training should be conducted more carefully in future years. It would also be helpful for a method of reminding the volunteers about blank protocols be developed for delivery when their turn to take a blank sample occurs.

Removing the four lake water samples from the blank analysis shows that six of 40 samples (15%) were contaminated (highlighted in yellow). While this does not indicate systematic contamination, it does suggest that there could be contamination from any of the aforementioned sources, namely improper sterilization of collection bottles, the breaking of seals on the bottles after sterilization and contamination of the samples by volunteers. In the future, greater attention should be paid to proper sterilization and volunteer training.

4.1.2 Bacteria ColiPlate Duplicates

Five percent of bacteria samples were duplicated and analysed with ColiPlates as described in Section 3.9. Figure 4.1 shows the results of a comparison between duplicate total coliform measures. An r^2 value of 0.8647 suggests a lower accuracy in duplicates than in 2004. This is due to the fact that total coliform readings were higher in 2005 than in previous years (as described in the Summary Report (Lura, 2005)). As values get larger, the ColiPlate technology uses a rougher (and more conservative) estimate of bacteria counts. That is, each blue dot represents more organisms. This rougher estimate means that replicability is lost. However, the graph suggests that ColiPlates still report total coliform contamination accurately, with an adequate consistency and without bias.

Total coliform data for all duplicated samples analysed internally using ColiPlates are shown in Table A.1 in Appendix A. There are five duplicates that were not graphed as their results were outside of the ColiPlate's detection limit (as total coliform levels in general were quite high).

Similarly, E.Coli duplicate results are shown in Figure 4.2, and listed in Table A.2 in Appendix A. The variability seen in the duplicate measurements is due to the clustered nature of bacteria, and the effect of the extreme low end of the ColiPlate detection limit (the graph of small numbers accentuates the differences between close readings).

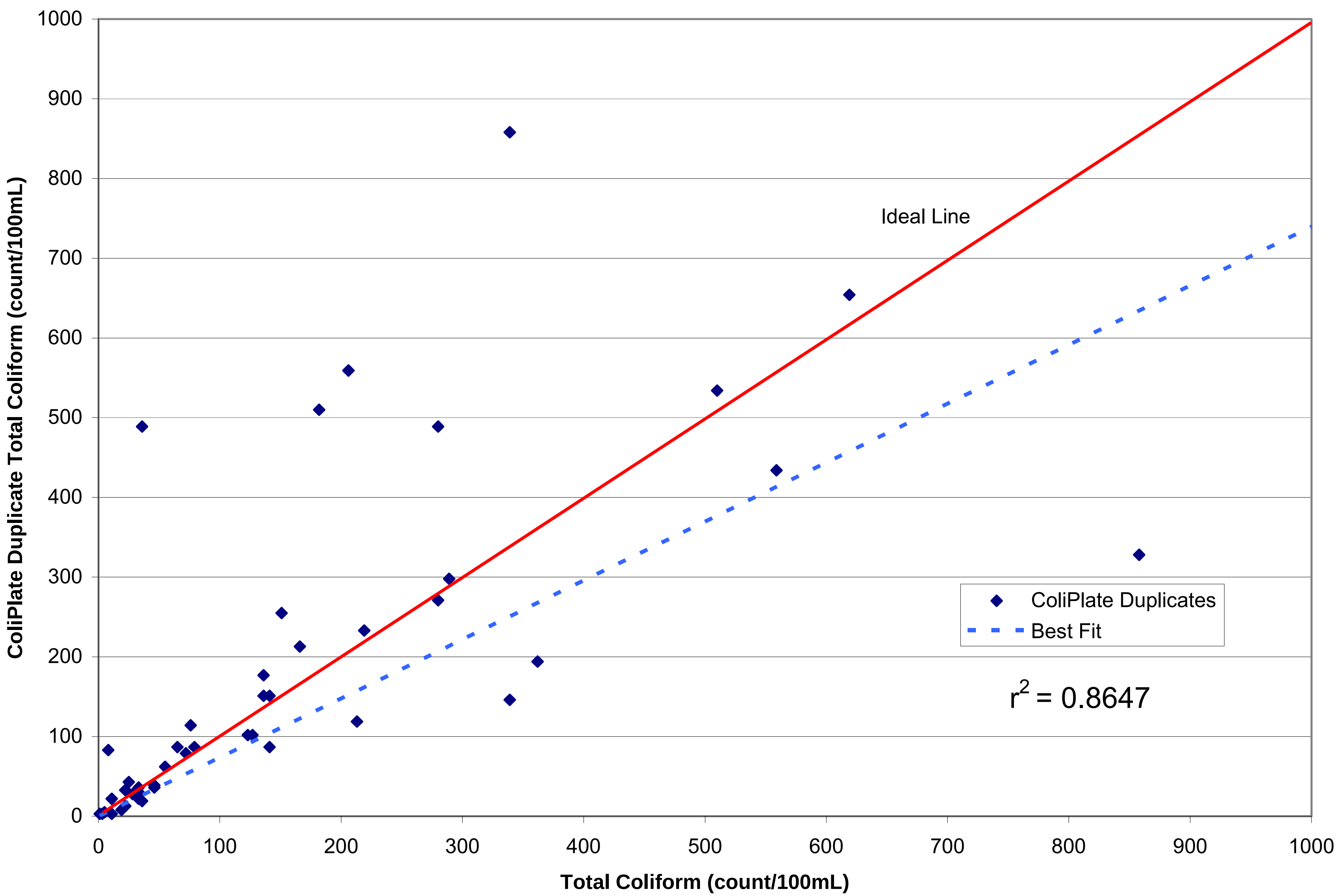

Figure 4.1 - Total coliform duplicates compared using ColiPlate technology

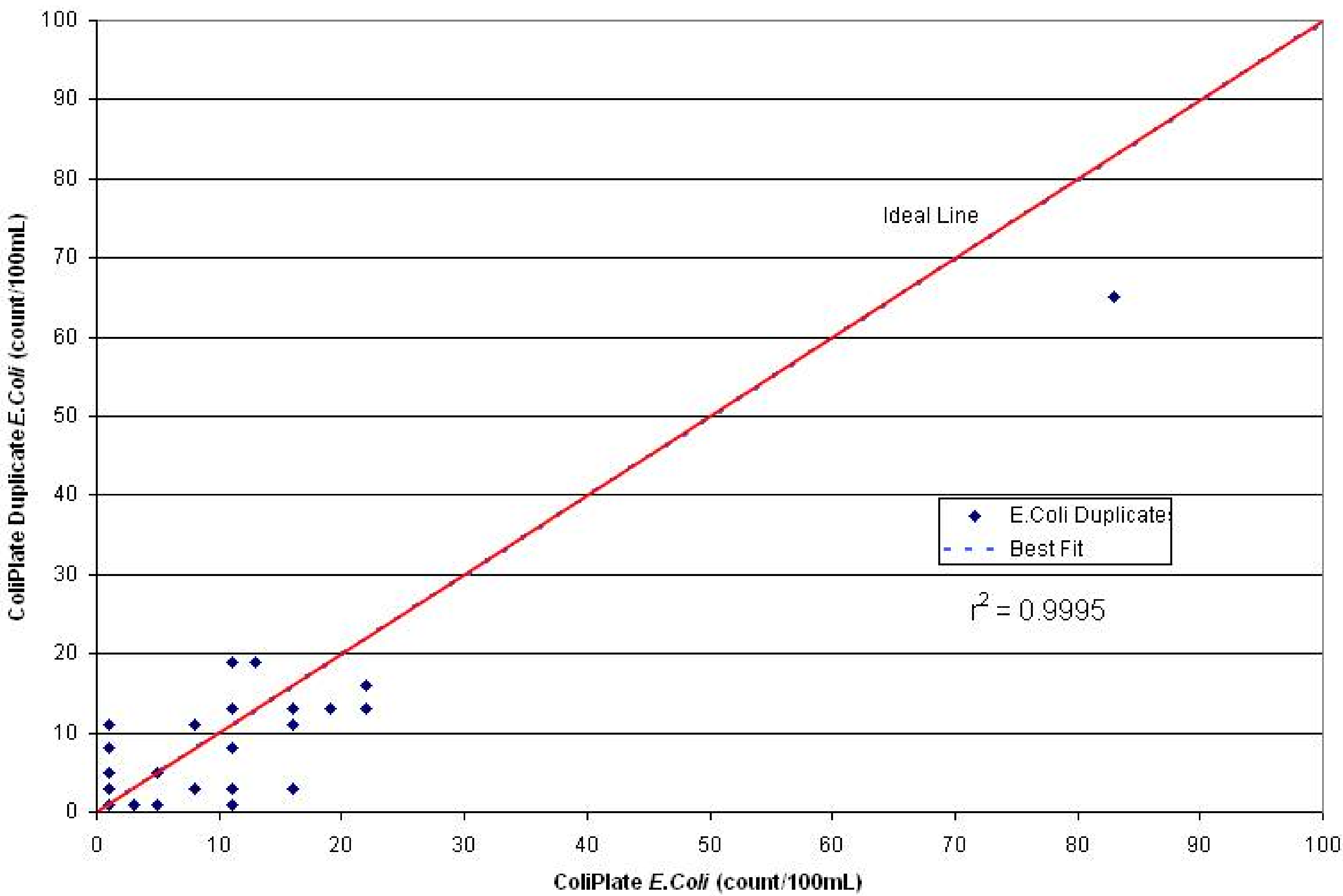

Figure 4.2 – E.Coli duplicates compared using ColiPlate technology

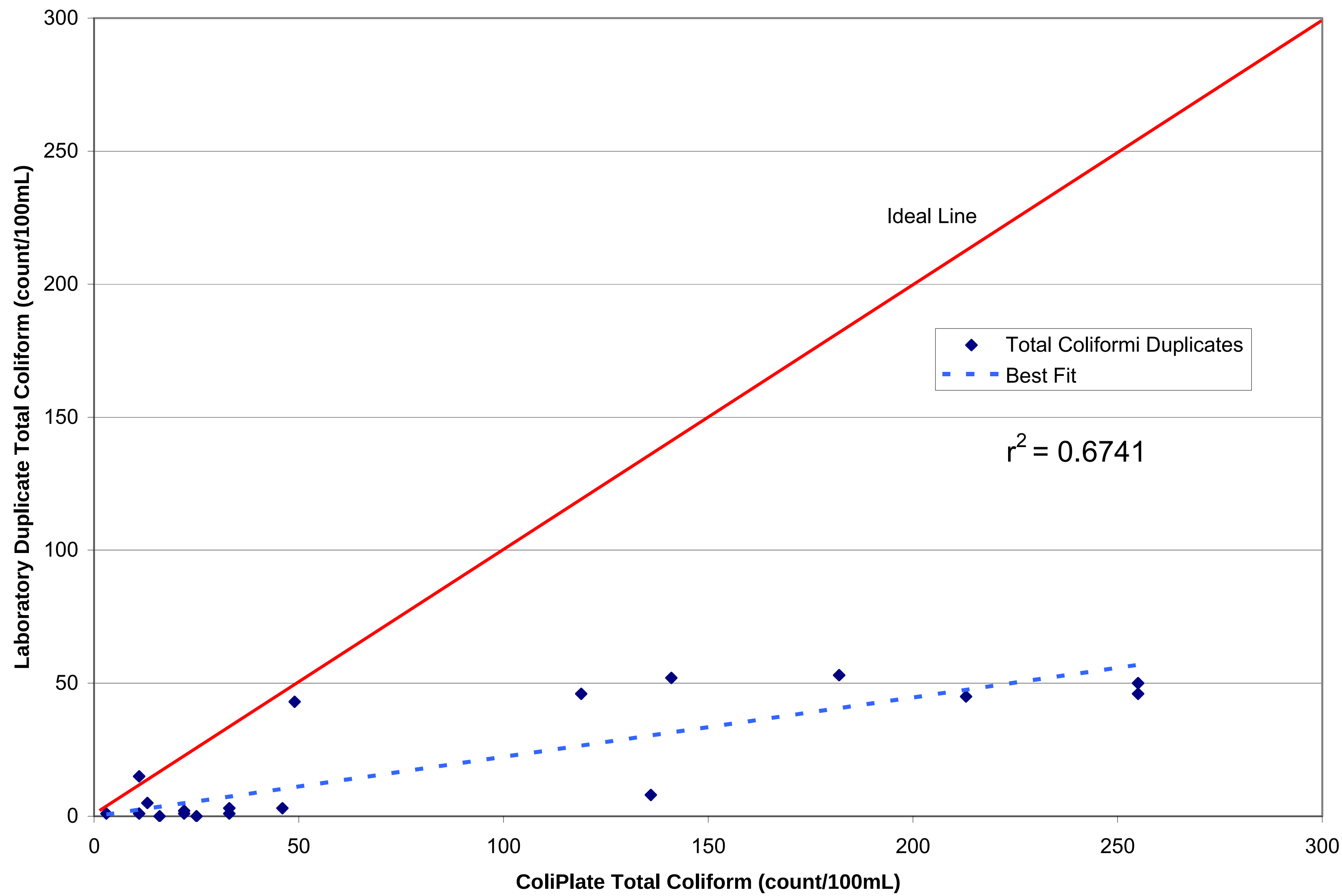

Figure 4.3 - Total coliform duplicates compared using Central Ontario Analytical Laboratory

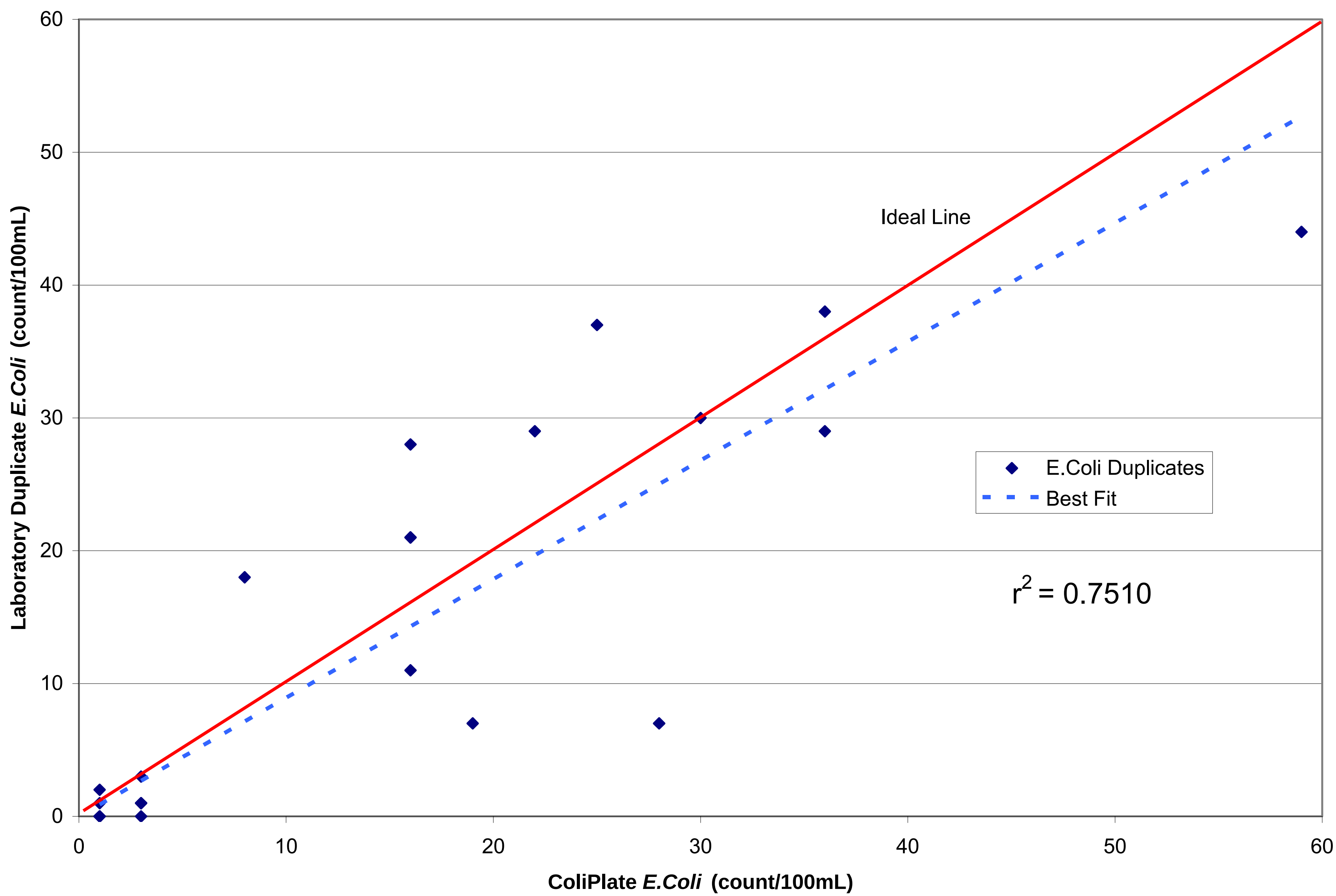

Figure 4.4 – E.Coli duplicates compared using Central Ontario Analytical Laboratory

Data received from the Simcoe Muskoka District Health Unit's public beach water quality monitoring program confirms that the observed range in *E.Coli* duplicates is appropriate. The Health Unit collects data from sets of five closely-spaced locations in the vicinity of public beaches. 2005 results from beaches within the Township of Muskoka Lakes shows that almost half the time, sample sets taken at the same time from the same area have a range in excess of 50 counts/100mL (Simcoe Muskoka District Health Unit, 2005). In contrast, the range in MLA program *E.Coli* duplicates for a single sample run did not exceed 41 counts/100mL in 2005. Moreover, the r^2 value of 0.9995 for E.Coli suggests extremely good correlation between duplicate results, with no bias observed.

4.1.3 Bacteria Lab Duplicates

As in previous years, a further five percent of bacteria samples were duplicated and analyzed by an accredited laboratory (Central Ontario Analytical Laboratory in Orillia). Tables A.3 and A.4 in Appendix A show total coliform and E.Coli lab duplicate data respectively.

Figure 4.3 shows the correlation between ColiPlate results and lab results (r^2 value of 0.6741). Figure 4.4 similarly shows results for the E.Coli duplicates (r^2 value of 0.7510).

Both total coliform and E.Coli lab duplicates varied more significantly from ColiPlate results than did ColiPlate duplicates. This variance is consistent with results from 2002, 2003 and 2004. The increased variance may be due to the time that passes between internal analysis and lab analysis. Figure 4.3 clearly shows that the ColiPlates overestimate total coliform levels.

Figure 4.4 shows that the ColiPlates typically overestimated *E.Coli* contamination by a small margin. This result is consistent with observations from 2003, but differs from observations in both 2002 and 2004 (when ColiPlates slightly

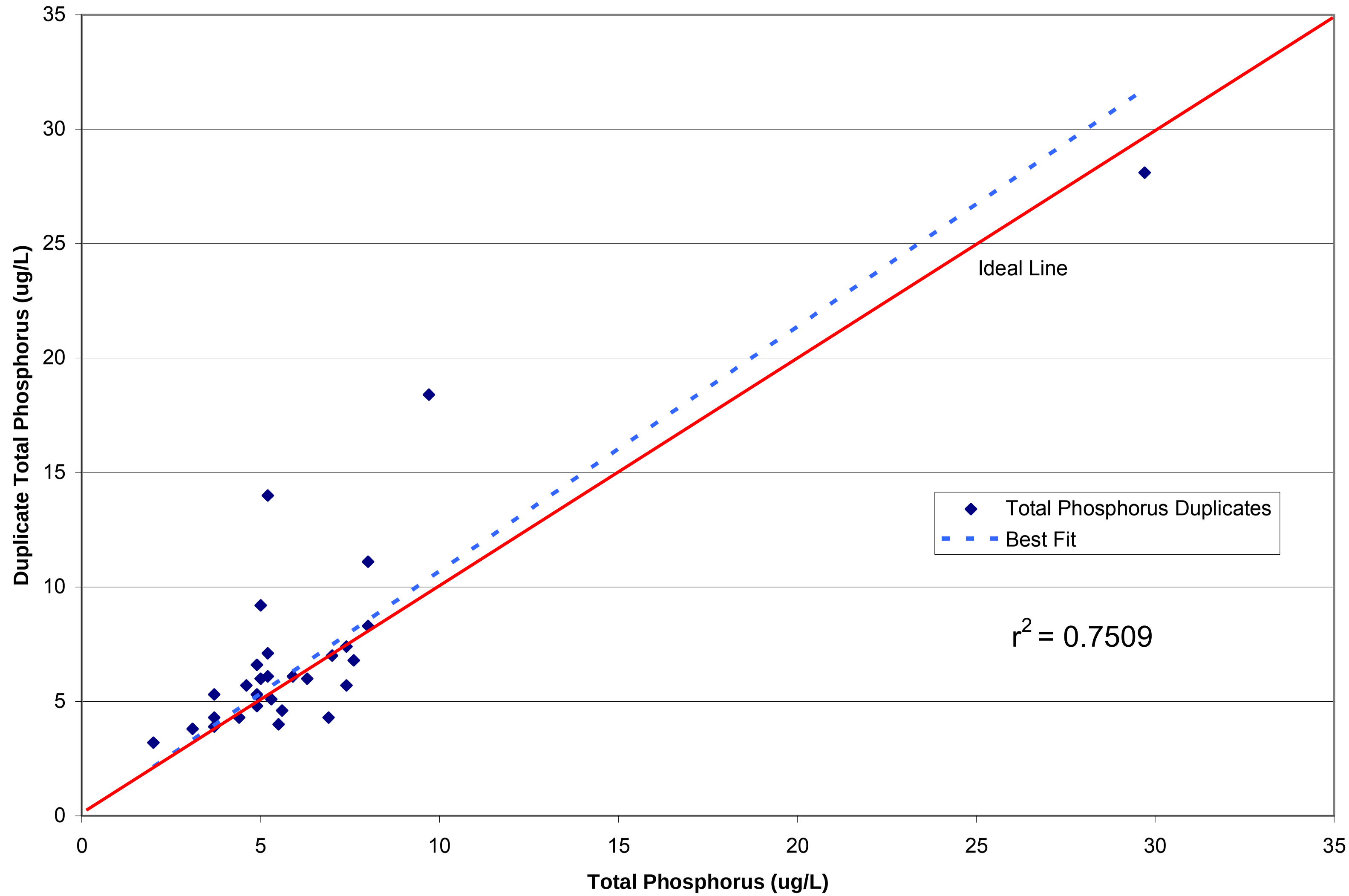

Figure 4.5 – Comparison of Phosphorus concentration duplicates

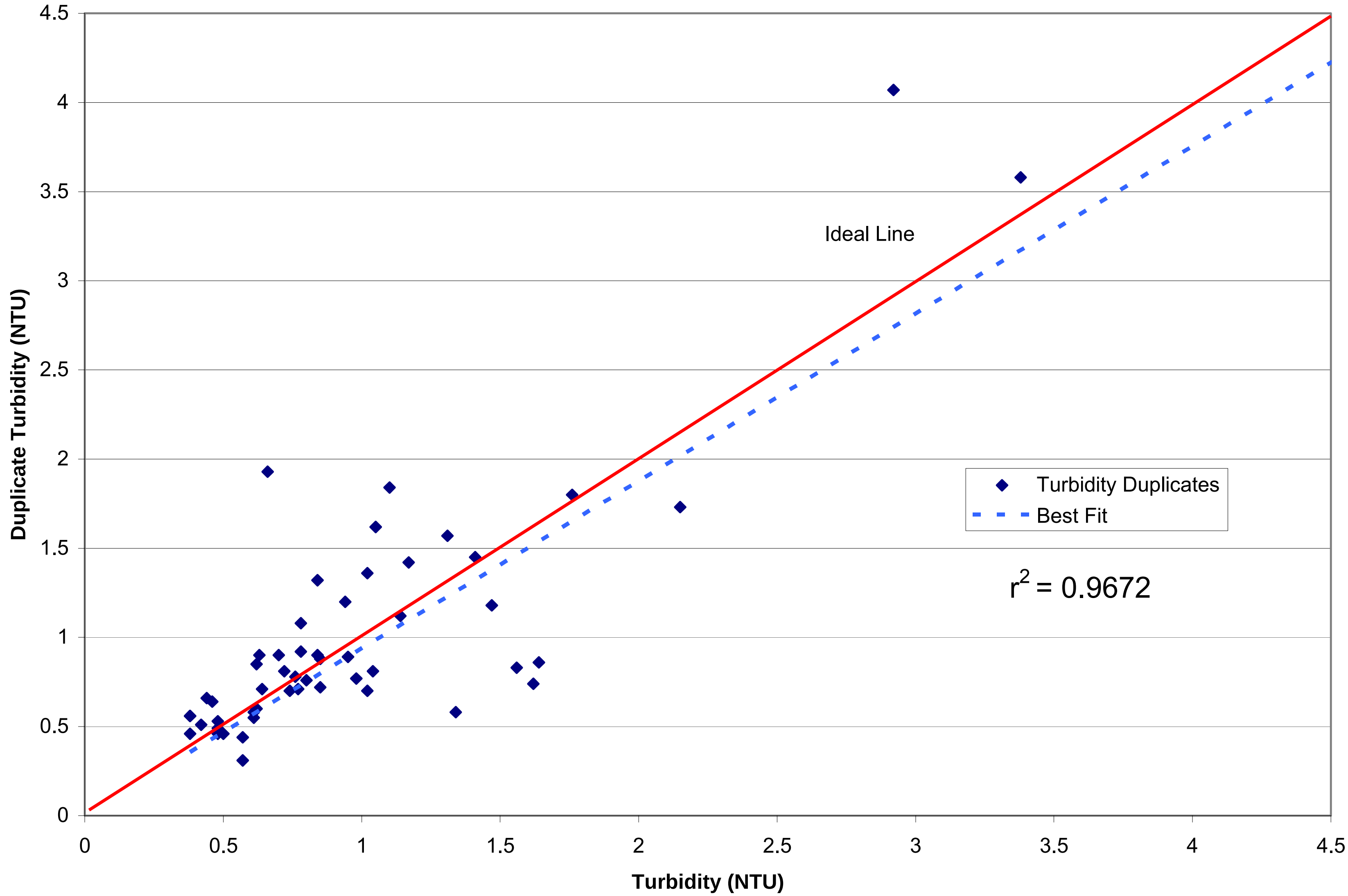

Figure 4.6 - Turbidity duplicates comparison

underestimated *E.Coli* contamination). From this four-year analysis, lab duplicates suggest that there is no consistent bias in the ColiPlate results; neither an overestimation nor an underestimation. Moreover, the ColiPlates return readings that are in the same range as laboratory results, which suggests that they accurately indicate contamination levels.

4.1.4 Phosphorus Duplicates

Five percent of all phosphorus samples were duplicated and analysed by Trent University's lab at the Environmental Science Centre in Dorset as described in Section 3.3. Possible sources of variation include lab error and the presence of particulate matter within the samples when collected. GLL, 2003 notes that a relatively large average difference between original and duplicate samples was observed during the 2002 program. To avoid collecting particulate matter in the samples, water was filtered through an 80 micron filter during the 2003 season, and average difference in duplicates was significantly reduced. Although the filter was effective in reducing the difference in duplicates, its use was discontinued in 2004 as recommended because results suggested that the filters were also reducing the observed effects of land-based influences on phosphorus concentration, which forms an important part of the research program.

Duplicate data is shown in Table A.5 of Appendix A and in Figure 4.5. Difference between duplicate samples averaged 1.6µg/L. This difference is much lower than the difference observed in 2004, and is more comparable to the difference observed in 2003. The 2004 Annual Report (Logan, 2004) suggests that significant variability is likely due to on-shore influences on the nearshore zone. In this case, a small variability in 2005 results may be due to low rainfall and water levels (reducing effects like erosion and overland runoff). The consistency of duplicate results in 2005 and in previous years suggests that there is no bias in the results and the range of TP concentrations observed should be considered normal.

4.1.5 Turbidity Duplicates

Bacteria duplicates analyzed internally using ColiPlates were also analyzed for turbidity. Turbidity duplicate data is shown in Table A.6 in Appendix A. Figure 4.6 compares the initial turbidity measurement and its corresponding duplicate measurement. As in previous years, the results show a high degree of correlation (with an r^2 value of 0.9672), suggesting that measurements recorded by the turbidimeter are consistent.

4.1.6 Quality Assurance/Quality Control Conclusion

Several methods of quality control and quality assurance are employed in the MLA water quality initiative. Results suggest that contamination of samples does occur from time to time, but generally there is no consistent bias in the analysis. While it would be ideal to eliminate all sources of contamination and error, the four-year volunteer program has consistently produced acceptable and useable data.

4.2 Research Program Results

The long-term goal of the MLA water quality initiative is to protect and enhance environmental quality by changing the way development occurs around Muskoka's lakes. The MLA intends to do this by objectively determining what style of development is most appropriate. Appropriate development can be implemented in the shorter term through regulations and restrictions outlined in local Official Plans and other planning policies. In the longer term, appropriate development must become part of the local culture. Both the shorter and longer-term success of this program is dependent on building knowledge about how development affects environmental quality, and in turn quality of life (Logan, 2003).

The 2003 Final Report gave the results of a detailed research program designed to quantify the effects of residential development on the nearshore waters of the

Muskoka Lakes. 29 research sites were selected for this analysis based on physical characteristics. Two hypotheses were tested in the analysis, which proved to be inconclusive. That is, the difference between nearshore and offshore water quality that had been previously observed was not proved to be statistically significant.

Recommendations from 2003 suggested that the research program be repeated in 2004 with a slight change in TP collection protocol (as discussed in Section 3.3) in order to determine whether or not there is a significant difference between nearshore and offshore water quality. Data was again collected at 27 of the same 29 research sites and the same two hypotheses tested. While the detailed analysis in the 2004 Annual Report showed that results were more conclusive than they were in 2003, the hypotheses held true at approximately 70% of the locations, while statistical significance was observed at between 10% and 35% of locations studied. The 2004 Annual Report therefore recommended that the research in 2005 be focused on a new research question.

Two research foci were identified for the 2005 program. The first focus is similar to that of 2003 and 2004, in that it aims to compare total phosphorus levels in the nearshore zone with total phosphorus levels in a corresponding offshore site in order to identify the effects of a local land use on the nearshore water quality. Golf courses were identified as the land use to be studied, as their construction and operation can have a significant impact on Muskoka's water quality, both esoterically and anecdotally. Moreover, the proliferation of golf course development in Muskoka has been significant in the recent past and will likely remain so into the foreseeable future. Significant research has been done regarding the effects of golf courses on water bodies (e.g. US Environmental Protection Agency, Manitoba Golf Superintendents Association, etc.) including recommended best management practices for the protection of aquatic ecosystems from golf course development and operation.

The second focus of research aims to help correlate MLA total phosphorus concentration data with the total phosphorus concentration data that has been collected by both the District of Muskoka (DMM) and the Ontario Ministry of the Environment (MOE) for several years. Different protocols are used to collect the data; DMM and MOE measure spring turnover phosphorus concentration [TP_{so}] and the MLA collects total epilimnetic phosphorus concentration [TP_{epi}]. A comparison of the datasets will show how MLA data, collected in both the offshore and the nearshore, relates to standards identified by the District's Lake System Health program. The MLA's detailed dataset, integrated with long-term deep water total phosphorus concentration data, should help lake managers, planners and communities better protect and enhance Muskoka's lake environments in the future by incorporating nearshore land-based water quality effects into appropriate regulations and land-use plans.

4.2.1 Golf Course Study

Golf courses dot the landscape in Muskoka. Some of these courses directly interface with the lakes, and others are set back in wooded areas. Regardless of where a golf course is located in a watershed, all drainage from the developed area eventually makes its way into Muskoka's rivers and lakes and therefore they can potentially impact water quality. Operating a golf course often means heavy usage of fertilizers and pesticides to maintain green grounds throughout the operating season. These materials pose a potentially serious threat to the health of Muskoka's lakes; as phosphorus from fertilizers increases trophic status, and pesticides can have detrimental effects on living aquatic organisms, including deformities, sterilization and death.

Most often, new golf courses are held to very high development and operational standards by local governments and provincial agencies (such as MOE through their system of permitting to take water). The MLA and the community are still concerned however, about the possible effects golf courses have on the aquatic environment for several reasons:

1) Older golf courses were not typically built with environmental standards in mind
2) Ongoing environmental monitoring after construction is only temporary, and is often undertaken by consultants of the developers' choosing who may not have the public interest in mind
3) There is little evaluative data to suggest that best management practices work in Muskoka

36 sites were chosen to represent nearshore and offshore water quality in the vicinity of golf courses around the Muskoka Lakes. Specific golf courses were not singled out for study, but golf courses in areas where the water quality initiative had previously operated were chosen. These courses are:

- Beaumaris Yacht Club (Beaumaris, Lake Muskoka)
- Kirie Glen (Willow Beach, Lake Muskoka)
- Lake Joseph Club (Cox Bay, Lake Joseph)
- Muskoka Woodlands/OviinByrd (Still's Bay, Lake Joseph and Bass Lake)
- The Rock (Minett, Lake Rosseau)
- Rocky Crest (Hamer Bay, Lake Joseph)
- Taboo (Muskoka Sands, Lake Muskoka)
- Windermere Golf Club (Windermere, Lake Rosseau)

Three hypotheses are used to explain the anecdotal and esoteric observation that nearshore water quality near golf course developments is impaired. These hypotheses, if shown to hold true, would form the basis for lakefront planning policy with respect to golf course developments. The hypotheses are:

1) Phosphorus is more concentrated in the nearshore zone than in the offshore zone (due to acute land-based influences like runoff and erosion)
2) Variance in phosphorus concentration is higher in the nearshore zone than in the offshore zone (acute land-based influences are more uniformly distributed through assimilation into deep water)
3) Land-based influences of golf course development can be specifically attributed to characteristics of the golf course landscape

Hypotheses one and two must be accepted before hypothesis three can be considered. The initial hypotheses are physical corollaries, since they attempt to predict two effects of the same phenomenon (land-based sources of phosphorus that acutely affect the nearshore zone due to its proximity to land). That is, phosphorus concentration is both higher and more varied in the nearshore zone because sources of phosphorus are land-based (and potentially attributable to specific characteristics of the landscape of golf courses).

4.2.1.1 Analysis

The eight phosphorus samples taken at each location were used to calculate the annual average phosphorus concentration as well as the standard deviation of each eight-point dataset. The annual average phosphorus concentration and standard deviation for each nearshore site was then compared with the data from its corresponding offshore site. Table 4.2 summarizes which hypotheses were confirmed for the 36 research sites (27 nearshore sites, nine offshore sites) considered in 2005. Statistical significance was only calculated for sites where hypotheses were confirmed.

The '▲' symbol indicates that the hypothesis was confirmed for the given site. Statistical significance between mean of offshore and nearshore data was determined using a one-tailed paired Student's T-test with $\alpha=0.05$. Statistical significance between variance of offshore and nearshore data was calculated using a one-tailed F-test with $\alpha=0.05$. Table 4.3 shows that the hypotheses hold true in nearly all situations (hypothesis 1 was true at 96% of sites and hypothesis 2 at 93% of sites). This implies that land-based influences have an impact on phosphorus concentration in the nearshore zone. The observed impact however, was not always statistically significant (37% of sites were statistically significant for hypothesis one and 33% for hypothesis two).

These observations suggest that there could be significant correlation between golf course landscapes and nearshore water quality degredation. Further data collection and analysis is necessary in order to support this observation.

Table 4.2 – Summary of hypothesis tests

	Hypothesis 1	Statistical Significance (H1)	Hypothesis 2	Statistical Significance (H2)
Beaumaris Yacht Club				
BMR-2	▲		▲	
BMR-4	▲		▲	▲
BMR-5	▲	▲	▲	
BMR-6	▲		▲	
Kirie Glen				
WLB-1	▲	▲	▲	▲
WLB-2	▲		▲	▲
WLB-3	▲		▲	
Lake Joseph Club				
COX-1	▲		▲	
COX-2	▲		▲	
COX-3	▲		▲	
COX-4	▲		▲	
Muskoka Woodlands/Oviinbyrd				
BAS-1			▲	
STI-2	▲		▲	
The Rock				
MIN-1	▲	▲	▲	
MIN-2	▲		▲	▲
MIN-4	▲			
MIN-5	▲		▲	
Rocky Crest				
HMB-1	▲	▲	▲	▲
HMB-2	▲			
HMB-3	▲		▲	
HMB-4	▲	▲	▲	
Taboo				
MSN-1	▲	▲	▲	▲
MSN-2	▲	▲	▲	▲
MSN-4	▲	▲	▲	▲
Windermere				
WIN-2	▲		▲	
WIN-3	▲	▲	▲	▲
WIN-4	▲	▲	▲	

4.2.1.2 Golf Course Research Conclusion

The 2006 study on the affects of golf course developments on nearshore water quality should be continued and expanded. The sampling program carried out in 2005 should be repeated, and a thorough review of the literature regarding best environmental management practices for golf courses should be undertaken in order to compare findings and recommendations of other studies to the findings of the MLA water quality initaitive. Efforts should be made to work with golf course managers in order to obtain information on fertilizer application schedules, rainfall statistics and local hydrologic information. This data should then be used to perform a thorough analysis of the effects of golf course landscapes on nearshore water quality. Findings of this research can then be compared to and build on findings of the literature review.

4.2.2 TP_{so}/TP_{epi} Study

Since the 1980s, the District Municipality of Muskoka (DMM) has monitored total phosphorus concentrations in lakes throughout Muskoka. DMM uses measurements to calibrate the Muskoka Water Quality Model, on which many planning and land-use decisions are made. During 2005, the new Muskoka Lake System Health Program was launched by DMM in order to expand the scope of considerations for planning decisions. An updated Muskoka Water Quality Model maintains a prominent place within this program that also considers a variety of other limits to growth around Muskoka's lakes. As the MLA is primarily interested in protecting and enhancing the lake environments and quality of life in Muskoka, it is most important that their water quality initiative be comparing total phosphorus concentration data with DMM data that guides this program. For this reason, all DMM total phosphorus sampling sites were included in the 2005 sampling program, and a thorough comparison of results can now be undertaken.

DMM measures phosphorus in the centre of lakes and bays at the spring turnover ([TP_{so}]), when the lakes are not stratified (that is, divided into thermal layers.) The spring turnover typically occurs during May. Theoretically, the phosphorus is distributed evenly throughout the water column at this time. Samples are taken approximately once every three to four years at each sampling location.

In contrast, the MLA measures total epilimnetic phosphorus ($[TP_{epi}]$) on a biweekly basis throughout the summer. The epilimnion is the upper layer of water in a stratified lake (the warmest layer). This is significant, because total phosphorus stored in the lake is divided up in different concentrations between the various thermal layers.

A direct comparison of the two sets of data is not possible as $[TP_{so}]$ and $[TP_{epi}]$ represent different parameters. The strategy for comparison therefore, is as follows:

1. Calculate predicted $[TP_{so}]$ given observed $[TP_{epi}]$ using formulas developed as part of the Ontario Lakeshore Capacity Simulation Model
2. Directly compare observed $[TP_{so}]$ and calculated $[TP_{so}]$ for years where both $[TP_{so}]$ and $[TP_{epi}]$ measurements were taken
3. Compare average observed $[TP_{so}]$ and average calculated $[TP_{so}]$ over the long term
4. Calculate the most appropriate conversion factor using observed data.

The Ontario Lakeshore Capacity Simulation Model's Trophic Status Module (Dillon et al, 1986) details the conversion between $[TP_{so}]$ and $[TP_{epi}]$, calibrated using several lakes around Ontario with data from the late 1970s. Combining the conversion from $[TP_{epi}]$ to $[TP_{if}]$ (ice-free period total phosphorus concentration) and from $[TP_{if}]$ to $[TP_{so}]$, the conversion becomes:

$$[TP_{so}] = 1.31\ [TP_{epi}] - 0.93 \qquad (1)$$

Table 4.3 lists all predicted $[TP_{so}]$ calculated using the MLA's $[TP_{epi}]$ observed data from 2005 and formula (1). (All DMM data was received from the District Municipality of Muskoka in an unpublished form, and is provided here with permission (DMM, 2005)).

Table 4.3 – Calculated [TP_{so}] (1) for 2005

Site	2005 Calculated [TP_{so}] (ug/L)
Bala Bay	7.88
Bass Lake	11.78
Brackenrig Bay	9.91
Brandy Lake	40.46
Cox Bay	5.53
Dudley Bay	6.86
Gull Lake	7.69
Lake Joseph (Main)	3.57
Lake Muskoka (South)	10.08
Lake Rosseau (Main)	5.05
Little Lake Joe	5.31
Long Lake	6.24
Muskoka Bay	14.10
Portage Bay	6.50
Silver Lake (GR)	13.03
Silver Lake (TML)	11.19
Whiteside Bay	6.59

Table 4.4 shows the comparison between [TP_{so}] observed by DMM and calculated from MLA [TP_{epi}] observations for years where both were taken.

Table 4.4 – Comparison of observed and calculated [TP_{so}]

Site	Year	Observed [TPso] (ug/L)	Calculated [TPso] (ug/L)
Lake Muskoka (North)	2002	7.6	6.01
Muskoka Bay	2002	10.9	9.39
Brackenrig Bay	2003	8.6	22.16
Cox Bay	2003	5.6	5.63
Bala Bay	2004	4.85	9.64
Gull Lake	2004	6.03	13.33
Long Lake	2004	3.25	7.28
Brackenrig Bay	2005	8	9.91
Cox Bay	2005	4.5	5.53
Joseph River	2005	9.5	7.08
Lake Joseph (Main)	2005	5.5	3.59
Lake Rosseau (Main)	2005	4.8	5.07
Little Lake Joseph	2005	5.3	5.33
Portage Bay	2005	7.4	6.54
Silver Lake (GR)	2005	8.8	13.03
Silver Lake (TML)	2005	10.6	11.19
Skeleton Bay	2005	6	5.32

Both DMM and MLA have measured [TP] at the same location in the same year seventeen times, as shown in Table 4.4. On average, the observed and calculated [TP_{so}] measurements differ by an absolute value of 2.7μg/L, or 27%.

Table 4.5 compares the long-term average observed and predicted [TP_{so}] (using MLA [TP_{epi}] data and formula (1)) for each site using all available data. Number of years of available data is also indicated.

Table 4.5 – Calculated [TP_{so}] (1) comparison

Site	Average Observed [TPso]		Average Calculated [TPso]	
	ug/L	Years of Data	ug/L	Years of Data
Bala Bay	5.88	7	8.10	3
Bass Lake	9.03	7	11.78	1
Brackenrig Bay	7.90	5	15.37	3
Brandy Lake	22.67	3	38.34	2
Cox Bay	4.96	5	5.25	4
Dudley Bay	6.30	2	6.86	1
Gull Lake	8.72	9	9.71	3
Joseph River	8.70	2	7.08	1
Lake Joseph (Main)	4.76	5	3.57	1
Lake Muskoka (North)	4.15	4	7.08	4
Lake Muskoka (South)	5.80	4	10.04	1
Lake Rosseau (Main)	5.70	5	5.05	1
Little Lake Joe	5.60	5	5.31	1
Long Lake	6.25	5	6.73	2
Muskoka Bay	14.85	4	11.52	4
Portage Bay	7.23	3	6.50	1
Silver Lake (GR)	9.41	7	11.04	2
Silver Lake (TML)	12.40	5	10.50	2
Skeleton Bay	6.30	2	5.32	1
Whiteside Bay	6.60	2	6.59	1

Similarly, Table 4.5 shows that the long-term average observed and calculated [TP_{so}] differ by an average absolute value of 2.5μg/L, or 21%. In all likelihood, a more accurate conversion can be developed for these datasets.

By using a linear regression equation, the most accurate relationship for long-term average data observed by DMM and calculated from data observed by MLA is as follows:

$$[TP_{so}] = 0.67\ [TP_{epi}] + 2.77 \qquad (2)$$

Table 4.6 shows average long-term observed $[TP_{so}]$ and $[TP_{so}]$ calculated using MLA $[TP_{epi}]$ data and formula (2).

Table 4.6 - Calculated $[TP_{so}]$ (2) comparison

Site	Average Observed [TPso] (ug/L)	Average Calculated [TPso] (ug/L)
Bala Bay	5.88	7.39
Bass Lake	9.03	9.27
Brackenrig Bay	7.90	11.11
Brandy Lake	22.67	22.86
Cox Bay	4.96	5.93
Dudley Bay	6.30	6.76
Gull Lake	8.72	8.21
Joseph River	8.70	6.85
Lake Joseph (Main)	4.76	5.07
Lake Muskoka (North)	4.15	6.85
Lake Muskoka (South)	5.80	8.38
Lake Rosseau (Main)	5.70	5.83
Little Lake Joe	5.60	5.96
Long Lake	6.25	6.69
Muskoka Bay	14.85	9.14
Portage Bay	7.23	6.57
Silver Lake (GR)	9.41	8.89
Silver Lake (TML)	12.40	8.62
Skeleton Bay	6.30	5.95
Whiteside Bay	6.60	6.62

An analysis of the long-term average observed and calculated $[TP_{so}]$ (2) show that corresponding values differ by an average absolute value of 1.3μg/L, or 16%.

Formula (2) is the best mathematical approximation of how the results of the two protocols are related currently available. The formula is however, based on limited data collection and a limited analysis of different lake characteristics. To further refine this conversion (and therefore more appropriately relate MLA observed data with the Muskoka Water Quality Model and in turn planning decisions) a more detailed analysis should be performed. This analysis should consider different lake classifications (e.g. stratification). Further research effort should be devoted to understanding how [TP] flux is realized within the nearshore zone, which is too shallow to be stratified. Through an understanding of these processes and allowing for differences given different lake classifications, the MLA's nearshore [TP] data may be integrated into the Muskoka Water Quality Model. This may allow the Lake System Health Program to consider nearshore [TP] as a limit to growth and may add to the general scientific understanding of [TP] flux.

5.0 Recommendations

Several recommendations are suggested regarding long-term goals of the MLA water quality initiative. These changes would help to increase the efficacy of the initiative in 2006, and also direct the MLA in stewardship initiatives into the future.

The public education campaign started by the MLA should be continued in the future. In addition to articles in *The Burgee*, the MLA should consider holding seminars for community members throughout the summer season. Use of the redeveloped MLA website is imperative. Biweekly or monthly updates on the program could easily be sent to all MLA members through new electronic newsletters and website updates, to complement the workshops that could be held throughout the area.

The MLA should work more closely with the District of Muskoka in developing and applying the Lake System Health Program. Significant capacity has already been built within the communities participating in the MLA Water Quality Initiative. This capacity should be used in the implementation of remedial action plans, and the MLA's interactive Water Quality Initiative website should be used as a tool to facilitate these plans. The MLA and other community groups should be involved in further determining limits to growth as part of the Lake System Health Program.

The MLA should also work towards a closer relationship with the Muskoka Watershed Council. The Watershed Council could help the MLA to adopt protocols that they already use for various water quality indicators. A significant opportunity for cooperation is the new MLA Water Quality Initiative website, which could be used by the Watershed Council and in fact house and manage the information currently indexed on the Muskoka Water Web (http://www.muskokawaterweb.ca).

The MLA should also support the work of the Muskoka Watershed Council in benthic community monitoring as discussed in Section 5.0 of the 2003 Annual Report. This would be an excellent way to cooperate with the Muskoka Watershed Council, and it would also give more MLA members the opportunity to participate in the initiative. In addition, children's ecological monitoring programs could be developed and taught to youth at various camps around Muskoka, to fill a need identified by the community during 2005.

Section 5.0 of the 2003 Annual Report details several suggestions relating to the acquisition of external funding, including ways in which to use any external funding acquired. In order to support and develop the long-term goals of the water quality initiative, the MLA should continue to search out external funding sources, but should also recognize in kind support from research groups such as Universities and other non-governmental organizations.

5.1 Research Function

The research function of the program is the cornerstone of the initiative, and promising results were shown in 2005. Research should build year after year, keeping in mind that the long-term goal of the MLA is to protect and enhance the Muskoka Lakes community and area. Only through careful, systematic research can human capacity and knowledge about the local environment and ecosystem be developed and used to help make our community better in the future.

With this in mind, the research program carried out in 2005 should be repeated and expanded in 2006. A thorough review of the literature regarding best environmental management practices for golf courses should be undertaken. In addition to sampling water quality in the nearshore zone in areas adjacent to golf course developments, fertilizer application schedules, rainfall statistics and local hydrologic information should be collected. A thorough analysis of the effects of golf course landscapes on nearshore water quality should be completed using this information, and compared to findings of the literature review.

5.2 Monitoring Function

The monitoring function of the program should be expanded as much as financial and human resources allow in order to acquire the most complete record of water quality possible. A more complete record would make it easier to evaluate unexpected results like those encountered in the offshore areas during the 2003 program. A more complete record would also make it easier to statistically analyze results.

In order to expand human capacity, volunteers should be used to analyse bacteria samples using ColiPlates and incubators. Partner associations in particular should be given the responsibility of analysing samples and maintaining the dataset for their own area. This would not only relieve some responsibility from the program coordinator, but would also give ownership of the program to the most local community.

The MLA should strive to build and maintain relationships with other residents groups in the area that are involved in the program. Specifically, the MLA should begin working now with groups that have expressed interest in participating in the program in 2006. A social event and meeting to specifically discuss program results and achievements would be very beneficial and it would be an appropriate way for the MLA to offer a good will gesture.

More consultant time should be devoted to advancing the long-term goals of the program, and developing these goals based on community feedback. In order to alleviate some of the time required of the project coordinator, part time staff should be employed to sterilize bottles, deliver samples and perform other day-to-day tasks.

To improve the program technically, more effort should be devoted to training volunteers in the protocols. Two training sessions may help to manage the large number of volunteers that now need to be trained, and may give everyone a better chance to attend a training session. More effort should also be devoted to proper sterilization of collection bottles; if at all possible, laboratory grade sterilization equipment should be acquired.

6.0 Conclusions

Overall, the 2005 season was successful. The database of water quality statistics grew to include more comprehensive results in the offshore (deep water) areas of Lakes Rosseau, Joseph and Muskoka, as well as all results from various lakes in the vicinity of these three large lakes. The community was effectively engaged in the analysis and understanding of the results through volunteers and seminars as evidenced by anecdotal feedback and cultural awareness. Significant advances in research were realized, as a first attempt at producing a conversion formula relating DMM and MLA [TP] data was developed (which will potentially allow MLA nearshore [TP] data to be considered by the Lake System Health Program in the future) and significant evidence of the effects of golf course landscapes on nearshore water quality was observed. Perhaps most significantly, the new water quality initiative website was launched. This tool will allow the MLA to further effectively disseminate knowledge generated through the water quality initiative, and it will aid the public education campaign in the future. The MLA should build on these successes in order to involve a wider community in the initiative, further develop knowledge based on the scientific research, and support, promote and facilitate responsible environmental stewardship in 2006.

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Appendix A

Table A.1 - Total coliform duplicates using ColiPlate technology

Site	Sample Number	Total Coliforms (counts/100mL)	TC ColiPlate Duplicate (counts/100mL)	Remarks
MIN-4	1	30	33	
RMI-5	1	22	11	
RSH-3	1	3	11	
BAL-4	2	33	22	
BMR-3	2	>2424	>2424	Omit (out of range)
LOL-2	2	102	123	
STN-2	2	>2424	>2424	Omit (out of range)
GUL-2	3	39	46	
MSN-3	3	119	213	
NRT-3	3	22	33	
SPC-3	3	3	1	
WAK-2	3	36	33	
WLB-2	3	28	28	
BRA-2	4	43	25	
CLR-1	4	83	8	
COX-2	4	30	33	
GNB-3	4	22	11	
HMB-3	4	13	22	
MRV-2	4	151	136	
BAS-3	5	489	36	
CLR-2	5	8	19	
JOR-2	5	87	79	
LLJ-2	5	33	22	
MOO-7	5	79	72	
RSH-4	5	255	151	
STN-3	5	102	127	
WIN-3	5	1696	2424	
CLR-3	6	87	65	
MBA-4	6	87	141	
MRV-3	6	271	280	
MSN-4	6	>2424	>2424	Omit (out of range)
BAL-2	7	194	362	
BMR-2	7	328	858	
BRA-3	7	177	136	
COX-3	7	534	510	
EAS-2	7	1370	>2424	Omit (out of range)
ELG-2	7	510	182	
FTB-3	7	654	619	
GNB-4	7		52	Omit (sample missing)
GUL-3	7	1696	2424	
HMB-4	7	5	5	
IND-3	7	434	559	
JOR-1	7	233	219	
LLJ-1	7	114	76	
LOL-1	7	146	339	
MIN-1	7	>2424	1174	Omit (out of range)
MOO-1	7	858	339	
RMI-1	7	489	280	
SPC-3	7	36	46	
WAK-2	7	559	206	
WLB-3	7	298	289	
BDY-3	8	3	3	
JOR-3	8	19	36	
LLJ-3	8	62	55	
RMI-4	8	213	166	
WIN-4	8	151	141	

Table A.2 - E.Coli duplicates using ColiPlate technology

Site	Sample Number	*E.Coli* (counts/100mL)	*E.Coli* ColiPlate Duplicate (counts/100mL)	Remarks
MIN-4	1	1	1	
RMI-5	1	3	1	
RSH-3	1	1	1	
BAL-4	2	1	1	
BMR-3	2	2424	2424	
LOL-2	2	22	16	
STN-2	2	5	5	
GUL-2	3	1	1	
MSN-3	3	11	8	
NRT-3	3	1	1	
SPC-3	3	1	1	
WAK-2	3	22	13	
WLB-2	3	1	1	
BRA-2	4	8	11	
CLR-1	4	1	1	
COX-2	4	1	1	
GNB-3	4	1	1	
HMB-3	4	1	3	
MRV-2	4	8	11	
BAS-3	5	3	1	
CLR-2	5	1	1	
JOR-2	5	11	13	
LLJ-2	5	1	1	
MOO-7	5	1	3	
RSH-4	5	16	13	
STN-3	5	1	3	
WIN-3	5	106	65	
CLR-3	6	1	3	
MBA-4	6	1	1	
MRV-3	6	13	19	
MSN-4	6	83	65	
BAL-2	7	1	8	
BMR-2	7	1	1	
BRA-3	7	1	1	
COX-3	7	1	8	
EAS-2	7	1	11	
ELG-2	7	16	3	
FTB-3	7	1	1	
GNB-4	7		1	Omit (sample missing)
GUL-3	7	11	3	
HMB-4	7	1	1	
IND-3	7	11	1	
JOR-1	7	3	1	
LLJ-1	7	1	1	
LOL-1	7	19	13	
MIN-1	7	19	13	
MOO-1	7	11	19	
RMI-1	7	1	1	
SPC-3	7	1	3	
WAK-2	7	16	11	
WLB-3	7	8	3	
BDY-3	8	1	1	
JOR-3	8	1	5	
LLJ-3	8	3	1	
RMI-4	8	3	1	
WIN-4	8	5	1	

Table A.3 - Total coliform duplicates using Central Ontario Analytical Laboratories

Site	Sample Number	Total Coliform (counts/100mL)	Total Coliform Lab Duplicate (counts/100mL)	Remarks
GNB-1	1	13	5	
HMB-1	1	46	3	
IND-2	1	11	1	
JOR-1	1	33	3	
LLJ-1	1	25	0	
RMI-4	1	22	2	
STI-2	1	22	1	
LLJ-2	2	11	15	
RMI-1	2	49	43	
BAL-1	3	119	46	
EAS-1	3	3	1	
MRV-1	3	182	53	
COX-1	5	255	50	
GNB-2	5	213	45	
HMB-2	5	141	52	
IND-3	5	255	46	
BDY-1	6	136	8	
MIN-2	6		10	Omit (missing sample)
RSH-2	6	16	0	
STN-2	6	33	1	

Table A.4 - E.Coli duplicates using Central Ontario Analytical Laboratories

Site	Sample Number	*E.Coli* (counts/100mL)	*E.Coli* Lab Duplicate (counts/100mL)	Remarks
GNB-1	1	1	2	
HMB-1	1	3	1	
IND-2	1	3	1	
JOR-1	1	3	3	
LLJ-1	1	1	0	
RMI-4	1	3	0	
STI-2	1	3	1	
LLJ-2	2	1	1	
MIN-1	2	16	28	
RMI-1	2	25	37	
RSH-1	2	36	29	
WIN-1	2	22	29	
BAL-1	3	16	21	
EAS-1	3	1	0	
MRV-1	3	36	38	
BRA-1	5	59	44	
COX-1	5	28	7	
FTB-3	5	30	30	
GNB-2	5	16	21	
HMB-2	5	16	11	
IND-3	5	8	18	
BDY-1	6	19	7	
MIN-2	6		4	Omit (missing sample)
RSH-2	6	1	0	
STN-2	6	1	0	

Table A.5 – Total Phosphorus duplicates

Site	Sample Number	Total Phosphorus (μg/L)	Total Phosphorus Duplicate (μg/L)
BRA-0	1	9.2	5
COX-0	1	6.1	5.9
IND-0	1	11.1	8
ROS-1	1	8.3	8
GNB-0	2	4.8	4.9
HMB-0	2	14	5.2
JOS-1	2	4.6	5.6
ROS-1	2	5.7	4.6
JOR-0	3	7.4	7.4
LLJ-0	3	6	5
MIN-0	3	6	6.3
RMI-0	3	6.1	5.2
RSH-0	4	4	5.5
STN-0	4	3.2	2
WIN-0	4	5.3	3.7
BDY-0	5	28.1	29.7
BMR-0	5	6.6	4.9
MUS-1	5	5.7	7.4
SPC-0	5	7.1	5.2
BAL-0	6	4.3	4.4
EAS-0	6	4.3	6.9
LOL-0	6	3.8	3.1
MBA-0	7	18.4	9.7
MRV-4	7	5.3	4.9
MSN-0	7	6.8	7.6
NRT-0	7	7	7
GUL-0	8	5.1	5.3
MUS-3	8	3.9	3.7
WLB-0	8	4.3	3.7

Table A.6 - Turbidity duplicates

Site	Sample Number	Turbidity (NTU)	Turbidity Duplicate (NTU)	Remarks
BDY-1	1		1.47	Omit (missing sample)
MIN-4	1	0.50	0.46	
RMI-5	1	0.38	0.46	
RSH-3	1	1.34	0.58	
STN-1	1	0.57	0.31	
BAL-4	2	1.31	1.57	
BMR-3	2	3.38	3.58	
LOL-2	2	2.15	1.73	
GUL-2	3	0.46	0.64	
MSN-3	3	0.76	0.78	
SPC-3	3	0.62	0.85	
WAK-2	3	0.78	1.08	
WLB-2	3	0.84	0.90	
BRA-2	4	1.14	1.12	
CLR-1	4		0.58	Omit (missing sample)
COX-2	4	0.61	0.58	
GNB-3	4	0.48	0.46	
HMB-3	4	0.38	0.56	
MRV-2	4	0.42	0.51	
BAS-3	5	1.62	0.74	
CLR-2	5	0.57	0.44	
JOR-2	5	0.98	0.77	
LLJ-2	5	0.70	0.90	
MOO-7	5	0.94	1.20	
RSH-4	5	1.64	0.86	
STN-3	5	0.48	0.49	
WIN-3	5	0.72	0.81	
CLR-3	6	0.44	0.66	
MBA-4	6	1.02	0.70	
MRV-3	6	1.41	1.45	
MSN-4	6	2.92	4.07	
BAL-2	7	1.56	0.83	
BMR-2	7	0.66	1.93	
BRA-3	7	1.76	1.80	
COX-3	7	0.74	0.70	
EAS-2	7	0.64	0.71	
ELG-2	7	0.85	0.72	
FTB-3	7	0.38	0.56	
GUL-3	7	1.10	1.84	
HMB-4	7	0.48	0.53	
IND-3	7	1.05	1.62	
JOR-1	7	1.02	1.36	
LLJ-1	7	0.61	0.55	
LOL-1	7	0.77	0.71	
MIN-1	7	0.63	0.90	
MOO-1	7	1.17	1.42	
RMI-1	7	0.62	0.60	
SPC-3	7	1.04	0.81	
WAK-2	7	0.84	1.32	
WLB-3	7	0.85	0.88	
BDY-3	8	17.20	15.80	
JOR-3	8	0.95	0.89	
LLJ-3	8	0.78	0.92	
RMI-4	8	1.47	1.18	
WIN-4	8	0.80	0.76	