Muskoka Lakes Association Water Quality Initiative:

2006 Annual Report

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Logan Environmental Consulting
1040 Islander Avenue, PO Box 942
Bracebridge, Ontario, P1L 1V2
http://www.loganenvironmental.com

Executive Summary

2006 marks the sixth 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 2006 program were developed during the 3-year pilot project and remained unchanged from those used in 2004 and 2005. Protocols and procedures may evolve in the future if necessary.

Research had two foci in 2006. The first research project focused on the effects of golf course landscapes on nearshore water quality. Data collected strongly suggested a difference between nearshore and offshore water quality, with statistical significance being evident at nearly 50% of sites monitored. Courses can be categorized as those that may have an impact on nearshore water quality and those that do not have an impact. Even with this level of correlation, it is impossible to draw defensible conclusions relating specific characteristics of courses to water quality impact.

Multiple years of inconclusive results from the research program suggest that the water quality initiative does not have the capacity to consider and draw conclusions about highly complex relationships between land uses and their impacts on water quality in the nearshore zone of Muskoka's lakes.

It is recommended that the golf course study be discontinued. Research should continue in the context of the community planning processes already initiated by the MLA. These processes, on lakes and lake segments currently facing environmental stressors, promise to engage local stakeholders in a thorough consideration of many possible environmental challenges. The community planning process will hopefully mobilize additional funding from local governments, as well as corporate and personal donations that will allow the collection of a broader range of samples if necessary.

The second research project compared offshore total phosphorus concentration measurements collected by the Muskoka Lakes Association to concentrations measured and predicted by the Lake System Health Program (LSHP). This was done in an effort to fill data gaps in the water quality model currently used by the District of Muskoka to trigger various management options suggested by the LSHP.

The phosphorus concentration measurement taken at each offshore location during the first sample period of the MLA water quality initiative could easily be used by the District of Muskoka to further calibrate their water quality model, including the provision of data where the District does not currently monitor. MLA water quality initiative nearshore data is also very valuable, as it may identify discrete sources of phosphorus loading throughout the season in an over-threshold lake or lake segment during a remedial action planning process.

One new Affiliate (the Skeleton Lake Cottagers' Organization) was added to the program in 2005. Monitoring efforts grew slightly to 156 sites monitored by over 80 volunteers. This represents a sustainable program size, especially on Lakes Muskoka, Rosseau and Joseph. Further expansion of the monitoring program on other lakes is possible, but should only be attempted with the help of outside expertise. Results of the monitoring program are once again available online at http://www.mla.on.ca.

Several recommendations are made for consideration in 2007. These recommendations include requiring a formally trained volunteer to be part of every sampling team, requiring every Affiliate to assign a volunteer "leader" to analyze bacteria samples, and undertaking an investigation into the reason that ColiPlates seemed to underestimate *E.Coli* levels when compared to lab duplicate results.

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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 2006 program represents the third year of ongoing commitment by the MLA Board of Directors to the initiative in 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 2006, the program remained funded entirely by MLA internal revenue streams and continues to be successful because of the hard work of MLA volunteers. Logan Environmental Consulting, a firm specializing in ecological monitoring and community engagement, provided strategic advice to the MLA on the initiative's design, implementation and sustainability. Mike Logan has been involved in the initiative since 2002, and served as the 2006 program advisor responsible for the oversight of day-to-day operations. Part-time summer staff hired by Logan Environmental (two individuals also employed as MLA Marine Patrollers) were responsible for field work. Increased volunteer responsibility, most notably by David Barker of Lake Muskoka, allowed more of Mike Logan's time to be spent on furthering various program objectives.

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 2006 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 that most interest them, 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 2006 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

Monitoring water quality in lakes and rivers is important for several reasons. Consumption of water (drinking) is important to all life forms, and governments around the world have instituted various health regulations and standards that water used for drinking must meet. Drinking water safety in Ontario is generally very well-regulated, despite some isolated cases of contamination such as Walkerton and Kashechwan. Ensuring safe recreational use of water bodies (e.g. swimming) is a different challenge. Environmental contaminants are always present in surface waters and various water bodies are used at different recreational intensities. The Government of Ontario has set thresholds for bacteria (*E.Coli*) to indicate safe recreational use. The Ministry of Health is responsible for monitoring water bodies and posting warnings when water is unsafe for recreation. The Ministry currently carries out this type of monitoring at public beaches.

A third type of water quality monitoring is used in some communities, particularly in Central Ontario, to document environmental quality and change. By measuring and tracking various characteristics of surface water, changes can be monitored, sources of change can be identified, and policy can be adopted to mitigate the causes of negative change.

The traditional approach to planning for lakeside development in Ontario is embodied in mathematical models that simplify both the mechanics of the ecosystem and the factors affecting regulation. 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).

This rational approach has been generally successful in predicting lakeshore capacity and limiting development. This type of approach has, in fact, been made more accurate by the latest interpretation of the District of Muskoka's water quality model, captured in the Lake System Health Program (LSHP) released in 2005. The LSHP predicts lake-specific total phosphorus thresholds over which ecosystems may be substantially altered and recommends strict development controls for lakes that have phosphorus concentrations over their threshold. This type of rational approach inevitably does not lead to one true, "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). This means considering all natural and anthropogenic influences and stresses on a lake system, including how they interrelate, and creating a plan that stakeholders can agree on.

The provincial Ministry of the Environment (MOE) also monitors lakes in several ways. The public can get involved in the Lake Partner Program, which uses volunteers to collect lake water samples. 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 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 that samples are collected infrequently (thus requiring several years' data to be scientifically meaningful) and volunteers simply 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 lacking.

The MLA water quality initiative approaches ecological monitoring differently than the District of Muskoka and the Ministry of Environment. Responding to MLA member interest, the Association began to thoroughly and systematically study water quality in both the offshore and nearshore zones in 2001, using multiple parameters to identify overall trends in water quality and to identify specific sources of stresses on the local aquatic ecosystems. Since then, the initiative has grown in scope and evolved into a marquis program of the MLA.

2.1 Objectives

Objectives for the three year pilot program were met and are documented in the 2001, 2002 and 2003 technical reports. This gave the MLA a review of existing water quality information in the Muskoka, an opinion regarding the water quality stresses of most significance to the Muskoka Lakes, and the development of a research and monitoring program. Liaison with other management initiatives and advice on stewardship initiatives are ongoing features of the water quality initiative, and capacity within the MLA itself has been developed through the water quality initiative to better meet these objectives.

Additional objectives identified in the 2005 Annual Report were as follows:

- Build on relationships and **work more closely** with the Muskoka Watershed Council (MWC) and District of Muskoka (DMM) to
    a. **adopt protocols** already used for various water quality indicators in Muskoka
    b. **collaboratively house and make available data** through new interactive web technology currently used by the MLA
- As per direction by the Lake System Health Program (LSHP), **begin to develop community-based remedial action plans** for those areas identified as over-threshold with respect to total phosphorus concentration
- **Formalize public education** program with regular seminars/workshops and email/website updates
- Attain **external funding** for the program

- Support the Muskoka Watershed Council's **benthic monitoring program** by promoting the protocol to volunteers and the MLA membership
- **Build relationships** with other residents' groups and associations in the vicinity of the Muskoka Lakes, especially program Affiliates by hosting a social event or meeting specifically to discuss results and achievements of the initiative

2.2 Technical Objectives

Several technical recommendations were also identified in 2005:

- **Continue the research program** and thoroughly review the literature dealing with waterfront golf course development in Ontario
- **Build human-capacity** by utilizing volunteers to analyze bacteria samples using ColiPlates and incubators
- Reduce consultant time commitment by **hiring part-time staff** to manage day-to-day activities
- Provide more manageable **training opportunities** for volunteers

2.3 Achievement of Objectives

Tables 2.1 and 2.2 outlines progress on each of the objectives identified in the 2005 Annual Report.

Table 2.2 - Progress on water quality initiative objectives

Objective	**Progress**
Adopt more of the protocols already used by the Watershed Council and District of Muskoka.	MWC staff invited to three workshops held to give overview of protocols used and available for the public to participate in. Minimal description of benthic monitoring given at two workshops. No follow up.
Collaboratively house and make available MLA, MWC and DMM data.	Approached MWC and DMM staff with proposal for collaboratively housing data. No interest shown.
Begin to develop community-based	Three workshops held to focus on six

remedial action plans as directed by LSHP.	lakes/lake segments identified as over-threshold. Five preliminary action plans developed.
Formalize public education program with regular seminars/workshops and email/website updates.	MLA seedling day seminar focused on water quality initiative, three additional workshops held. Regular Burgee articles and e-news articles continue. No budget provided for regular web updates.
Attain external funding for the program.	Partnership being developed with not-for-profit group Citizen's Environment Watch, which includes comprehensive fundraising strategy.
Support the Muskoka Watershed Council's benthic monitoring program.	MWC staff gave minimal description of benthic monitoring at two workshops. No interest shown by participants.
Build relationships with other residents' groups and associations in the vicinity of the Muskoka Lakes, especially program Affiliates.	Traditional volunteer appreciation BBQ held. Meeting of all Affiliates held in May to outline legal implications of initiative.

Table 2.3 - Progress on water quality initiative technical objectives

Objective	**Progress**
Continue the 2005 research program and thoroughly review the literature dealing with waterfront golf course development in Ontario.	2005 research program duplicated, with addition of sites at Muskoka Lakes Golf & Country Club. Literature review completed – multi-year study by Ministry of Environment never completed. Existing literature dependent on unfinished study.
Utilize volunteers to analyze bacteria samples using ColiPlates.	Five volunteers analyzed all samples with the help of co-ordinator and part-time staff.
Reduce consultant time commitment by hiring part-time staff to manage day-to-day activities	Two members of the MLA Marine Patrol hired for one day/week (combined) to manage day-to-day activities, with great success.

Provide more manageable training opportunities for volunteers.	Two training sessions available in May. Most volunteers participated in traditional session in Port Carling. A few participated in Gravenhurst. Generally, participation was down.

2.3.1 Partnerships

During the 2006 season there were no new partnerships created with any level or government or other decision-making agencies. However, 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. The Skeleton Lake Cottagers' Association became affiliated with the MLA on the water quality initiative for the 2006 season. The Friends of Long Lake did not participate in the initiative due to lack of organization. As a result the MLA had a total of nine community groups affiliated with the MLA's Water Quality Initiative for the 2006 season:

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

Ten more local community groups, including Ben Lake (Gravenhurst), Black Lake (Torrence), Three Mile Lake (Windermere), Clear Lake (Port Cockburn), High Lake (Rosseau), Medora Lake (Port Carling), Muldrew Lake (Gravenhurst), Pine

Lake (Gravenhurst), Sunny Lake (Gravenhurst) and Wood Lake (Bracebridge) 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 2007 water quality initiative.

3.0 Methods

3.1 Volunteers

During the 2006 season over 80 volunteers participated in the water quality initiative. The volunteers were divided into 31 teams that sampled each area across 16 lakes and rivers in Muskoka. Each team consisted of between one and nine volunteers. The large number of volunteers working on the initiative this year increased the number of individuals per team and provided more flexibility and reliable support to ensure that the required sampling was completed on each sampling day. Below is a list of the 31 teams responsible for sampling 156 sites every two weeks:

Lake Joseph

Hamer Bay
Terry Johnson
Sean Sutton

Cox Bay
Gord Ross
Fred Morrison
Susan Ross

Gordon Bay
Bev Rutherford

Little Lake Joseph
Dirk Soutendijk
Mark Johnstone

Foot's Bay
John Maas
Morag Fitzgerald
Beth Guy

Stanley Bay
Anne Jonker

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
David Burrows

Tobin's Island
Doug Applegath
John Curran

Indian River
Bill Jennings
Betty Jennings

Brackenrig Bay
Ian Wallace

Arthurlie Bay
Byron Coaker
John Reimer
Mary Reimer

Portage Bay
Larisa Long

ML G&CC
Ed Reimer
Marianne Reimer

Lake Muskoka

Bala
Bill Sloan
Len Wait
Arch Nordstrum

Muskoka River
John Wood

Boyd's Bay
John Jarvis
Thelma Jarvis

Beaumaris
Louise Cragg
Chris Cragg

East Bay
Marine Patrol

Willow Beach
Liz Denyar

Walker's Point
Mary Wiley
Peter Wiley
Alex Tilley

Muskoka Sands
Anne Stanway
Al Ward

Muskoka Bay
Brian Yeates
Diane Yeates
John Soutar
John Storey

Affiliate Associations

Bass Lake
Jon Sykes
Joanna Davey
Peter Long

Gull & Silver
Jim Davis
Brendan Davis
Gord Lee

Brandy Lake
Jim Cormack
Jerry Fisher

Silver Lake (Port Carling)
Perry Bowker

Skeleton Lake
Dan Duke
Paul Pieper

Moon River
Linda Neumann
Brian McDonald
Sherri Hopkins

Clear Lake
Bill Barker
John Frame

3.2 Sites

Rationale for site selection remained unchanged from previous years. Bacteria monitoring was maintained in the nearshore zone, with total phosphorus monitoring in the deep water zone. Sampling near golf courses was continued, and sites were added near the Muskoka Lakes Golf and Country Club, the only golf course on Lakes Muskoka, Rosseau and Joseph that was not monitored in 2005. 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 5.0.

The monitoring program did not substantially expand for the first time in the history of the water quality initiative. A total of 156 sites (up from 152 sites in 2005) were monitored biweekly throughout the summer (22 May 2006 to 4 September 2006). 148 sites were analysed for temperature and turbidity and 115 sites were analysed for bacterial contamination. Total phosphorus was measured at 77 sites.

Expansion of the monitoring program did not occur as only one additional Affiliate organization joined the program in 2006 (Skeleton Lake) and one Affiliate discontinued participation (Long Lake). Monitoring efforts on Lakes Muskoka, Rosseau and Joseph were reorganized to sample at four new sampling areas (Boyd's Bay, Muskoka Lakes Golf & Country Club, Portage Bay and Tobin's Island) and re-sample at one area (Arthurlie Bay) not sampled since 2002. To accommodate these changes, sampling at four areas was discontinued. Two of these areas (North Bay and Royal Muskoka Island) were areas where results showed no concern and two (Eilean Gowan Island and Joseph River) were areas where no volunteers were found.

As in previous years, the 156 sampling 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.

Table 3.1 - Sampling Groups

Sample Number	Group 1	Group 2
	Lake Joseph, Lake Rosseau, Bass Lake	Lake Muskoka, Gull & Silver Lakes, Brandy Lake, Muskoka River, Moon River, Clear Lake,
1	May 22, 2006	May 29, 2006
2	June 5, 2006	June 12, 2006
3	June 19, 2006	June 26, 2006
4	July 3, 2006	July 10, 2006
5	July 17, 2006	July 24, 2006
6	July 31, 2006	August 7, 2006
7	August 14, 2006	August 21, 2006
8	August 28, 2006	September 4, 2006

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

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Arthurlie Bay	ART-0	Offshore		▲	▲	▲
(Lake Rosseau)	ART-1	Residential	▲		▲	▲
	ART-2	Agriculture	▲		▲	▲
	ART-3	Agriculture	▲		▲	▲
Bala Bay	BAL-0	Offshore		▲	▲	▲
(Lake Muskoka)	BAL-1	Residential	▲		▲	▲
	BAL-2	Town Site	▲		▲	▲
	BAL-3	Residential	▲		▲	▲
	BAL-4	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	▲		▲	▲
	BDY-6	Residential	▲		▲	▲
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)	▲	▲	▲	▲
Boyd's Bay	BOY-0	Offshore		▲	▲	▲
(Lake Muskoka)	BOY-1	Residential	▲		▲	▲
	BOY-2	Residential	▲		▲	▲
	BOY-3	Marina/Airport	▲		▲	▲
Brackenrig Bay	BRA-0	Offshore		▲	▲	▲
(Lake Rosseau)	BRA-1	Residential	▲		▲	▲
	BRA-2	Residential	▲		▲	▲
	BRA-3	Residential	▲		▲	▲

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

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Clear Lake	CLR-0	Offshore		▲	▲	▲
	CLR-1	Residential	▲		▲	▲
	CLR-2	Residential	▲		▲	▲
	CLR-3	Residential	▲		▲	▲
	CLR-4	Camp (YMCA)	▲		▲	▲
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	▲	▲	▲	▲
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	▲		▲	▲
Little Lake Joseph	LLJ-0	Offshore		▲	▲	▲
	LLJ-2	Residential	▲		▲	▲
	LLJ-4	Residential	▲		▲	▲
	LLJ-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-4	Deep Water		▲		

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

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Minett	MIN-0	Offshore		▲	▲	▲
(Lake Rosseau)	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	▲		▲	▲
	MOO-8	Residential	▲		▲	▲
	MOO-9	Residential	▲		▲	▲
Muskoka Bay	MBA-0	Offshore		▲	▲	▲
(Lake Muskoka)	MBA-3	Residential	▲		▲	▲
	MBA-4	Town (Gravenhurst)	▲		▲	▲
	MBA-5	Town (Gravenhurst)	▲		▲	▲
	MBA-6	Residential	▲		▲	▲
Muskoka Lakes G&CC	MLG-0	Offshore		▲	▲	▲
(Lake Rosseau)	MLG-1	Golf Course (MLG&CC)	▲	▲	▲	▲
	MLG-2	Golf Course (MLG&CC)	▲	▲	▲	▲
	MLG-3	Golf Course (MLG&CC)	▲	▲	▲	▲
Muskoka River	MRV-1	Mouth	▲		▲	▲
	MRV-2	Santa's Village	▲		▲	▲
	MRV-3	South Branch	▲		▲	▲
	MRV-4	North Branch	▲	▲	▲	▲
Muskoka Sands	MSN-0	Offshore	▲	▲	▲	▲
(Lake Muskoka)	MSN-1	Resort (Muskoka Sands)	▲	▲	▲	▲
	MSN-2	Golf Course (Taboo)	▲	▲	▲	▲
	MSN-3	Residential	▲		▲	▲
	MSN-4	Golf Course (Taboo)	▲	▲	▲	▲
Portage Bay	POR-0	Offshore		▲	▲	▲
(Lake Rosseau)	POR-1	Agriculture	▲	▲	▲	▲
	POR-2	Residential	▲		▲	▲
Rosseau/Shadow River	RSH-0	Offshore		▲	▲	▲
(Lake Rosseau)	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	SPC-0	Offshore	▲	▲	▲	▲
Lakes)	SPC-1	Residential	▲		▲	▲
	SPC-2	Residential	▲		▲	▲
	SPC-3	Residential	▲		▲	▲

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

Location	Code	Land Use	Bacteria	Phosphorus	Turbidity	Temperature
Skeleton Lake	SKL-1	Residential	▲		▲	▲
	SKL-2	Resort (Wilson's Lodge)	▲		▲	▲
	SKL-3	Residential	▲		▲	▲
	SKL-4	Residential	▲		▲	▲
	SKL-5	Offshore		▲	▲	▲
Stanley Bay	STN-0	Offshore		▲	▲	▲
(Lake Joseph)	STN-1	Residential	▲		▲	▲
	STN-2	Residential	▲		▲	▲
	STN-3	Residential	▲		▲	▲
Tobin's Island	TOB-0	Offshore		▲	▲	▲
(Lake Rosseau)	TOB-1	Residential	▲		▲	▲
	TOB-2	Residential	▲		▲	▲
	TOB-3	Residential	▲		▲	▲
Walker's Point	WAK-0	Offshore		▲	▲	▲
(Lake Muskoka)	WAK-1	Residential	▲	▲	▲	▲
	WAK-2	Residential	▲	▲	▲	▲
	WAK-3	Residential	▲		▲	▲
	WAK-4	Residential	▲		▲	▲
Windermere	WIN-0	Offshore		▲	▲	▲
(Lake Rosseau)	WIN-1	Dee River	▲		▲	▲
	WIN-3	Golf Course (Windermere)	▲	▲	▲	▲
	WIN-4	Resort (Windermere House)	▲	▲	▲	▲
	WIN-5	Golf Course (Windermere)	▲	▲	▲	▲
Willow Beach	WLB-0	Offshore		▲	▲	▲
(Lake Muskoka)	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 again 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. It is prudent to note that 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 since 2002. 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 has remained unchanged since 2004. Water left in bacteria sampling bottles, or water collected separately for sites where bacteria was not sampled, 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

Sampling and analytical procedure for temperature has 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 QA/QC

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, 2004 and 2005, rigorous training, documentation, random duplicate measures and blank samples were used throughout the 2006 season.

Volunteers filled out and submitted data sheets providing meta-data for every sample. Training was available to all volunteers and was mandatory for new volunteers. Results of samples were recorded on paper, in MS Excel spreadsheets, and in an MS Access database. Data is additionally stored (and daily backed-up) on Web servers that host the MLA water quality initiative website.

Duplicate and blank sampling protocols are detailed in the 2002 Annual Report (Hutchinson, 2003). Five percent of phosphorus samples were duplicated and analyzed by Trent University at the Dorset Environmental Science Centre, 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 (Aquafina) 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 and analyzed internally.

4.0 Results of Quality Assurance/Quality Control Program

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 and do not 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 misinformation and procedural error are of utmost importance in the water quality initiative.

4.1 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, improper storage or contamination of ColiPlates, and contamination of the samples by volunteers.

Table 4.1 - Blank sample results

Site	Sample Number	EC Blank	TC Blank	Turb Blank	Sampler
BMR-4	1	1	1	0.12	L. Cragg
BOY-3	1	1	1	0.23	T. Jarvis
EAS-3	1	1	1	0.22	D. Hamilton
GUL-4	2	1	1	0.09	B. Davis
MBA-4	2	1	3	0.12	J. Slater
MSN-3	2	1	1	0.16	T. Smith
SKL-4	3	1	1	0.22	P. Pieper
GNB-4	4	1	1	0.18	B. Rutherford
HMB-4	4	1	1	0.21	S. Sutton
BMR-5	5	1	1	0.25	M. deGruy
BOY-1	5			0.34	T. Jarvis
EAS-1	5	1	1	0.76	Marine Patrol
MRV-2	5	1	1	0.24	J. Wood
POR-2	5	1	1	0.24	L. Long
TOB-3	5	1	1	0.18	D. Applegath
BDY-5	6	1	1		J. Cormack
MSN-1	6	1	1	0.11	A. Ward
WLB-1	6	1	1	0.18	L. Denyar
BRA-1	7	1	3	1.5	I. Wallace
COX-1	7	1	16	0.23	G. Ross
GNB-1	7	1	3	0.47	B. Rutherford
HMB-1	7	1	1	2.43	S. Sutton
POR-1	7	1	1	1.2	E. Logan
BAS-2	8	1	1	0.42	J. Davey
LLJ-2	8	1	1	0.34	D. Soutendijk
MIN-1	8	1	1	0.13	D. Burrows
MLG-1	8	1	1	0.39	E. Reimer
RSH-1	8	1	1	0.19	C. White
WIN-1	8	1	1	0.68	B. Manchee

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 a reading that could be 0, 1 or 2. Four of 29 blank samples (13.8%) therefore showed contamination. This level of contamination is approximately half the level of contamination observed in 2005, and consistent with contamination in blank samples recorded 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 one of the samples had a turbidity that exceeded twice the standard deviation above the average of all readings (highlighted in red). Interestingly, this sample did not show bacteriological contamination, which suggests that in this particular case, there may have been something wrong with the turbidimeter, foreign material on the glass vial, or some physical contaminant in the sample. In any case, one sample out of 29 does not represent systematic problems with the turbidimeter or its analysis.

Unfortunately, only 29 out of 46 scheduled blank samples were submitted by volunteers. This suggests that volunteers were either not provided with the material they needed to take the blank samples or that they were unaware of how to take the sample. Following a recommendation in the 2005 Annual Report (Lura, 2005), instructions for all QC protocols were printed on data sheets that volunteers had with them in the boat for each sampling date. Many of the volunteers are also quite familiar with QC protocols, having participated in the program for multiple years. These observations suggest that volunteers were not adequately supplied with materials to take blank samples. In the future, sampling kits should be assembled more carefully and training of part-time summer staff that may assemble the kits should be carried out more thoroughly.

While contamination in four out of 29 samples (highlighted in yellow) 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, improper handling or contamination of ColiPlates and contamination of the samples by volunteers. As this level of contamination is fairly consistent over the years of the water quality initiative, it may be helpful to refine and improve upon the sterilization protocols.

4.2 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 0.8114 suggests a lower correlation between initial samples and duplicates than in previous years. Replicability between samples (originals and duplicates) was lost even though total coliform levels were generally lower than they were in 2005.

Despite a few results that show large discrepancies between original and duplicate samples, inspection of Figure 4.1 suggests that ColiPlates still report total coliform contamination well, with an adequate consistency and without bias, especially when results are low (less than 200 counts/100mL).

Total coliform data for all duplicated samples analysed internally using ColiPlates is shown in Table A.1 in Appendix A. There was one duplicate that was not graphed as its result was outside of the ColiPlate's detection limit.

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).

Even though linear regression indicates that there is a relatively low correlation between original samples and *E.Coli* duplicates (r^2=0.7205), the largest difference between samples was 18 counts/100mL and the average absolute

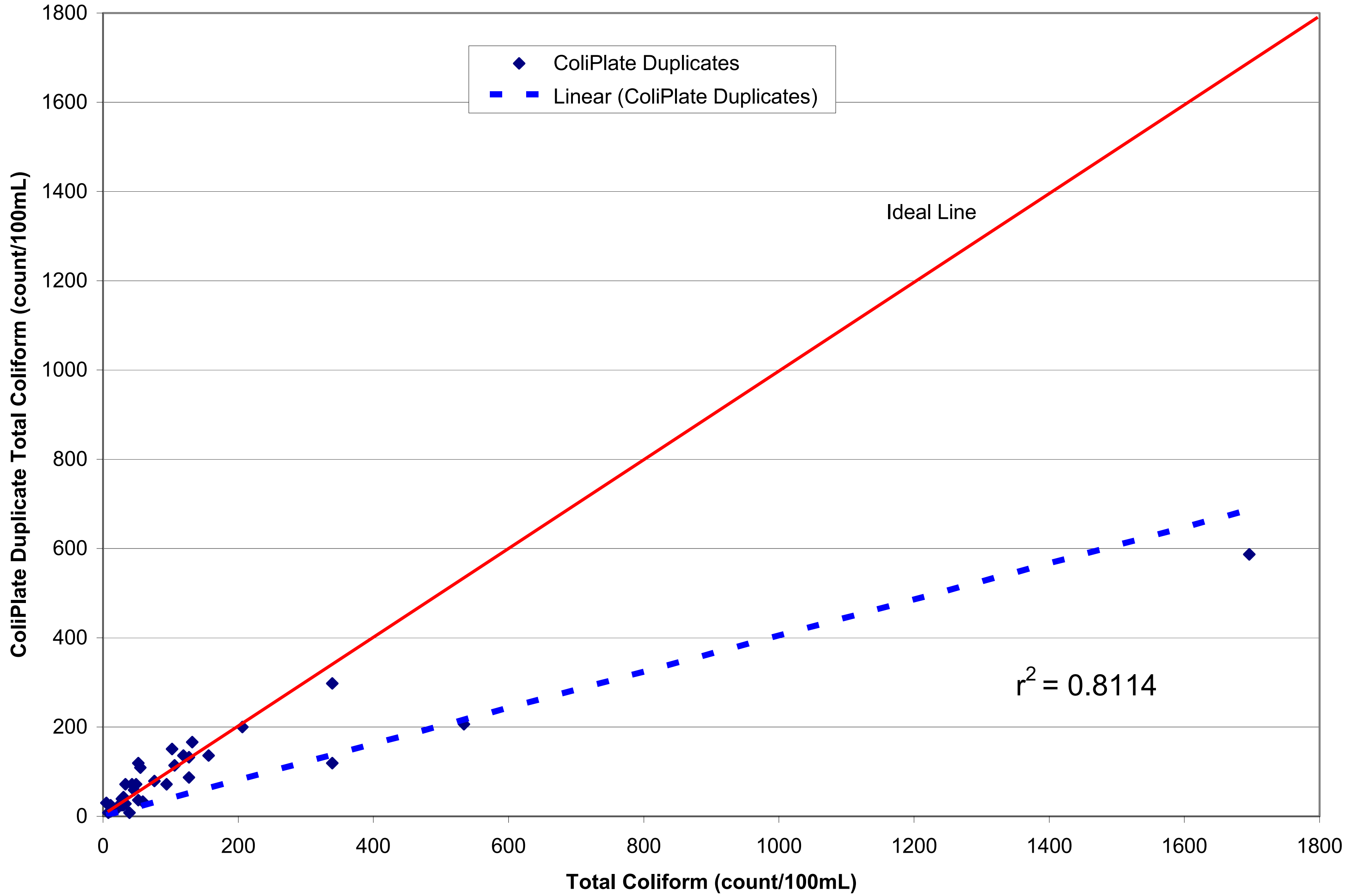

Figure 4.1 - Total coliform duplicates compared using ColiPlate technology

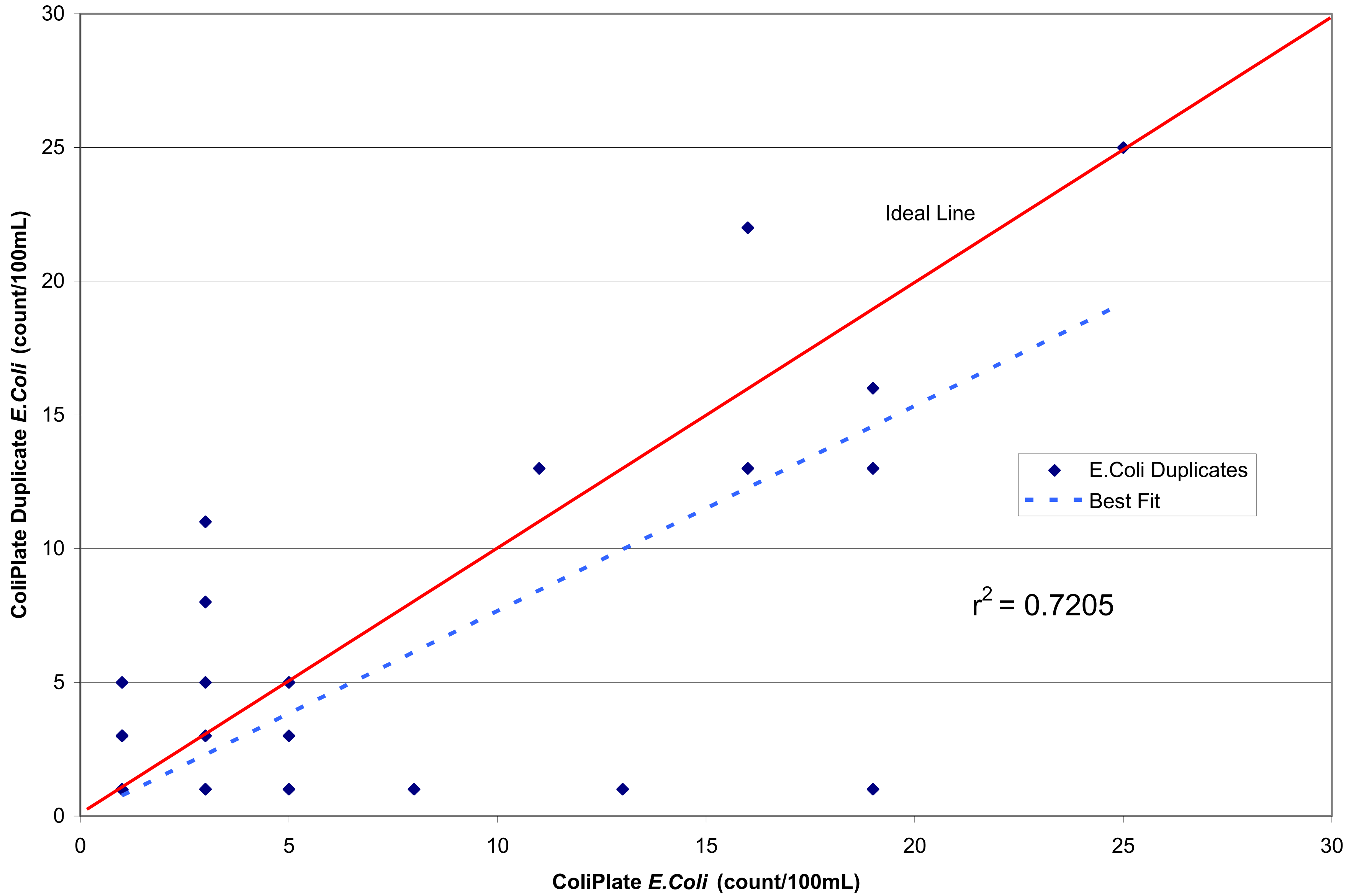

Figure 4.2 – E.Coli duplicates compared using ColiPlate technology

value difference was 3 counts/100mL. In comparison, data received from the Simcoe Muskoka District Health Unit's public beach water quality monitoring program in 2005 and discussed in Section 4.1.2 of the 2005 Annual Report (Lura, 2005) routinely showed a range in excess of 50 counts/100mL for samples taken at the same location at the same time. This suggests that accuracy of the ColiPlate technology is acceptable.

4.3 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 0.4234). Figure 4.4 similarly shows results for the E.Coli duplicates (r^2 value of 0.5571).

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 all previous years, as well as other evaluations of methods using defined substrate technology (used in the ColiPlates) (Schiefer, 2004). The increased variance is most likely due to inaccuracies in membrane filtration techniques used by commercial laboratories and may also be due to the time that passes between internal analysis and lab analysis. Figure 4.3 clearly shows that the membrane filtration techniques consistently underestimate total coliform levels, a commonly observed phenomenon (Schiefer, 2004).

Figure 4.4 shows that the ColiPlates typically underestimated *E.Coli* contamination. This result is consistent with observations from 2002 and 2004. That is, in 2002, 2004 and 2006, ColiPlates underestimated *E.Coli* levels, and in 2003 and 2005, ColiPlates overestimated *E.Coli* levels. This five-year analysis generally suggests that there is no consistent bias in the ColiPlate results; neither

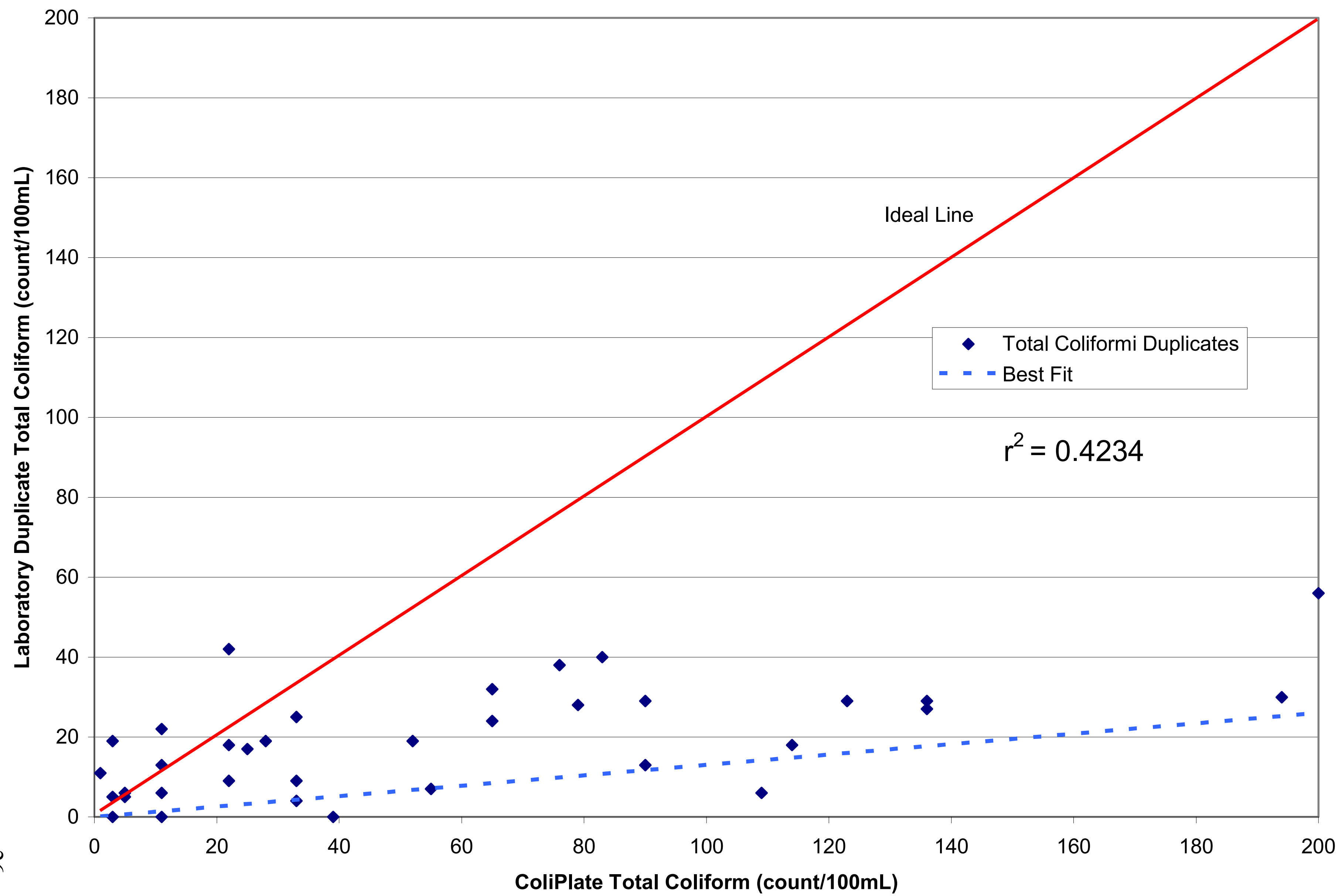

Figure 4.3 - Total coliform duplicates compared using Central Ontario Analytical Laboratory

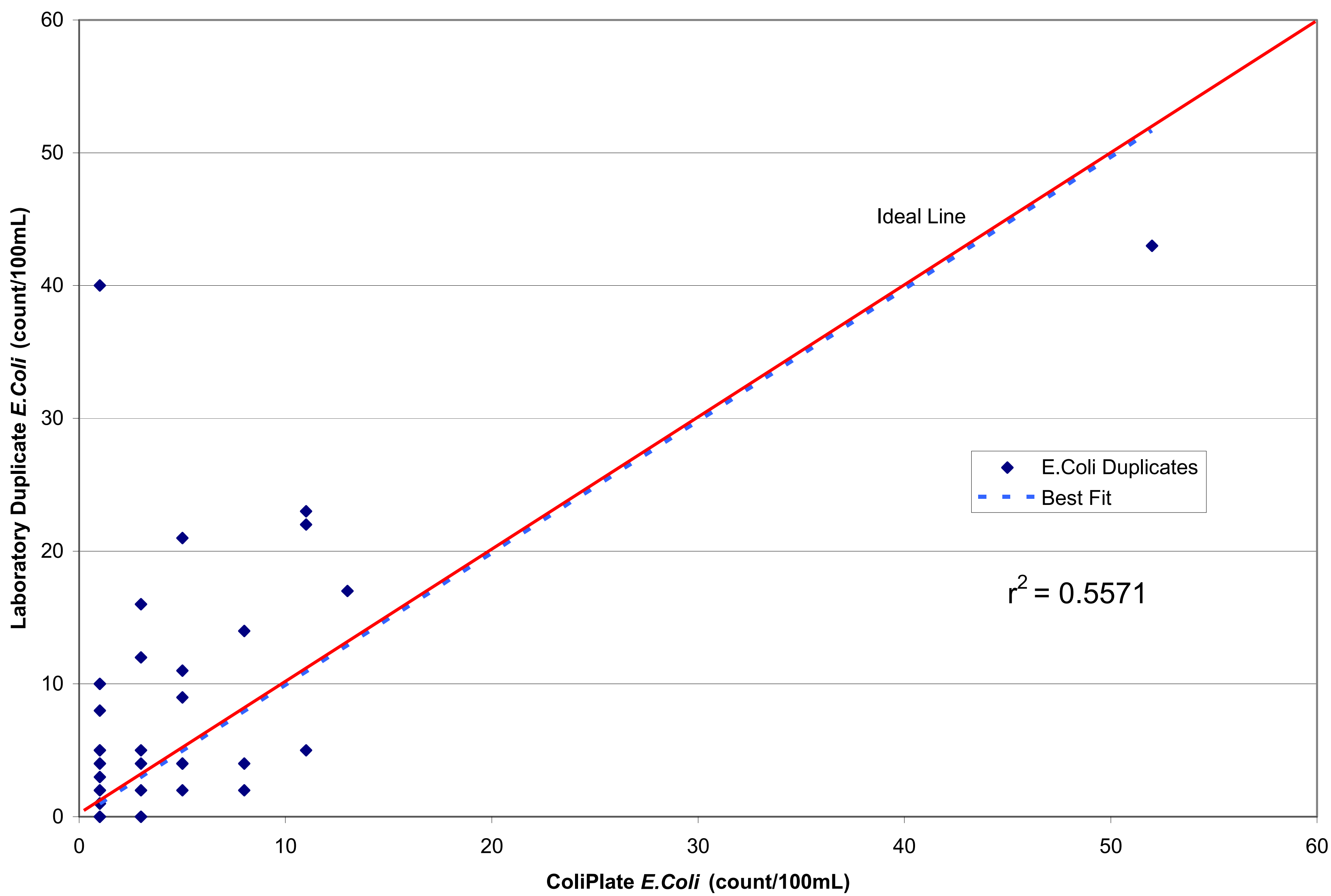

Figure 4.4 – E.Coli duplicates compared using Central Ontario Analytical Laboratory

an overestimation nor an underestimation. The ColiPlates have also typically returned readings that are in the same range as laboratory results, which suggest that they accurately indicate contamination levels. As stated above, other studies have suggested that defined substrate technology used in the ColiPlates tends to be most accurate.

It is important to note that some large discrepancies between ColiPlate results and lab results occurred in 2006. In nine out of 39 samples taken, ColiPlates returned "no contamination" (<3 counts/100mL) while lab results reported in excess of three counts/100mL, to a maximum of 40 counts/100mL. In fact, for samples where lab results were higher than ColiPlate results (22/39 samples), on average the lab reported readings 450% higher than the ColiPlates (eight lab results were lower than ColiPlate results and nine samples were the same). These large discrepancies in *E.Coli* counts seem to be somewhat systematic and are significant. It is recommended that the manufacturer of the ColiPlates be consulted to see if other users have had similar results in the past year. Possible causes and remedies should be considered.

4.4 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 the 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

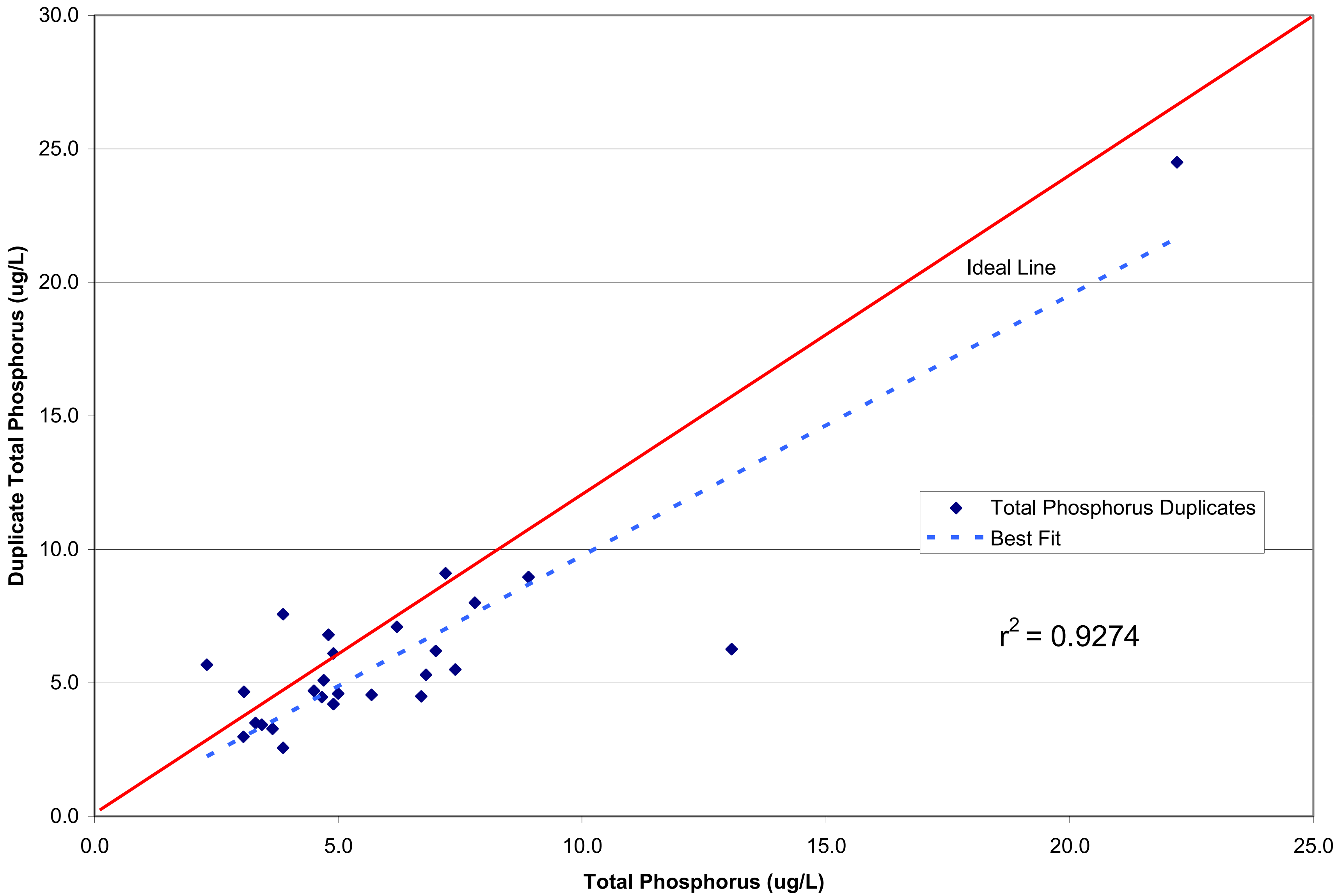

Figure 4.5 – Comparison of Phosphorus concentration duplicates

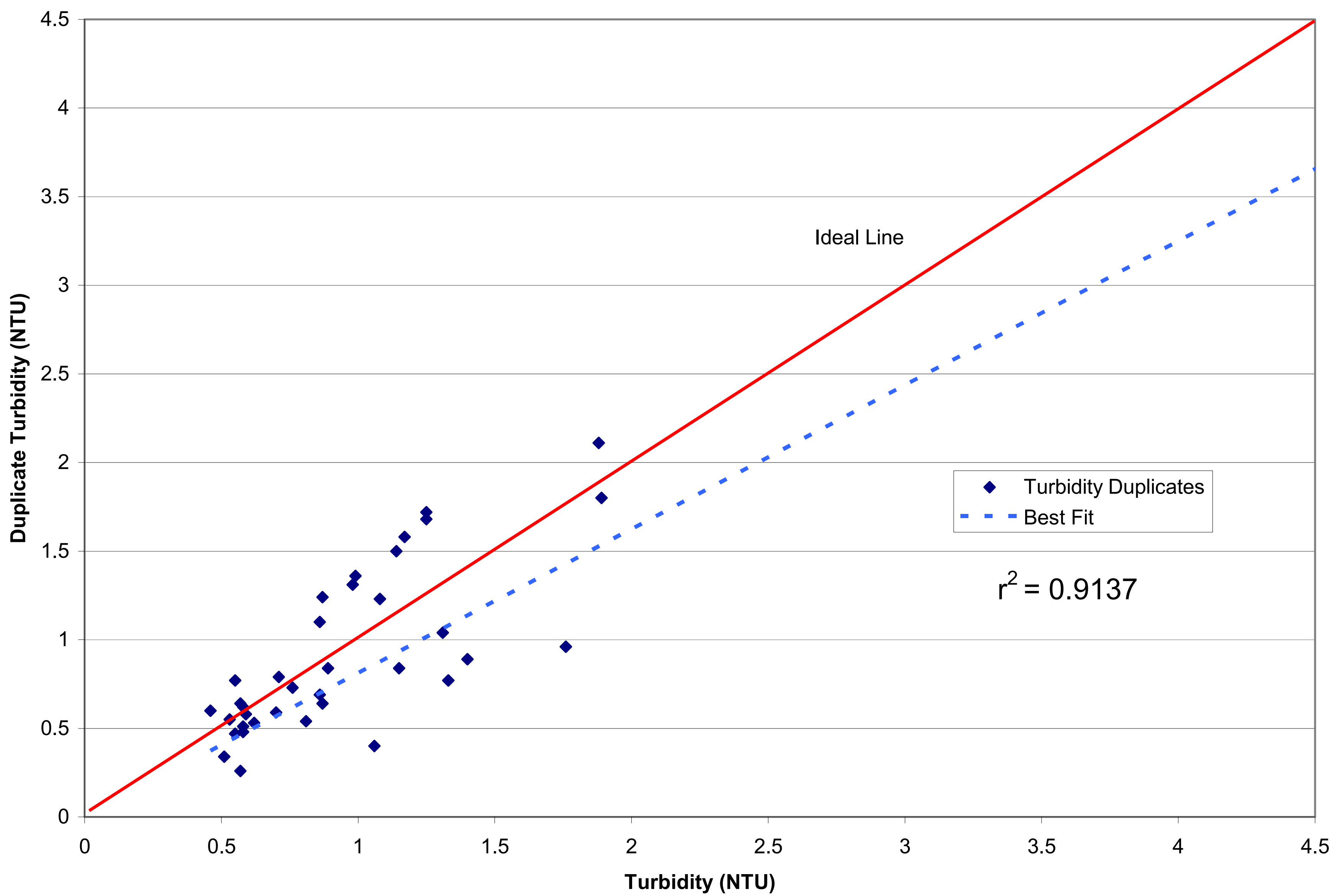

Figure 4.6 - Turbidity duplicates comparison

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 1.3µg/L and variability is represented as an r^2 value of 0.9274. This absolute difference in concentration is comparable to that observed in 2003 and 2005. The 2004 Annual Report (Logan, 2004) suggests that significant variability is likely due to on-shore influences on the nearshore zone and the 2005 Annual Report (Lura, 2005) suggests that the small variability observed that year may be due to low rainfall and water levels (reducing effects like erosion and overland runoff). It is more likely that the results in 2005 and 2006 show limited variability because they are almost exclusively taken at deep water sites, far from nearshore influences. Nearshore sites, which are more likely to contain particulate matter, constituted a much higher proportion of phosphorus duplicates prior to 2005 when phosphorus samples were first collected offshore at every sampling area (only two of 27 2006 duplicate TP samples were taken at nearshore sites). The consistency of duplicate results in 2006 and in previous years suggests that there is no bias in the results and the range of TP concentrations observed should be considered normal.

4.5 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 0.9137), suggesting that measurements recorded by the turbidimeter are consistent.

4.6 Quality Assurance/Quality Control Conclusion

Several methods of quality assurance and quality control are employed in the MLA water quality initiative. Results suggest that contamination of samples does occur from time to time, but generally there is not a consistent bias in the analysis. Results from 2006 for the first time indicated that there may be significant underestimation of *E.*Coli levels reported by the ColiPlate technology. Follow-up should be done with the manufacturer of the ColiPlates to identify possible causes and remedies for these discrepancies.

While it would be ideal to eliminate all sources of contamination and error, the five-year volunteer program has consistently produced acceptable and useable data. This consistency must be maintained, especially in the reporting of *E.Coli*, thus follow-up on the apparent underestimation is of paramount concern.

5.0 Research Program Results

The long-term goal of the MLA water quality initiative is to protect and enhance environmental quality. The primary way of accomplishing this is to change the way lands adjacent to the lakes and rivers are used and developed. The MLA hopes to do this by objectively determining what uses and styles of development are most appropriate. Hopefully, appropriate use and development can be regulated in the shorter term through local Official Plans and other planning policies. To ensure environmental sustainability and enhancement of the local ecosystem in the long term, however, appropriate development must become part of the local culture. Both the short- and long-term success of this program is dependent on building knowledge and understanding in local communities about how land use and development affects environmental quality and in turn quality of life (Logan, 2003).

The research function of the water quality initiative first considered the nearshore impacts of residential development. This research took place between 2002 and 2004. After results suggested a correlation between residential development and impacts to nearshore water quality in 2002, two hypotheses were tested at 29 research sites selected for this analysis based on physical characteristics. Results from 2003 (presented in the 2003 Final Report) proved to be inconclusive. That is, the difference between nearshore and offshore water quality that had been previously observed was not proven to be statistically significant. The 2003 research program was repeated in 2004 with a slight change in TP collection protocol (as discussed in the 2004 Annual Report) in order to determine whether 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 the results were more conclusive than they were in 2003, the hypotheses only held true at approximately 70% of the locations, and statistical significance was only 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 was similar to that of 2003 and 2004, in that its purpose was 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. Results of this comparison were not fully conclusive, as only about one third of all sites showed a difference between nearshore and offshore water quality that was statistically significant (Lura, 2005). It was felt that the observed significance was sufficient impetus to repeat the same study in 2006.

The second focus of research in 2005 was to develop a correlation between 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. A formula to best describe the relationship between the datasets was determined to be:

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

The 2005 Annual Report (Lura, 2005) recommended several ways to refine this study, including a consideration of stratification and TP flux in the nearshore zone. With the release of the District of Muskoka's Lake System Health Program (LSHP) and its official adoption in the fall of 2006, the focus of this research changed to better reflect some important knowledge gaps highlighted by the science presented in the policy. This research is fully described in Section 5.2.

5.1 Golf Course Study

The construction and operation of golf courses 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. None of this research has been adapted specifically to Muskoka. Despite the intention of the Muskoka Golf Course Research Advisory Committee of Ontario's Ministry of Natural Resources to publish Muskoka-specific data and best management practices, this report is more than five years past due. Mr. Bob Bergmann, Chairman of the aforementioned committee, did not respond to multiple phone enquiries about the status of this report.

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 can potentially impact water quality. Operating a golf course typically 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; 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, is undertaken by consultants of the developers' choosing who may not have the public interest in mind, and monitoring data is not released to the public in a timely fashion.
3) There is no evaluative data to suggest that best management practices are being practiced in Muskoka or if they work.

Forty sites were chosen to represent nearshore and offshore water quality in the vicinity of golf courses around the Muskoka Lakes (35 sites were studied in both 2005 and 2006). Specific golf courses were not singled out for study – in fact, sites in the nearshore zone adjacent to all golf courses on Lakes Muskoka, Rosseau and Joseph were monitored. These courses are:

- Beaumaris Yacht Club (Beaumaris, Lake Muskoka)
- Kirrie Glen (Willow Beach, Lake Muskoka)
- Lake Joseph Club (Cox Bay, Lake Joseph)
- Muskoka Woodlands/OviinByrd (Still's Bay, Lake Joseph and Bass Lake)
- Muskoka Lakes Golf and Country Club (south Lake Rosseau)
- 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 of golf course developments 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) Impairment of water quality around golf course developments can be attributed to characteristics of the developed landscape or operational practices of the courses.

Hypotheses 1 and 2 must be accepted before Hypothesis 3 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 or operational practices of the golf courses).

5.1.1 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 5.1 summarizes which hypotheses were confirmed for the 40 research sites (30 nearshore sites, 10 offshore sites) considered in 2006, as well as for the 36 research sites (27 nearshore sites and 9 offshore sites) considered in 2005 and the 36 research sites (26 nearshore sites and 10 offshore sites) considered in both years. 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 the 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 5.1 shows that the hypotheses were

Table 5.1 – Summary of hypothesis tests

	Hypothesis 1			Statistical Significance (H1)			Hypothesis 2			Statistical Significance (H2)		
	2005	2006	2005-06	2005	2006	2005-06	2005	2006	2005-06	2005	2006	2005-06
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	▲	▲	▲				▲	▲	▲			▲
Muksoka Lakes Golf and Country Club												
MLG-1		▲						▲			▲	
MLG-2		▲						▲				
MLG-3		▲						▲				
The Rock/Clevelands House												
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	▲	▲	▲	▲		▲	▲	▲	▲			
WIN-5		▲			▲			▲			▲	

most often true over the two-year study (Hypothesis 1 was true at 88% of sites and Hypothesis 2 at 69% 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 (50% of sites were statistically significant for Hypothesis 1 and 38% for Hypothesis 2).

It is interesting to note that statistical significance of the observations improved as the length of study increased. For example, the difference between mean phosphorus concentration at sites BMR-0 and BMR-2 was not significant in either 2005 or 2006, but was significant when 2005 and 2006 were considered together. At the same time, significance was never lost when the two years were considered together. This suggests that a larger dataset taken over a longer timeframe is useful in identifying impairment of water quality in the nearshore zone.

Perhaps more significantly, after two years of study, the data suggests that certain golf courses may have an impact on the quality of the lake water adjacent to them, while others have a lesser impact or no impact. For the purpose of this study, it is appropriate to define two categories: courses that may have an impact and those not having an impact. The former category is defined as courses where the majority (greater than 50%) of significance tests over 2005 and 2006 as summarized in Table 5.1 are positive. The latter category is defined as courses where the majority of these significance tests are negative.

Using this convention, the data from 2005 and 2006 suggest that the following courses may have an impact on the quality of lake water adjacent to them:

- Beaumaris
- The Rock/Clevelands House
- Taboo
- Windermere

and the following courses do not have an impact:

- Kirrie Glen
- The Lake Joseph Club
- Muskoka Woodlands/Oviinbyrd
- Rocky Crest

(Note that the Muskoka Lakes Golf & Country Club was not tested in both 2005 and 2006. Considered alone, 2006 results suggest that this course does not have an impact on the quality of adjacent lake water.)

Table 5.1 indicates that impairment was confirmed by between 75% and 83% of the significance tests on sites studied at the courses that may have an impact on nearshore water quality. At courses that don't seem to have an impact, between 0% and 25% of significance tests on sites studied were positive.

5.1.2 Hypothesis 3

To draw any sort of actionable conclusions from this analysis, we must consider why some courses seem to have an impact on what quality and others do not. The reasons may be related to physical features like course design or natural landscape. They may be related to management practices like fertilization application schedule, watering or runoff collection/treatment, or they may simply be related to the sensitivity of adjacent water bodies. Clearly, the complexity of the chosen research question is significant.

5.1.2.1 Sensitivity of Adjacent Water Bodies

Perhaps the easiest of these variables to eliminate from this complex scenario is the sensitivity of adjacent water bodies. One would expect that the courses that may have an impact on water quality might be located adjacent to water bodies that are more sensitive to phosphorus loading and those that do not seem to be having an impact might be located adjacent to water bodies that have high capacities for assimilating phosphorus loading. At the same time, a water body that is over-threshold may be wholly impaired to a point where the impacts of a golf course on the nearshore zone are not significant. Table 5.2 summarizes the sensitivity and current status, according to the LSHP, of the bays and lake segments adjacent to each course.

Table 5.2 - Summary of Sensitivity and Current Status of Lake Segments Adjacent to Golf Courses

Course	Bay/Lake Segment	Sensitivity	Over-threshold
Courses that May Have Impact			
Beaumaris	Lake Muskoka North	Low	No
The Rock/Cleveland's House	Lake Rosseau Main	Medium	No
Taboo	Lake Muskoka South	Low	No
Windermere	Lake Rosseau Main	Medium	No
Courses Not Having Impact			
Kirrie Glen	Lake Muskoka South	Low	No
The Lake Joseph Club	Cox Bay	Medium	Yes
Muskoka Lakes Golf & Country Club	Lake Rosseau Main	Medium	No
Muskoka Woodlands/Oviinbyrd	Lake Joseph Main	High	No
Rocky Crest	Lake Joseph Main	High	No

Table 5.2 shows that the courses that seem to have an impact on nearshore water quality are all adjacent to lake segments with low or medium sensitivity. Conversely, the courses that seem to have no impact are adjacent to lake segments that predominantly have medium and high sensitivity. In the latter grouping, Cox Bay is identified as ”over-threshold” by the LSHP, which indicates that the segment as a whole may be impaired (due to the presence of the golf course or not) to a point where the golf course landscape no longer has a recognizable impact. Moreover, the two courses in the latter category that are listed as being adjacent to highly sensitive lake segments are in fact on bays that may be substantially different from the main basin of Lake Joseph but are themselves not considered by the LSHP. It is therefore possible that these bays, considered independently, would either not be sensitive to phosphorus loading or would actually be wholly impaired, making nearshore impacts less obvious.

Generally, consideration of the sensitivity of adjacent lake segments is inconclusive.

5.1.2.2 Course Operations

We may also consider best management practices (BMPs) for course operations, and how they may affect water quality in the nearshore zone. As noted earlier, there is no published environmental data from Canadian Shield courses that indicates what BMPs are used or their effectiveness, despite several years of research by the Muskoka Golf Course Research Advisory Committee of the Ministry of Natural Resources. The committee did commission Gartner Lee Limited to write a report based on secondary research, summarizing a number of BMPs for Muskoka golf courses, including operations (GLL, 2001(b)). A series of questions based on the best management practices described in this report was posed to superintendents of the golf courses in this study. If it is apparent that courses that do not have an impact on nearshore water quality are managed using different practices than courses that may have an impact, a more detailed study into this aspect would be warranted.

Staff from greenskeeping departments from only three golf courses studied responded to the questions (henceforth referred to as the BMP Survey) in time for inclusion in this report. Courses represented were Beaumaris Yacht Club, Taboo and Rocky Crest. Clearly, this response sample is not large enough to draw conclusions from. However, these courses represented both categories of courses as discussed in Section 5.1.1; the data suggests that both Beaumaris Yacht Club and Taboo may have an impact on the water quality in the nearshore zone, while Rocky Crest does not appear to have a similar impact.

Table 5.3 summarizes the questions asked as part of the BMP survey, as well as responses of the greenskeepers surveyed. Clearly, the Beaumaris Yacht Club has fewer codified plans governing the operation of its course, while the staff person from Rocky Crest who was interviewed was less familiar with the operations of his course. Generally, the author's impression was that Taboo was the most formally organized of the three courses, that staff from the Beaumaris Yacht Club and Taboo were best educated about their course, and that all three courses employed most of the best management practices recommended by GLL, even though they weren't necessarily formally recognized in documentation. Despite the intent of staff to follow the best management practices, the formal process of planning and writing policies is extremely important to ensure that characteristics specific to the course and knowledge of the local environmental is understood by all staff (present and future) and to ensure that best management practices are being followed.

Table 2.3 - Results of BMP Survey

Golf Course Name	Beaumaris Yacht Club	Taboo	Rocky Crest
General			
Course opened	40s-50s	2002	2000
Number of holes	18	18	18
Average number of rounds/season	7000		23000
BMPs			
Do you have an Operations Manual?	Yes	Yes	No
Do you have a detailed management and reporting structure?	Yes	Yes	Yes
Are emergency response procedures documented?	No		Yes
Does you have a detailed Erosion Plan?	No	No	
Does you have a detailed Stormwater Management Plan?	No	Yes	
Do you keep a journal of environmental observations?	Yes	Yes	Yes
Do you have a fertilizer management plan?	Yes	Yes	Yes
Does you perfiorm soil sampling and analysis?	Irregularly	Yes	Yes
Do you employ Integrated Pest Management?		Yes	Yes
Does this include application rates and times for pesticides?	Yes	Yes	Yes
Does you have a site-specific monitoring program (soils, water etc.)?	Water Quality	Water Quality	Yes
Do your monitoring programs include triggers for management actions?	No	Yes	Yes
Do you have contingencies for dealing with unexpected monitoring results?	No	No	Yes
Older Courses			
Are there areas without buffer zones (at least 5m) next to watercourses?	No		
Is there currently discharge of stormwater directly to surface water bodies?	Yes		
Has there ever been an assessment of the course to determine where it may be appropriate to naturalize the landscape?	Yes		

In general, all courses need to prioritize the codification of their best management practices. Without detailed information about what practices are used to operate a course, along with detailed record-keeping, it is very difficult to evaluate the effectiveness of these practices.

5.1.3 Golf Course Research Conclusion

Even though a larger set of data collected over a longer period of time is useful in identifying impairment of water quality in the nearshore zone, it is still very difficult to attribute field observations either to the sensitivity of the adjacent lake segments or to operational practices of the courses. Both of these preliminary analyses, as described in Section 5.1.2, were inconclusive.

Multiple years (2002-2006) of inconclusive results from the research program suggest that the water quality initiative does not have the capacity to consider highly complex relationships between land uses and their impacts on water quality in the nearshore zone of Muskoka's lakes. Quite simply, these relationships must be studied in a more systematic, thorough and comprehensive way than the current program with its volunteers, funding structure and scientific protocols is capable of.

At this time, it is recommended that the golf course study be discontinued, with inconclusive results. Research should instead focus on lakes and lake segments that are facing known or unknown environmental stressors. Continuing the research through community planning processes, already started by the MLA, will allow a more thorough consideration of many possible environmental challenges in certain areas. By focussing the research on discrete geographical areas and potentially a variety of issues (rather than one specific issue across a vast region), it is likely that local stakeholders will become more engaged. The community planning process will hopefully also mobilize additional funding from local governments, as well as corporate and personal donations that will allow the collection of a broader range of samples if appropriate.

5.2 Comparison of MLA and DMM Data

As previously mentioned and discussed in some detail in previous Annual Reports, the District of Muskoka has collected total phosphorus data on about 150 lakes and lake segments (bays and unique basins within lakes) across Muskoka for more than 25 years. This data has been used to determine each lake and lake segments' trophic status, which has in turn been used to determine if restrictions to development should be employed on specific water bodies. The latest update to this model is the Lake System Health Program (LSHP). The LSHP was adopted as a planning policy by the District of Muskoka in the summer of 2006 after lengthy public consultation. The LSHP is presented as "a comprehensive program to protect our water resources" (DMM, 2006). This is an important conceptual step forward, as suggested in previous Annual Reports, as well as previous research conducted by the author (Logan, 2003). However, the program remains largely a "water quality program." Even the title of the website where information about the LSHP resides ("Enhanced Recreational Water Quality Program") makes this quite clear.

Total phosphorus collected by DMM is spring turnover total phosphorus ([TP_{so}]). Taken properly, it has been shown that [TP_{so}] adequately represents the average phosphorus concentration in the whole water body, since it is taken when the concentration is homogenous from surface to bottom. This point is called the "turnover," because it happens only when springtime warming surface waters are the same temperature as the bottom waters which stay the same temperature all year long (a second turnover occurs in the fall as cooling surface waters reach the same temperature). At other times of the year, water in most deep lakes at latitudes and altitudes similar to Central Ontario does not mix vertically, as thermal stratification physically dominates the system. Phosphorus is "locked" into one layer or another. For example, external phosphorus loading typically remains in the epilimnion, and previously stored phosphorus can be released into the hypolimnion. As with any environmental measurement, multiple averaged data more accurately represent the true value.

The updated water quality model included in the LSHP predicts the average total phosphorus concentration in all lakes and some unique lake segments across the district using a phosphorus budget. The model is then calibrated using [TP_{so}] data collected by DMM (known, measured average concentration) to give more accurate results. The calibrated phosphorus budget is then used to estimate the "background" or pre-development phosphorus concentration in the same water bodies. This estimation is simply made by removing the anthropogenic phosphorus loading from the calibrated budget. Lakes and lake segments whose predicted current phosphorus concentration is more than 50% greater than the estimated background concentration for the same lake are then identified as "over-threshold" and theoretically subjected to strict development regulations.

While this approach to modelling phosphorus concentration is logical and incorporates several guidelines to cautiously change lake classifications, there are several deficiencies with the sampling program that supports it. Clearly, it is impossible for DMM staff to take [TP] measurements precisely at the time of spring turnover (which may last a few days at most) at every lake and unique lake segment considered by the LSHP. Instead, samples are taken at some lakes and segments between ice-out and the first week of June. Some lakes are sampled bi-annually, others less frequently. Moreover, many lakes and lake segments have only been sampled a few times, or not at all, since the DMM monitoring program began in 1980.

This frequency of sampling makes model calibration, as well as lake classification, difficult, since the LSHP policy states that for a lake to change classification, three consecutive [TP_{so}] samples must indicate the change (that is, three consecutive [TP_{so}] samples must be over the lake's threshold [TP] for it to be classified as "over-threshold" and three consecutive must be under the lake's threshold for it to be de-classified) (GLL, 2005; Brouse, 2006). Therefore, if a lake is monitored bi-annually, this change in classification would take at least four years. If a lake is sampled less frequently, reclassification would take much longer. Many lakes and lake segments considered by the LSHP have never been monitored by the DMM program, meaning that they cannot be classified at all. This problem is especially significant for many bays on the large lakes (especially Muskoka, Rosseau, and Joseph) that are not considered separate segments despite having hydrologic characteristics that are esoterically very different from the open basins. Many of these segments are also experiencing acute and significant development pressures.

Since DMM only collects spring turnover data, it is also very difficult, if not impossible, to identify sources of phosphorus loading in lakes and segments that are classified as "over-threshold." Continued monitoring over many years will only serve to identify average [TP] trends. Information required for designed effective stewardship activities and other remedial measures is not collected by DMM or any other government agency.

Two distinct LSHP data gaps that could be filled by MLA TP data emerge from this evaluation of the DMM monitoring program. These are supplementing the [TP_{so}] measurements taken with more frequent measurements and identifying sources of phosphorus loading within over-threshold areas.

5.2.1 Comparing MLA [TP] Data to LSHP Classifications

The first way MLA [TP] data can be used to fill data gaps in the DMM monitoring program is by using deep water or "offshore" results from the MLA program to supplement DMM monitoring data. This may include adding MLA [TP_{so}] results to the dataset to provide more frequent measurements (including sampling areas that are not specifically modelled by the LSHP). The MLA data can also be used as a "second opinion;" MLA results can be compared to DMM results and calculated threshold to confirm or dispute a lake or lake segment's classification. Table 5.4 shows how the phosphorus concentration measured in each lake and

Table 5.4 - Comparison of 2006 [TP] (ug/L) to Threshold Concentrations Identified in LSHP

Sampling Area	Threshold	MLA $[TP_{so}]$	MLA Offshore Average [TP]	MLA Average [TP]	DMM $[TP_{so}]$
Arthurlie Bay	6.225	6.2	5.6		
Bala Bay	6.58	5.7	5.9		6.1
Bass Lake	9.15	10.9	7	7.6	23.9
Brandy Lake	28.39	20.7	26		22.9
Beaumaris	6.73	5.5	5.8	8.5	
Boyd's Bay	7.9	6.8	9.8		5.1
Brackenrig Bay	5.18	5.6	7.7		
Clear Lake	4.79	12.4	6.4		6.4
Cox Bay	3.85	4.4	8.5	7.2	
Dudley Bay	6.6	5	5.7		5.2
East Bay	6.58	9.7	6.2	6.8	
Gordon Bay	3.47		3.2		
Gull Lake	8.07	6.4	9		6.4
Hamer Bay	3.47	7.1	6.1	6.5	
Hoc Roc River	25.06	26.1	22.4		
Indian River	6.22	2.9	5.8	23.3	
Joseph River	4.23	7.5	5.7		
Lake Joseph (Main)	3.47	2.5	3.8		
Lake Muskoka (South)	7.9	4.7	6		5.1
Lake Rosseau (Main)	6.22	3.1	4		
Little Lake Joseph	4.64	3.9	4		
Minett	6.22	4.5	4.5	6.2	
Moon River	6.46	5.1	7.9	7.4	
Muskoka Bay	10.25	5.9	8		12.3
Muskoka Lakes G&CC	6.22	4.8	5.2	10.1	
Muskoka River	11.08	6.6	9.4		
Muskoka Sands (no Hoc Roc)	7.9	5.1	7.5	9	
Portage Bay	3.92		4.2	5.6	
Rosseau	4.24	6.2	4.4		
Skeleton Bay	5.44	4.9	5.1		
Skeleton Lake	4.45	4.7			4.2
Silver Lake (GR)	13.28	8.3	9.1		
Silver Lake (TML)	5.23	10.6	7.8		
Stanley Bay	3.43				
Still's Bay	3.47	5	4.2	4.4	
Tobin's Island	6.22	5.9	5.2		
Walker's Point	7.9	5.1	7.9	7.9	
Whiteside Bay	10.16	4.4	7.1		5.4
Winderemere	6.22	3.9	4.6	9.5	
Willow Beach	7.9	55.3	14.2	16.8	

lake segment within the MLA program area compares with the specific threshold identified in the LSHP. The table summarizes whether the LSHP classifies the lake or lake segment as over-threshold ("Threshold" column shaded red). It also summarizes whether or not four measurements were above this same threshold (corresponding column shaded red). These four measurements are as follows:

1. Spring turnover total phosphorus concentration ([TP_{so}]) measured by the MLA water quality initiative (the first [TP] sample taken at each areas' offshore site).
2. Average (seasonal) [TP] measured by the MLA water quality initiative at each areas' offshore site.
3. Average (seasonal) [TP] measured by the MLA water quality initiative at all sites in each area (if nearshore sites are sampled).
4. ([TP_{so}]) measured by DMM (collected to calibrate and update the LSHP as discussed).

Table 5.5 describes the sampling areas that returned results different from the lake or lake segment classification in the LSHP, including recommended actions. All MLA [TP_{so}] data, plotted against lake- and segment-specific threshold, are shown in Appendix B.

Table 5.5 - MLA data differing from LSHP classifications

Sampling Area	Discussion	Recommendation
Bass Lake	[TP_{so}] readings from both the MLA and DMM indicated that Bass Lake was over-threshold in 2006.	Review all MLA [TP] data to establish the priority for reclassifying Bass Lake.
East Bay	East Bay is not specifically considered by the LSHP. When compared with the [TP] threshold value determined for Bala Bay, [TP_{so}] readings from the MLA indicate that East Bay was over-threshold in 2006. Note that one out of seven readings taken was above the threshold value.	None

Gull Lake	[TP_{so}] readings from both the MLA and DMM indicated that Gull Lake was not over-threshold in 2006.	Engage in community-based action plan, with support of DMM.
Hamer Bay	Hamer Bay is not specifically considered by the LSHP, and it is not within the District of Muskoka. When compared with the [TP] threshold value determined for the main basin of Lake Joseph, [TP_{so}] readings from the MLA indicate that Hamer Bay was over-threshold in 2006. Six out of seven readings taken were above the threshold.	Consider Hamer Bay to be "over-threshold" and prioritize community-based action plan with support of Seguin Township.
Hoc Roc River	[TP_{so}] readings from the MLA indicate that the Hoc Roc River was over-threshold in 2006. Two out of seven readings were above the threshold. DMM has never sampled the Hoc Roc River, and therefore cannot classify this segment.	Review all MLA [TP] data to establish the priority for reclassifying the Hoc Roc River. Lobby DMM to monitor Hoc Roc River.
Joseph River	[TP_{so}] readings from the MLA indicate that the Joseph River was over-threshold in 2006. Five out of seven readings were above the threshold. DMM has only sampled this site twice, and therefore cannot classify this segment.	Review all MLA [TP] data to establish the priority for reclassifying the Joseph River. Prioritize community-based action plan.
Muskoka Bay	[TP_{so}] readings from the MLA indicate that Muskoka Bay was not over-threshold in 2006. Eight out of eight readings were below the threshold. [TP_{so}] readings from the DMM indicate that Muskoka Bay was over-threshold in 2006.	Engage in community-based action plan with support of DMM.
Town of Rosseau (north Lake Rosseau)	North Lake Rosseau is not specifically considered by the LSHP, and it is not within the District of Muskoka. When compared with the [TP] threshold value determined for Morgan Bay, [TP_{so}] readings from the MLA indicate that the north basin was over-threshold in 2006. Four out of eight readings taken were above the threshold.	Review all MLA [TP] data to establish the priority for classifying North Lake Rosseau.
Skeleton Lake	[TP_{so}] readings from the MLA indicate that Skeleton Lake was over-threshold in 2006. One out of five readings were above the threshold. [TP_{so}] readings from the DMM	None

	indicate that the lake was not over-threshold in 2006.	
Still's Bay	Still's Bay is not specifically considered by the LSHP. When compared with the [TP] threshold value determined for the main basin of Lake Joseph, [TP_{so}] readings from the MLA indicate that Still's Bay was over-threshold in 2006. Seven out of seven readings taken were above the threshold value.	Review all MLA [TP] data to establish the priority for classifying Still's Bay. Lobby DMM to consider Still's Bay as a unique lake segment and begin monitoring.
Willow Beach	Willow Beach is not specifically considered by the LSHP. When compared with the [TP] threshold value determined for the south basin of Lake Muskoka, [TP_{so}] readings from the MLA indicate that Willow Beach was over-threshold in 2006. Two out of seven readings taken was above the threshold value.	Review all MLA [TP] data to establish the priority for classifying Willow Beach. Lobby DMM to consider Willow Beach as a unique lake segment and begin monitoring.

5.2.2 Using MLA [TP] Data to Identify Sources of TP Loading

The second way MLA [TP] data can be used to fill data gaps in the DMM monitoring program, is to use nearshore total phosphorus results to determine differences in nutrient concentration and sources of phosphorus loading on a finer scale within a small lake or bay. The analysis of the data for this purpose is complex and must be considered as part of a large-scale strategy such as the community planning process that the MLA is currently engaging (Logan Environmental, 2006). In fact, this more detailed knowledge is necessary for taking actions to remediate a local environment with a high phosphorus concentration and is not currently collected by any government agency or other research program.

5.2.3 MLA and DMM Data Comparison Conclusion

Two significant deficiencies exist in the current system of data collection for the calibration of the LSHP's water quality model. These are significant, because as a model is refined, the expectations of its users increase and the model demands more advanced data and calibration. The MLA water quality initiative has the capacity to fill these two data gaps.

The MLA should suggest to the District of Muskoka that data from the water quality initiative be used alongside DMM-collected data to calibrate the water quality model and classify lakes and lake segments. Slight changes to the MLA phosphorus protocol could be made, or additional samples could be collected on the first sample date to accommodate protocol requirements of DMM. Further, the MLA should insist that Lakes Muskoka, Rosseau and Joseph be further divided into unique lake segments to truly reflect unique hydrological characteristics, development pressures, and [TP] data collected since 2001. Each of these lake segments should be monitored and classified as part of the LSHP.

Finally, the MLA should continue with its intended community-based plans at specific over-threshold areas on Lakes Muskoka, Rosseau and Joseph, using the nearshore [TP] and bacteria data to identify environmental stressors and design remedial actions.

6.0 Recommendations

Several changes are recommended to increase the efficacy of the 2007 MLA water quality initiative.

Despite the apparent lack of interest in cooperation from the Muskoka Watershed Council, the MLA should continue to work towards a closer relationship with this agency. It would benefit all if the Watershed Council helped the MLA to adopt protocols that MWC already uses 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 could, in fact, house and manage the information currently indexed on the Muskoka Water Web (http://www.muskokawaterweb.ca).

The MLA should also continue to endeavour to work more closely with the District of Muskoka in developing and applying the Lake System Health Program. The MLA should continue to support the community planning process started in six over-threshold areas in 2006.

The public education campaign should make full use of the MLA website. Bi-weekly or monthly updates on the program could easily be sent to all MLA members through new electronic newsletters and website updates.

The MLA should build a relationship with Citizens' Environment Watch, a not-for-profit environmental organization interested in citizen monitoring and capacity building. This relationship could be most beneficial in terms of further developing the program, attaining external funding and liaising with local media and governments.

6.1 Research Function

Multiple years of inconclusive results from the research program suggest that the water quality initiative does not have the capacity to consider and draw conclusions about highly complex relationships between land uses and their impacts on water quality in the nearshore zone of Muskoka's lakes. Neither the level of funding for the program nor the commitment of volunteers are sufficient to perform the level of background research and to collect and analyze the range of indicators necessary for drawing conclusions about these complex relationships.

It is recommended that the golf course study be discontinued. Research should continue in the context of the community planning processes already initiated by the MLA. These processes, on lakes and lake segments currently facing environmental stressors, promise to engage local stakeholders in a thorough consideration of many possible environmental challenges directly of interest to these stakeholders. The community planning process will hopefully also mobilize additional funding from local governments, corporate and personal donations that will allow the collection of a broader range of samples.

In conducting research in the lakes and lake segments subject to a community plan, greater significance and consideration should be given to bacteriological results (Coliform and *E.Coli*.) In this context, it is also imperative that an investigation of the underestimation of *E.Coli* by Coliplates be undertaken.

6.2 Monitoring Function

The monitoring function of the program on Lakes Muskoka, Rosseau and Joseph has reached a capacity in terms of number of volunteers engaged and sites sampled. While significant opportunity for expanding the geographical scope of the program exists outside of the "big three" Muskoka Lakes, this should be accomplished in partnership with an ENGO that specializes in this type of work, such as Citizens' Environment Watch. The expertise and capacity of Citizens'

Environment Watch or a similar group would alleviate some of the demands currently placed on volunteer MLA Directors.

The program should continue to utilize volunteers to analyse bacteria samples using ColiPlates and incubators. Affiliate associations should be required to provide at least one volunteer to analyse samples and maintain the dataset for their own area. This would not only reduce program operating costs, 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. 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.

Part time staff involved in program management should be more thoroughly trained to ensure that all sampling equipment is distributed to the volunteers appropriately. This is especially true of the equipment needed for duplicate and blank samples.

To improve the program technically, more effort should be devoted to training volunteers in the protocols. Training should be required for all volunteers (meaning at least one formally trained volunteer must always be present on a sample collection team). More effort should also be devoted to proper sterilization of collection bottles; if at all possible, laboratory grade sterilization equipment should be acquired.

Report Prepared by:

Michael Logan, BSc MASc MURP
Principal
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Appendix A

Detailed QA/QC Results

Table A.1 - Total coliform duplicates using ColiPlate technology

Site	Sample Number	Total Coliforms (counts/100mL)	TC ColiPlate Duplicate (counts/100mL)	Remarks
MLG-2	1	11	13	
POR-1	1	339	119	
RSH-2	1	206	200	
TOB-2	1	30	43	
WIN-3	1	11	25	
BAL-3	2	8	8	
BMR-3	2	11	11	
BOY-2	2	28	28	
SKL-2	2	156	136	
GUL-2	3	171	>2424	Omit (out of range)
WAK-2	3	22	19	
WLB-2	3	339	298	
MOO-4	3	55	109	
ART-2	4	59	33	
BRA-2	4	52	119	
COX-3	4	132	166	
IND-6	4	22	22	
SPC-2	4	28	25	
CLR-2	4	28	39	
GNB-3	5	5	30	
HMB-3	5	39	8	
IND-5	5	76	79	
LLJ-5	5	52	36	
MIN-4	5	11	13	
MLG-3	5	1696	587	
RSH-3	6	49	72	
SKL-2	6	94	72	
STN-3	6	46	59	
TOB-3	6	127	132	
WIN-3	6	43	72	
BAS-3	7	119	136	
GUL-3	7	30	25	
MRV-3	7	106	114	
WAK-3	7	28	28	
WLB-3	7	534	206	
ART-3	8	127	87	
BRA-3	8	33	72	
CLR-3	8	33	28	
COX-4	8	102	151	

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

Site	Sample Number	*E.Coli* (counts/100mL)	*E.Coli* ColiPlate Duplicate (counts/100mL)	Remarks
MLG-2	1	1	3	
POR-1	1	19	16	
RSH-2	1	16	22	
TOB-2	1	1	1	
WIN-3	1	3	1	
BAL-3	2	5	1	
BMR-3	2	1	3	
BOY-2	2	1	1	
SKL-2	2	16	13	
GUL-2	3	1	3	
WAK-2	3	3	8	
WLB-2	3	25	25	
MOO-4	3	1	1	
ART-2	4	8	1	
BRA-2	4	19	13	
COX-3	4	1	5	
IND-6	4	3	1	
SPC-2	4	1	1	
CLR-2	4	1	1	
GNB-3	5	1	1	
HMB-3	5	1	3	
IND-5	5	3	11	
LLJ-5	5	1	1	
MIN-4	5	1	3	
MLG-3	5	1	1	
RSH-3	6	1	1	
SKL-2	6	5	3	
STN-3	6	3	3	
TOB-3	6	5	5	
WIN-3	6	1	3	
BAS-3	7	1	1	
GUL-3	7	1	1	
MRV-3	7	11	13	
WAK-3	7	1	1	
WLB-3	7	13	1	
ART-3	8	19	1	
BRA-3	8	3	3	
CLR-3	8	1	1	
COX-4	8	3	5	

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

Site	Sample Number	TC (counts/100mL)	TC Lab Duplicate (counts/100mL)	Remarks
HMB-1	1	39	0	
MIN-1	1	3	0	
COX-1	1	3	5	
IND-2	1	11	22	
LLJ-2	1	11	6	
STI-2	1	25	17	
TOB-1	2	11	0	
MIN-4	2	22	18	
WIN-5	2	510	8	
BAS-3	2	76	38	
STN-1	2	5	6	
MLG-1	2	1	11	
RSH-1	2		29	Omit (missing sample)
EAS-1	3	33	4	
BOY-1	3	156	>80	Omit (data out of range)
MRV-1	3	83	40	
BMR-2	3	22	42	
MBA-6	3	52	19	
MSN-1	4	136	29	
WAK-1	4	33	9	
WLB-1	4	11	13	
GUL-1	4	240	52	
MOO-8	4	22	9	
BAL-1	4	102	>80	Omit (data out of range)
ART-1	5	55	7	
BRA-1	5	28	19	
POR-2	6	65	24	
COX-2	6	114	18	
HMB-2	6	194	30	
GNB-2	6	90	29	
IND-3	6	28	>80	Omit (data out of range)
LLJ-4	6	136	27	
FTB-3	6	280	>80	Omit (data out of range)
BAL-2	7	200	56	
SPC-1	7	33	25	
MSN-2	7	79	28	
CLR-1	7	5	5	
WAK-2	8	171	>80	Omit (data out of range)
MOO-3	8	65	32	
MBA-3	8	109	6	
MRV-2	8	123	29	
BDY-2	8	3	19	
BMR-6	8	90	13	

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
HMB-1	1	3	0	
MIN-1	1	3	0	
COX-1	1	1	0	
IND-2	1	3	16	
LLJ-2	1	1	0	
STI-2	1	5	11	
TOB-1	2	1	0	
MIN-4	2	1	3	
WIN-5	2	1	4	
BAS-3	2	8	4	
STN-1	2	1	0	
MLG-1	2	1	1	
RSH-1	2		22	Omit (missing sample)
EAS-1	3	8	2	
BOY-1	3	1	>60	Omit (data out of range)
MRV-1	3	13	17	
BMR-2	3	1	10	
MBA-6	3	3	5	
MSN-1	4	11	5	
WAK-1	4	3	2	
WLB-1	4	1	8	
GUL-1	4	11	23	
MOO-8	4	1	4	
BAL-1	4	1	>60	Omit (data out of range)
ART-1	5	5	2	
BRA-1	5	8	14	
POR-2	6	1	1	
COX-2	6	5	4	
HMB-2	6	5	9	
GNB-2	6		0	Omit (missing sample)
IND-3	6	5	21	
LLJ-4	6	1	5	
FTB-3	6	1	40	
BAL-2	7	11	22	
SPC-1	7	1	5	
MSN-2	7	5	4	
CLR-1	7	1	1	
WAK-2	8	52	43	
MOO-3	8	1	10	
MBA-3	8	1	2	
MRV-2	8	3	12	
BDY-2	8	1	2	
BMR-6	8	3	4	

Table A.5 – Total Phosphorus duplicates

Site	Sample Number	Total Phosphorus (μg/L)	Total Phosphorus Duplicate (μg/L)
MUS-3	1	4.7	4.5
ROS-1	1	3.1	4.7
COX-0	2	3.9	2.6
HMB-0	2	13.1	6.3
STI-0	2	3.9	7.6
BDY-0	3	22.2	24.5
IND-0	3	6.7	4.5
LLJ-0	3	4.9	6.1
MIN-0	3	4.5	4.7
MLG-0	4	3.1	3.0
RSH-0	4	3.7	3.3
STN-0	4	2.3	5.7
TOB-0	4	3.4	3.4
WIN-0	4	5.7	4.6
POR-0	5	4.5	4.7
BAL-0	6	6.8	5.3
BMR-0	6	7.4	5.5
EAS-0	7	4.8	6.8
MBA-0	7	7.2	9.1
STI-2	7	3.3	3.5
WIN-0	7	4.9	4.2
GUL-0	8	7.8	8.0
MSN-0	8	6.2	7.1
POR-1	8	8.9	9.0
ROS-1	8	4.7	5.1
ROS-4	8	5.0	4.6
WLB-0	8	7.0	6.2

Table A.6 - Turbidity duplicates

Site	Sample Number	Turbidity (NTU)	Turbidity Duplicate (NTU)
MLG-2	1	0.87	1.24
POR-1	1	0.99	1.36
RSH-2	1	6.46	4.41
TOB-2	1	1.40	0.89
WIN-3	1	1.33	0.77
BAL-3	2	0.76	0.73
BMR-3	2	0.55	0.47
BOY-2	2	0.81	0.54
GUL-2	3	1.14	1.50
WAK-2	3	0.86	1.10
WLB-2	3	0.71	0.79
ART-2	4	0.55	0.77
BRA-2	4	1.88	2.11
CLR-2	4	0.58	0.51
COX-3	4	0.62	0.53
IND-6	4	1.31	1.04
SPC-2	4	0.58	0.62
GNB-3	5	0.70	0.59
HMB-3	5	0.59	0.58
IND-5	5	1.89	1.80
LLJ-5	5	0.57	0.26
MIN-4	5	0.51	0.34
MLG-3	5	1.08	1.23
RSH-3	6	0.86	0.69
SKL-2	6	0.53	0.55
STN-3	6	0.87	0.64
TOB-3	6	1.76	0.96
WIN-3	6	0.46	0.60
BAS-3	7	1.25	1.68
GUL-3	7	0.98	1.31
MRV-3	7	1.15	0.84
WAK-3	7	0.57	0.64
WLB-3	7	1.25	1.72
ART-3	8	1.06	0.40
BRA-3	8	1.17	1.58
CLR-3	8	0.89	0.84
COX-4	8	0.58	0.48

Appendix B

MLA [TP] Results Plotted Against Threshold Value

Figure B.1 - Arthurlie Bay Total Phosphorus Concentration

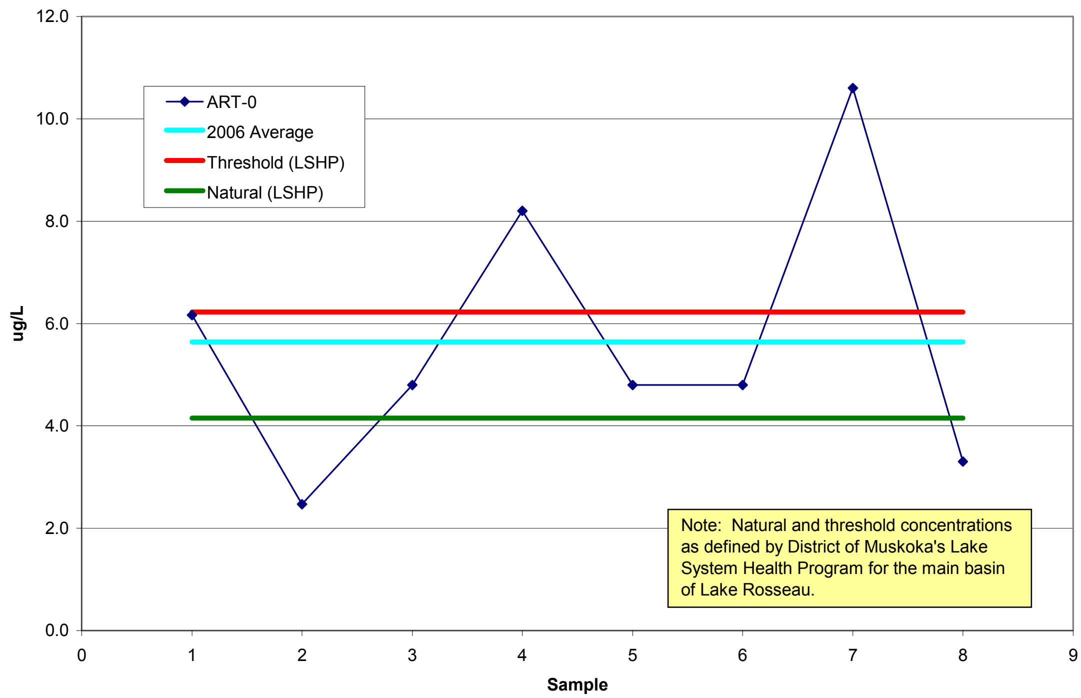

Figure B.2 - Bala Bay Total Phosphorus Concentration

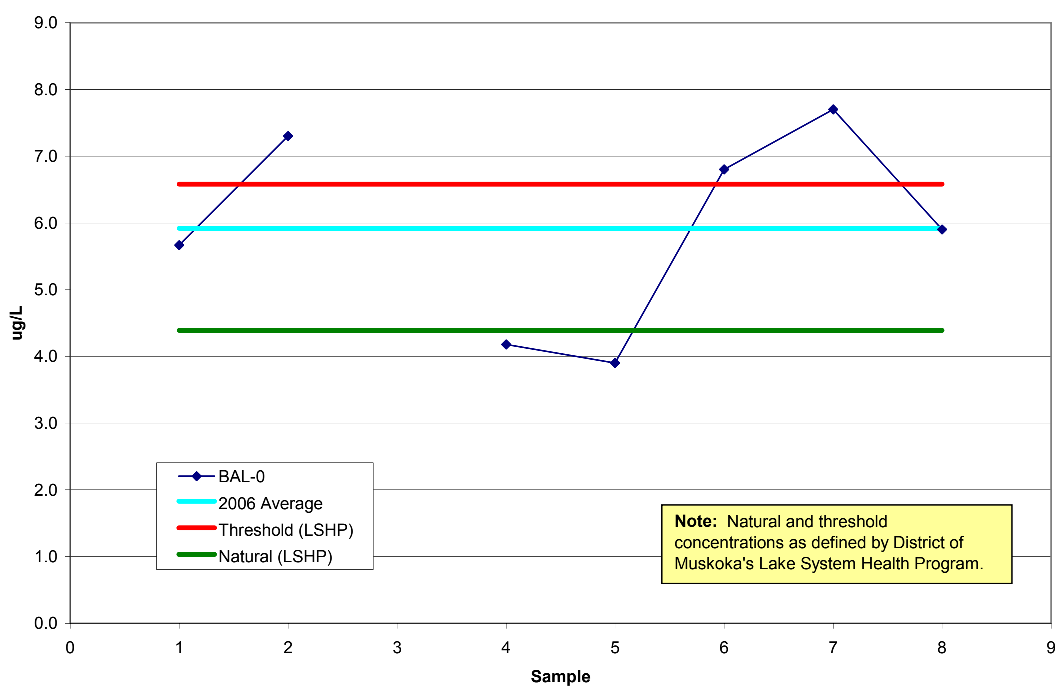

Figure B.3 - Bass Lake Total Phosphorus Concentration

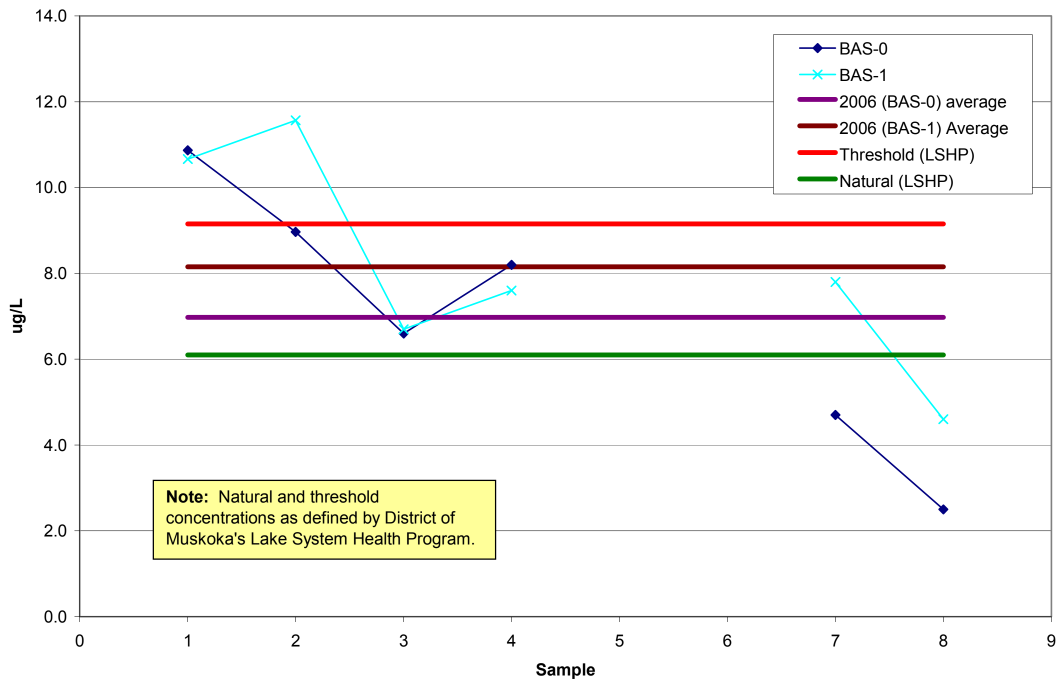

Figure B.4 - Brandy Lake Total Phosphorus Concentration

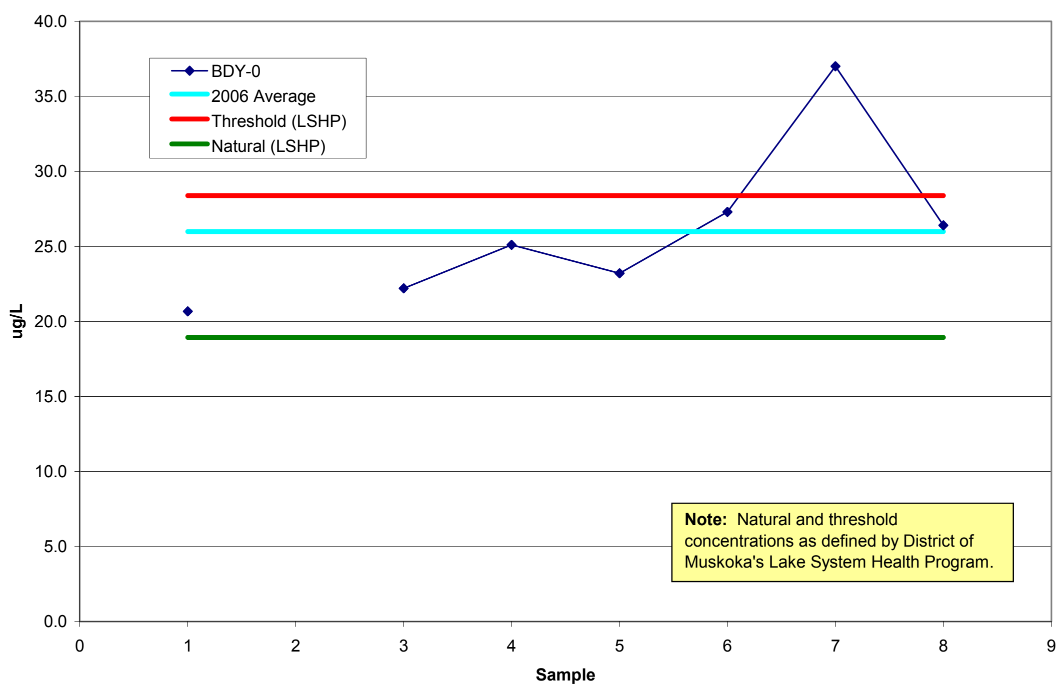

Figure B.5 - Beaumaris Total Phosphorus Concentration

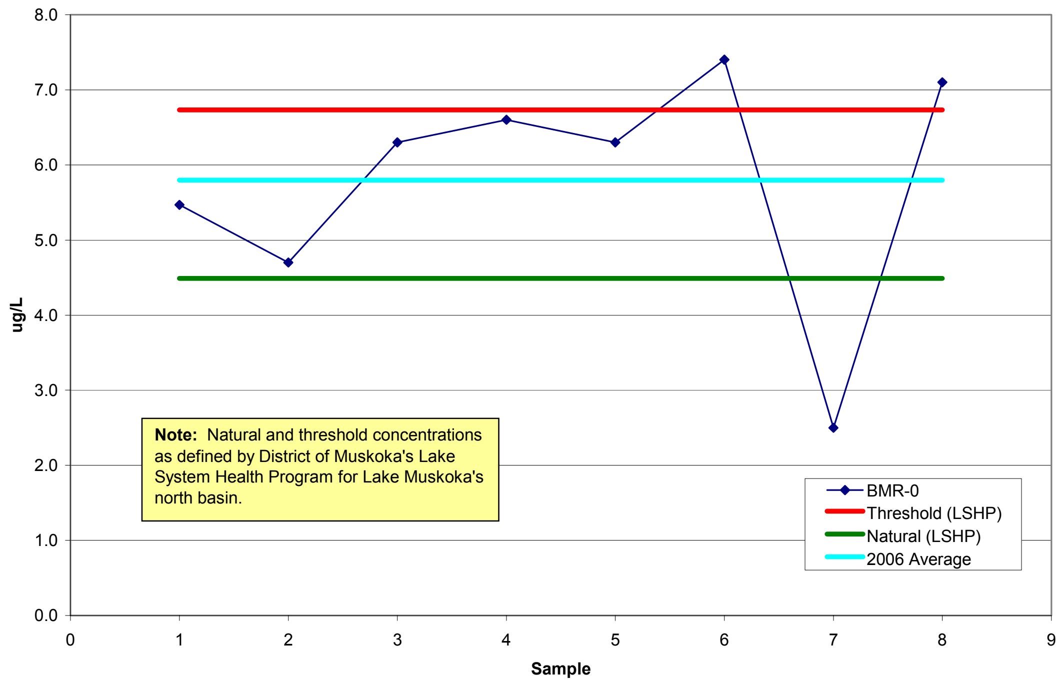

Figure B.6 - Boyd's Bay Total Phosphorus Concentration

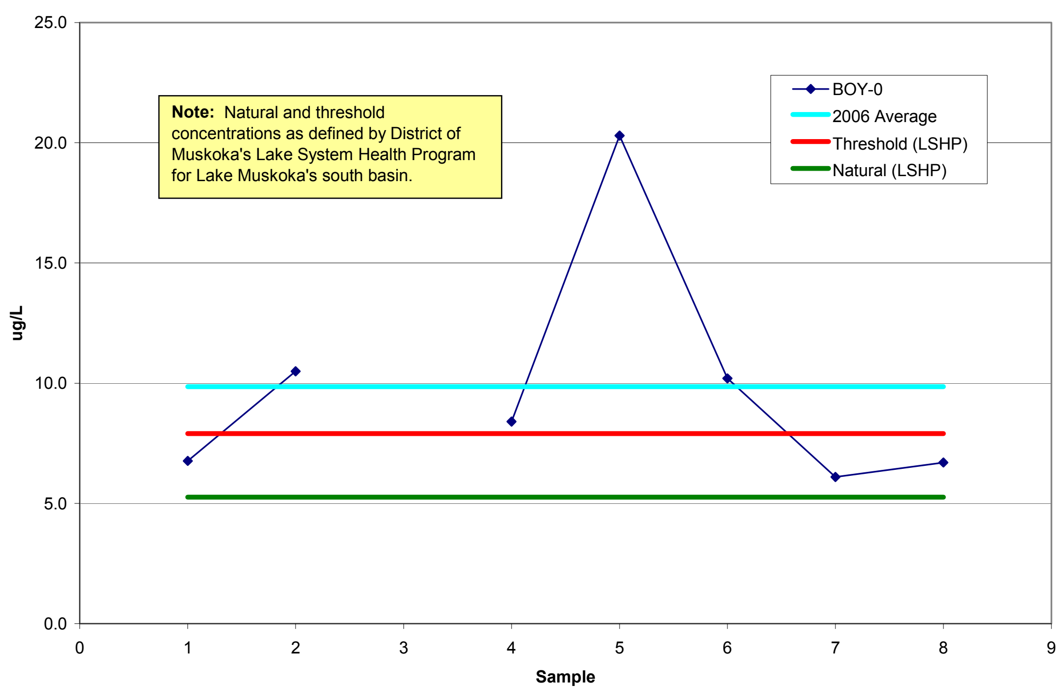

Figure B.7 - Brackenrig Bay Total Phosphorus Concentration

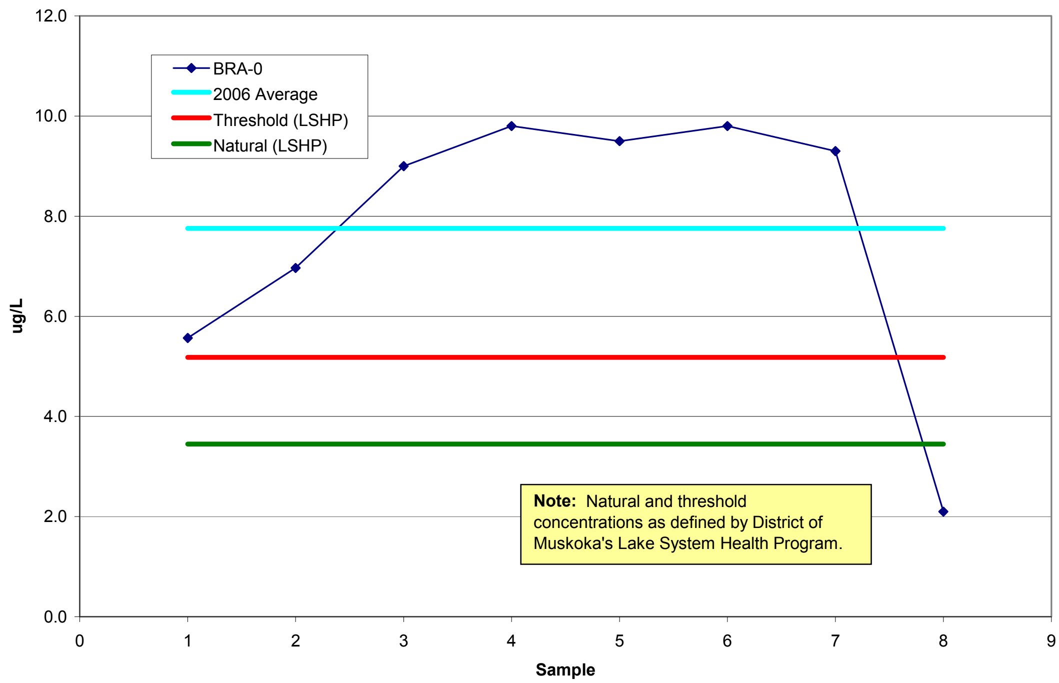

Figure B.8 - Clear Lake Total Phosphorus Concentration

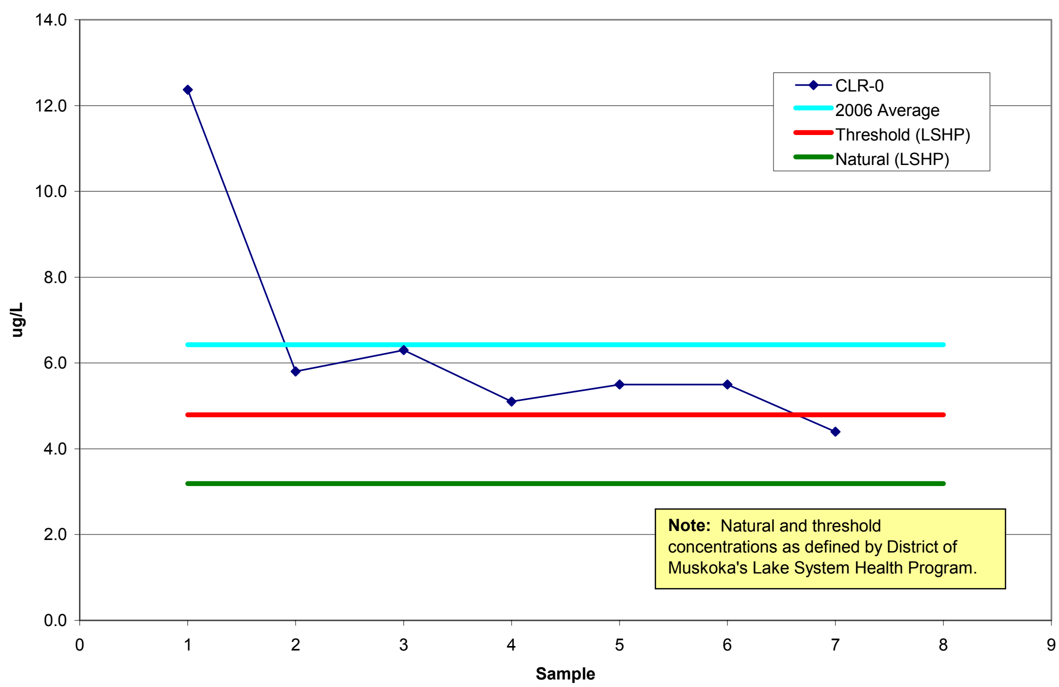

Figure B.9 - Cox Bay Total Phosphorus Concentration

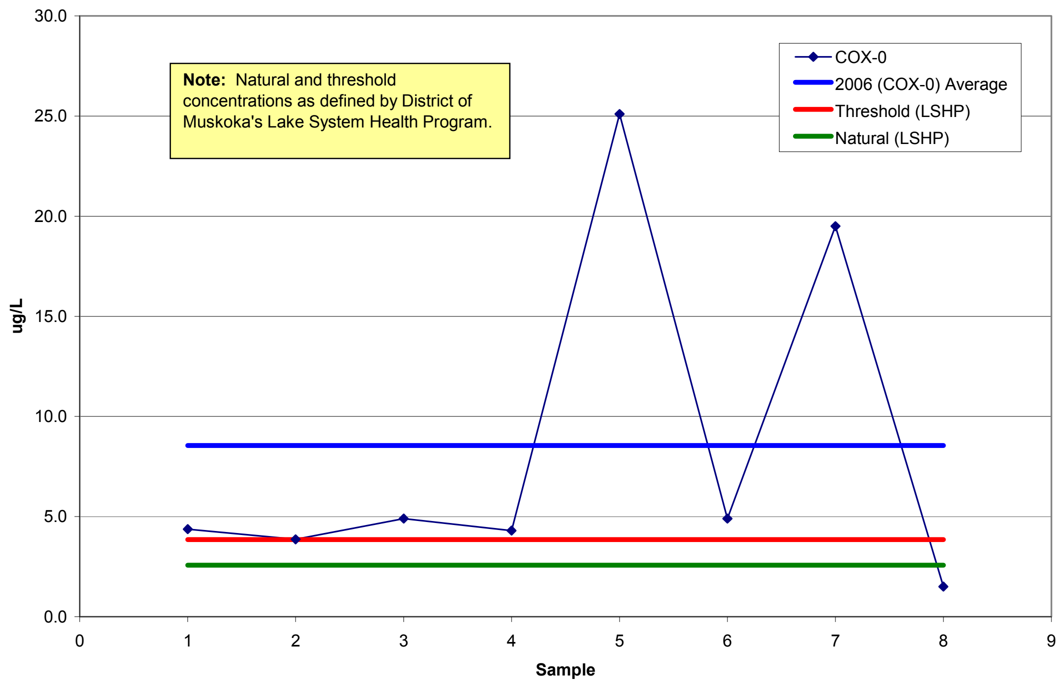

Figure B.10 - East Bay Total Phosphorus Concentration

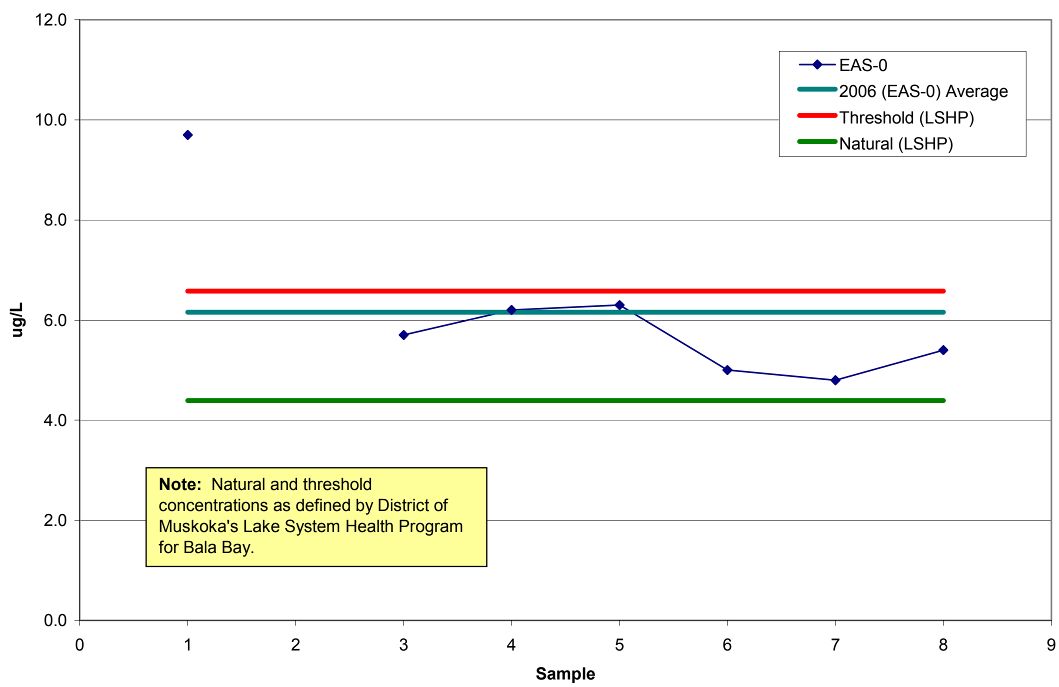

Figure B.11 - Gordon Bay Total Phosphorus Concentration

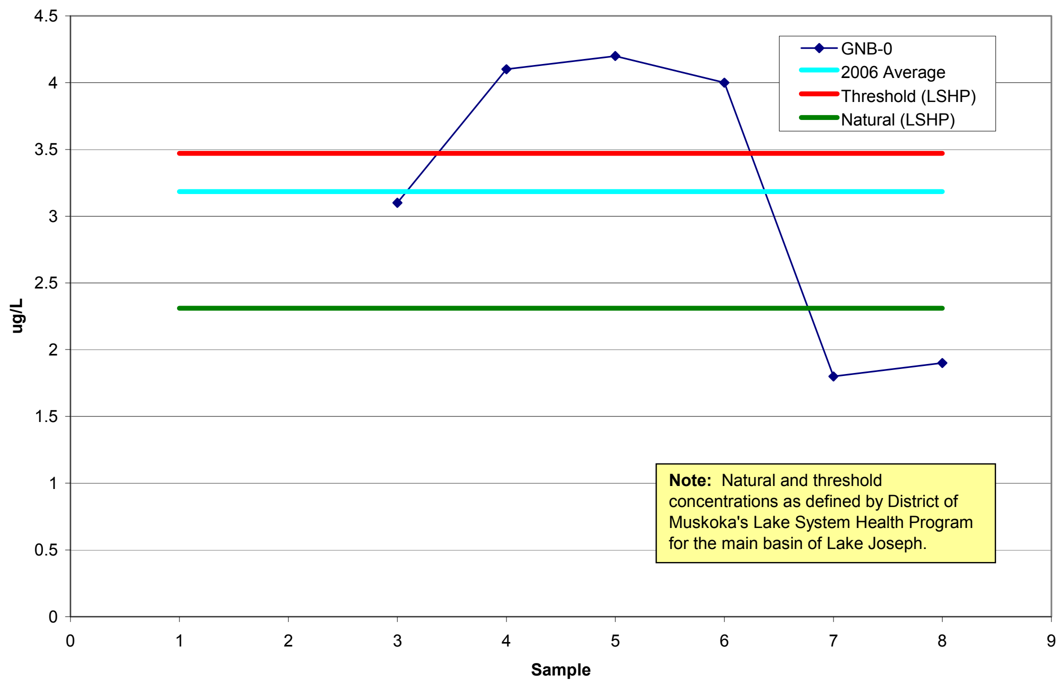

Figure B.12 - Gull Lake Total Phosphorus Concentration

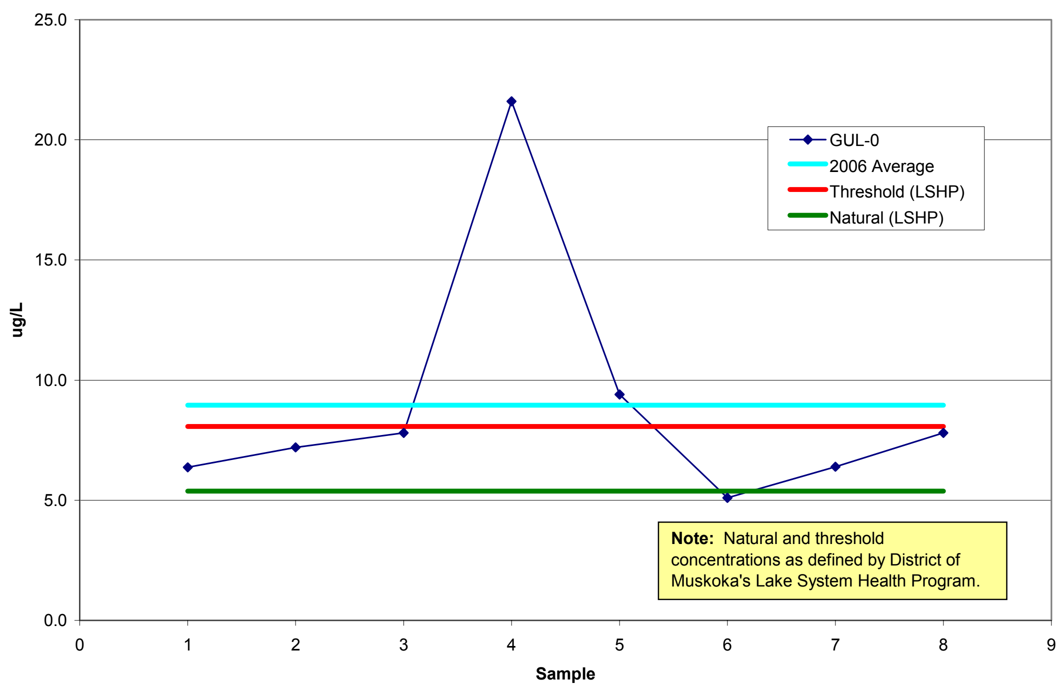

Figure B.13 - Hamer Bay Total Phosphorus Concentration

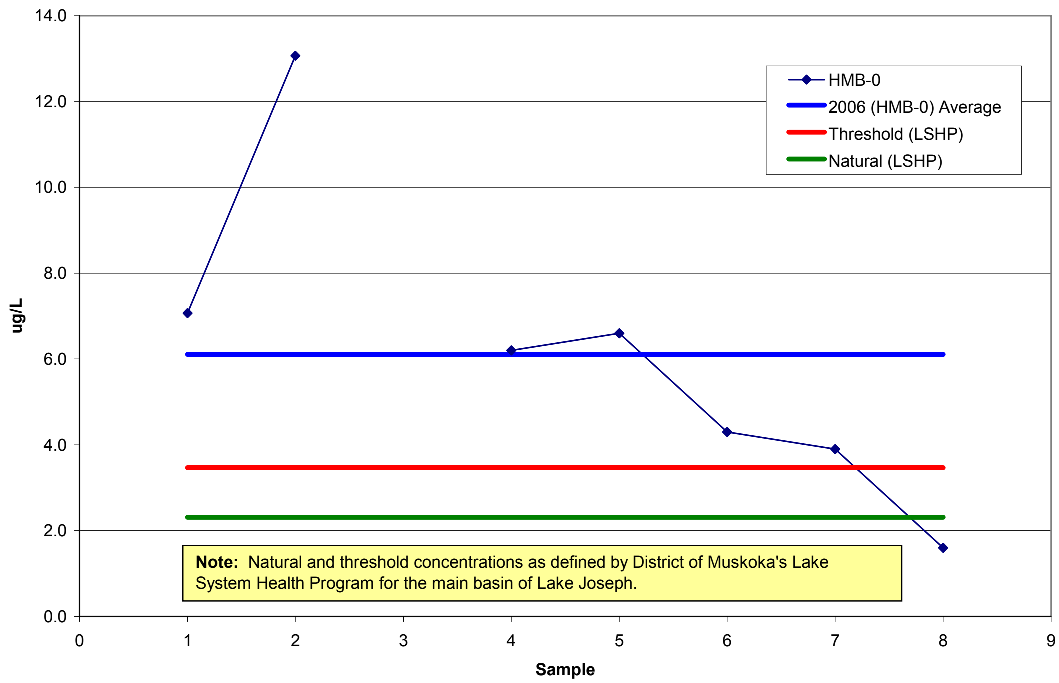

Figure B.14 - Indian River Total Phosphorus Concentration

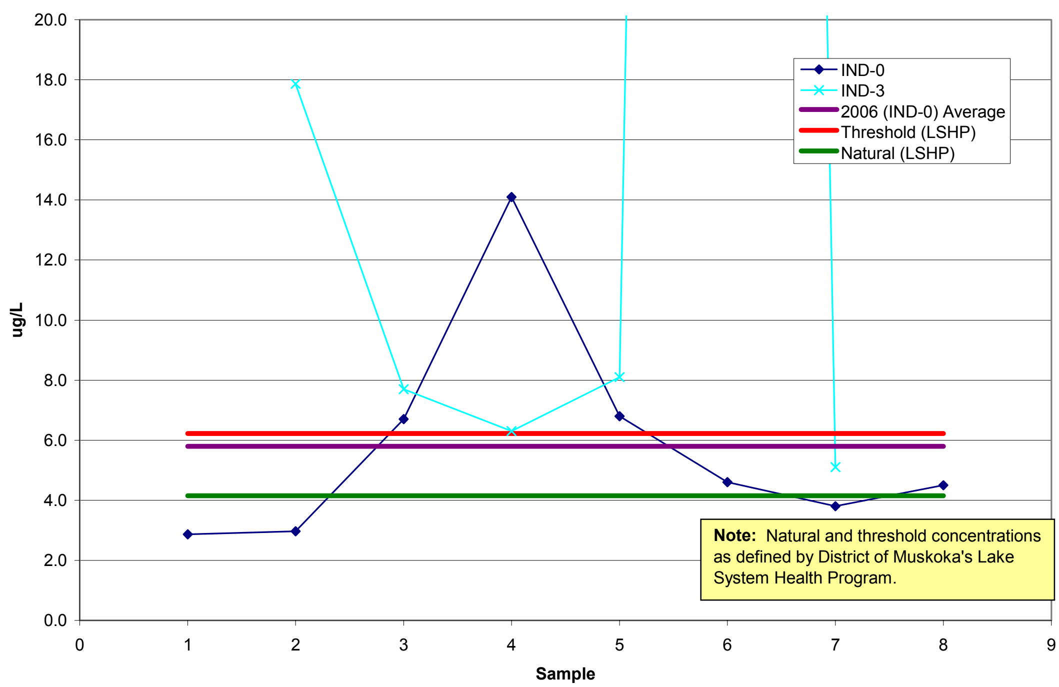

Figure B.15 - Lake Joseph (Main Basin) Total Phosphorus Concentration

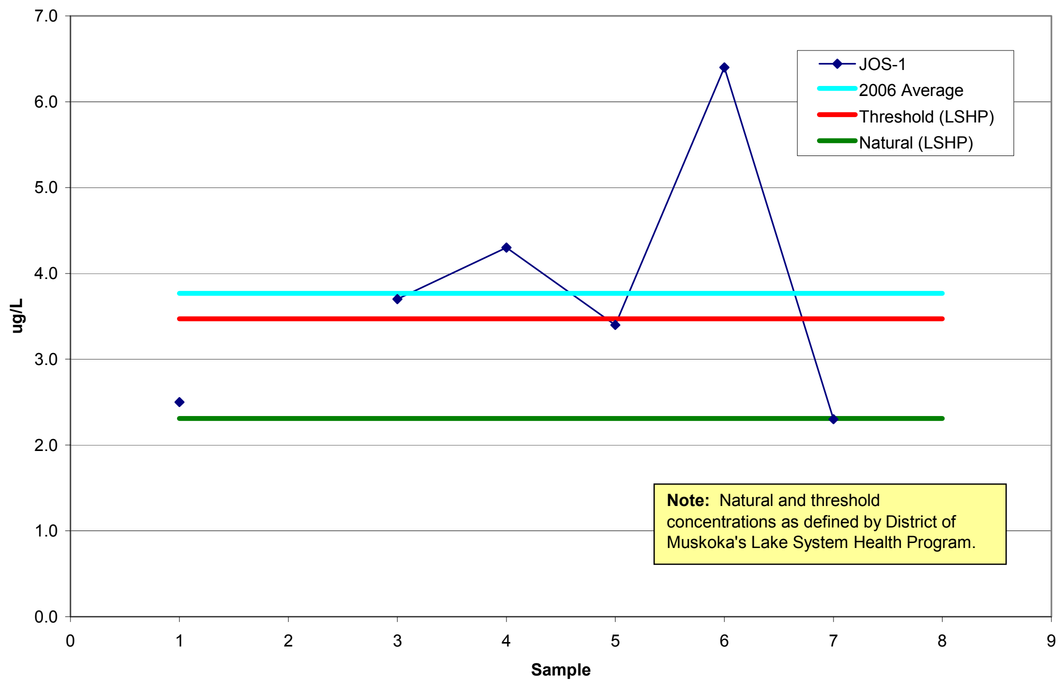

Figure B.16 - Little Lake Joseph Total Phosphorus Concentration

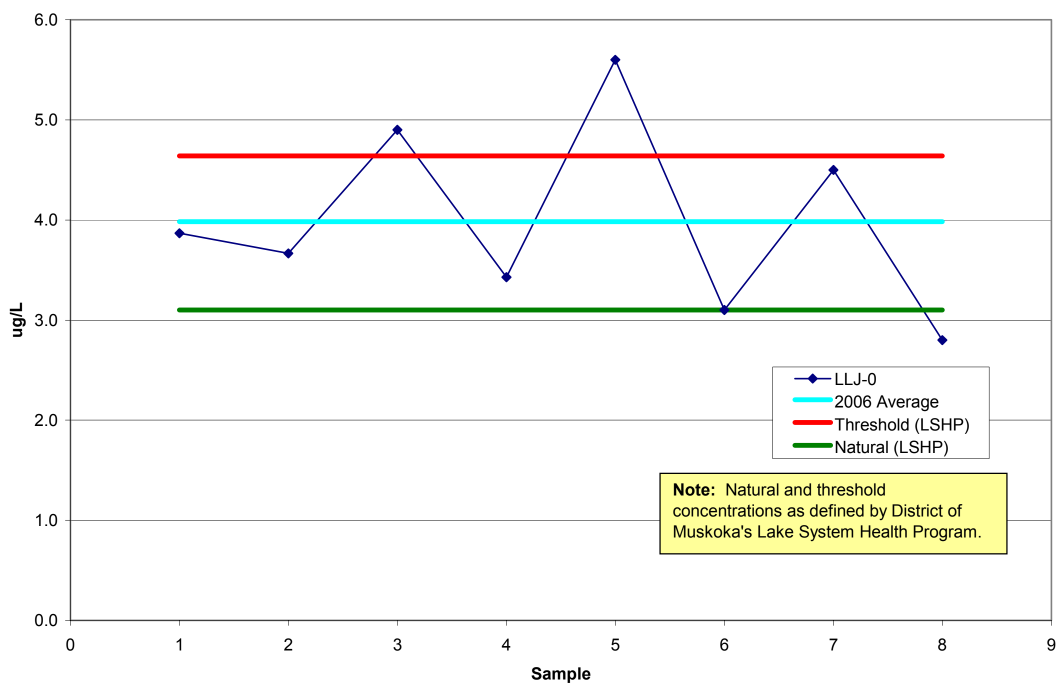

Figure B.17 - Muskoka Bay Total Phosphorus Concentration

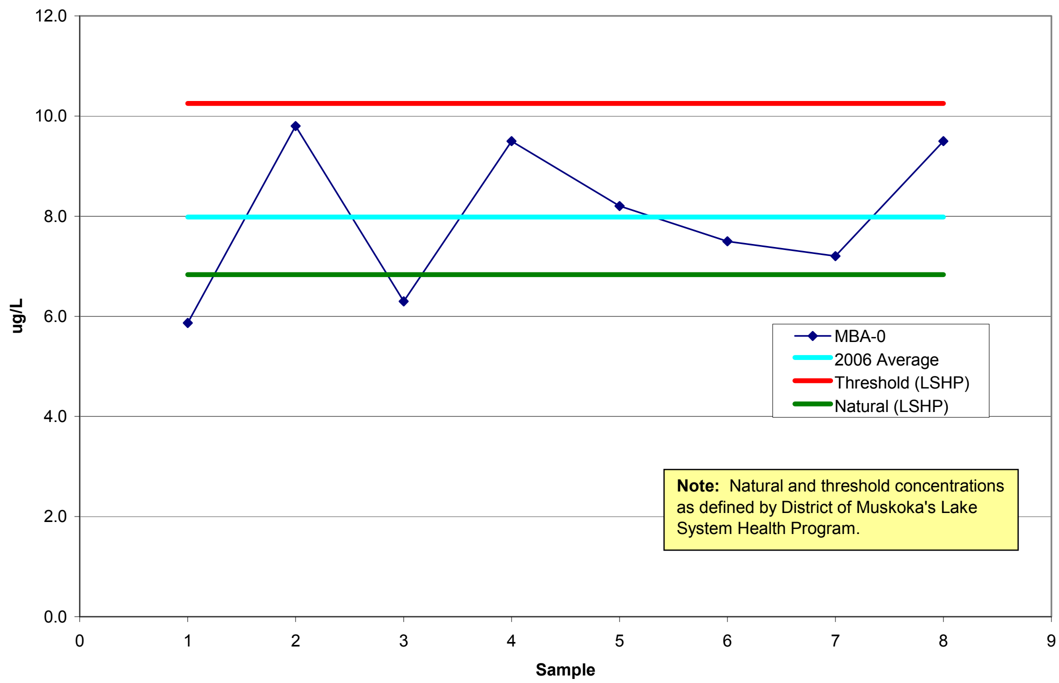

Figure B.18 - Minett Total Phosphorus Concentration

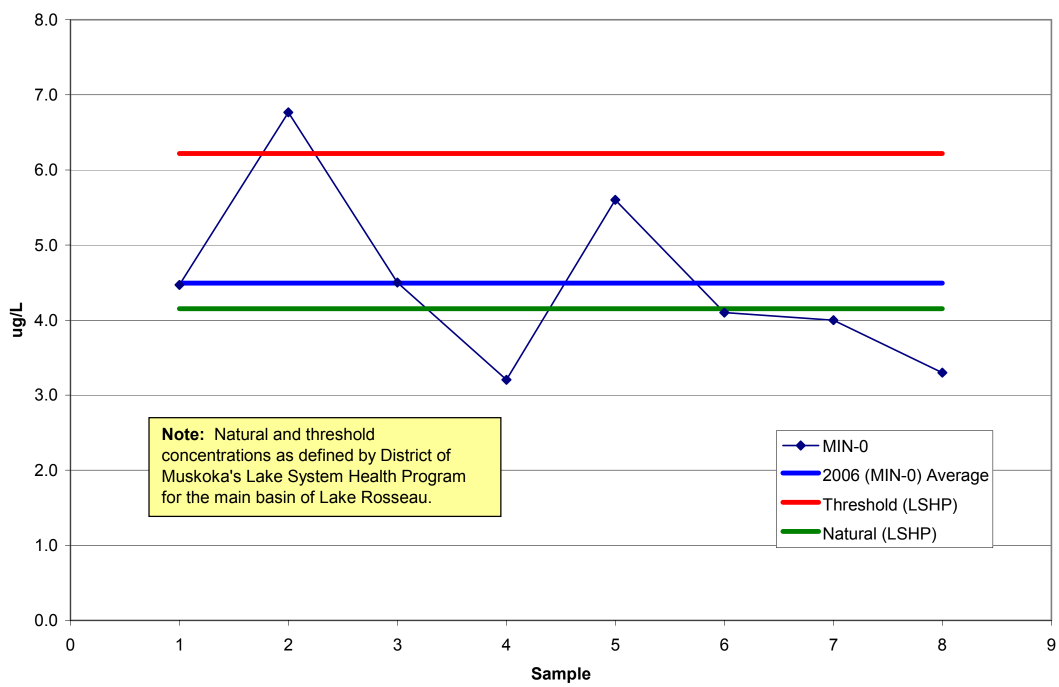

Figure B.19 - Muskoka Lakes Golf & Country Club Total Phosphorus Concentration

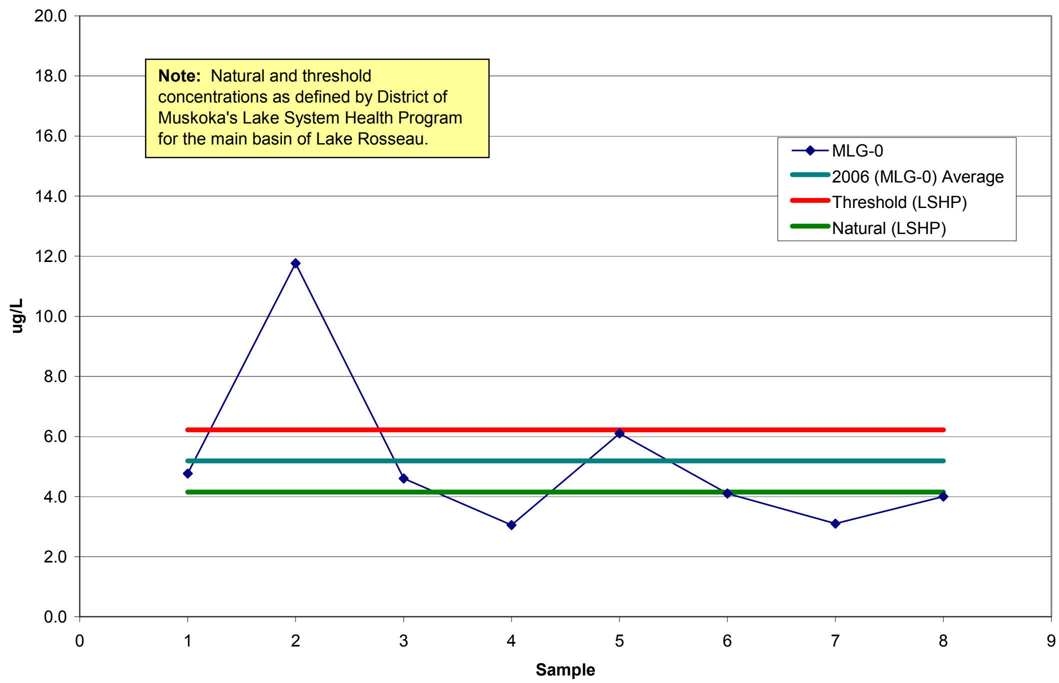

Figure B.20 - Moon River Total Phosphorus Concentration

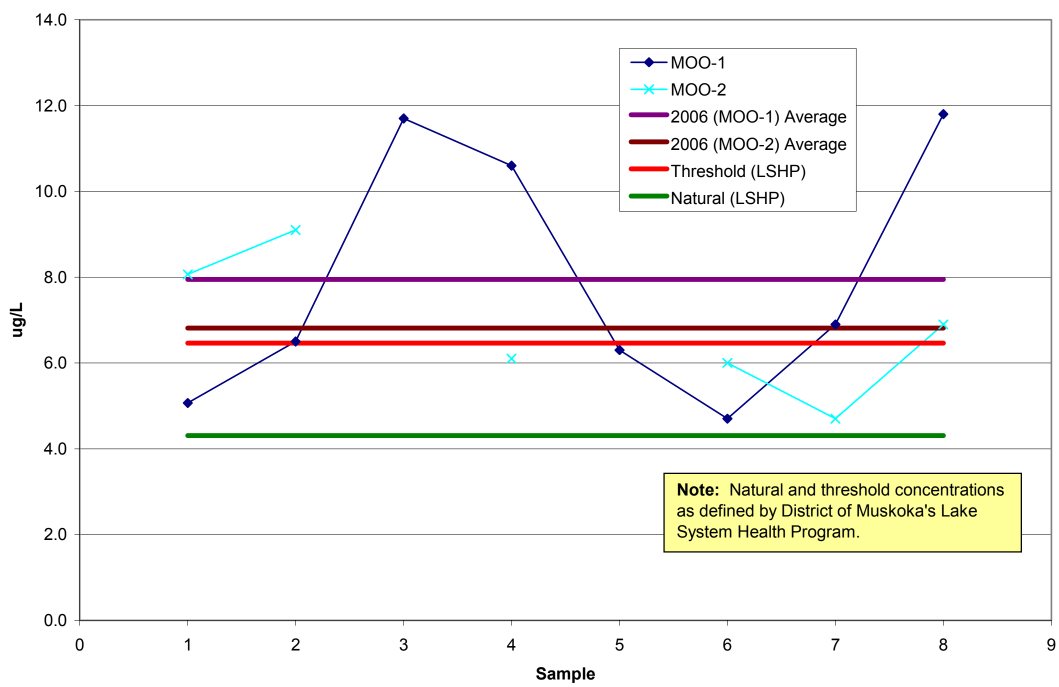

Figure B.21 - Muskoka River Total Phosphorus Concentration

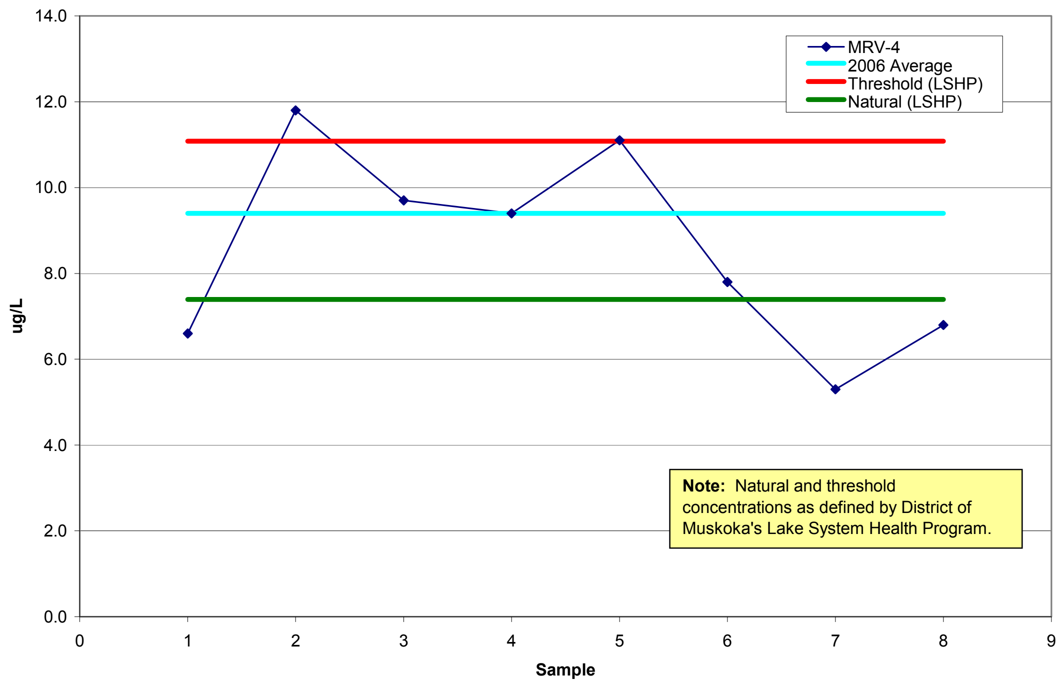

Figure 22 - Muskoka Sands Total Phosphorus Concentration

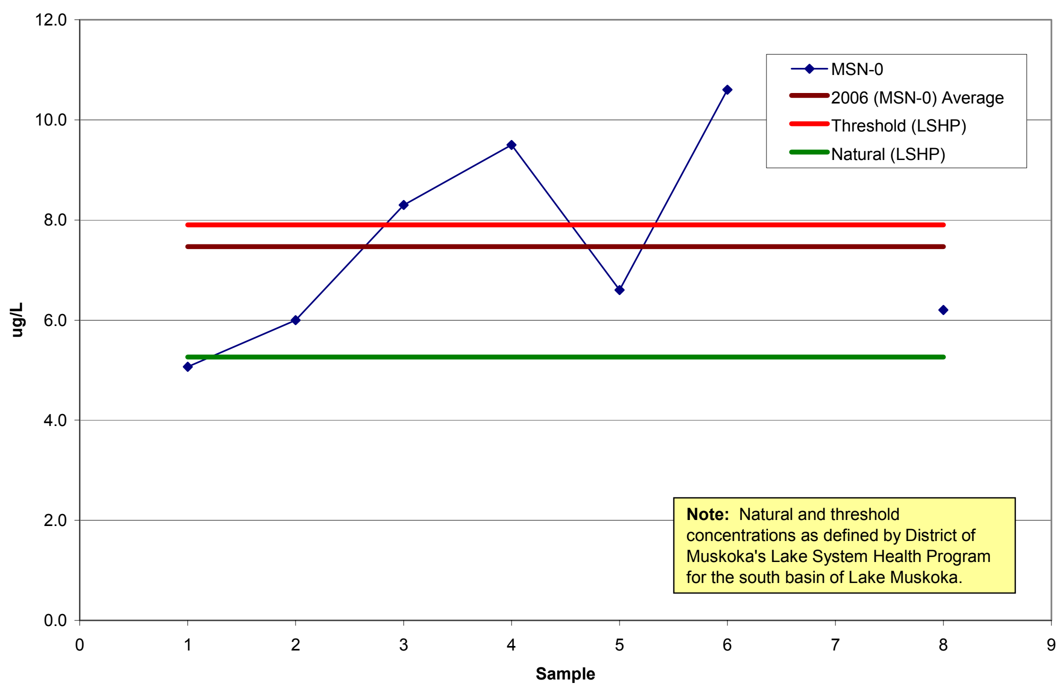

Figure B.23 - Hoc Roc River Total Phosphorus Concentration

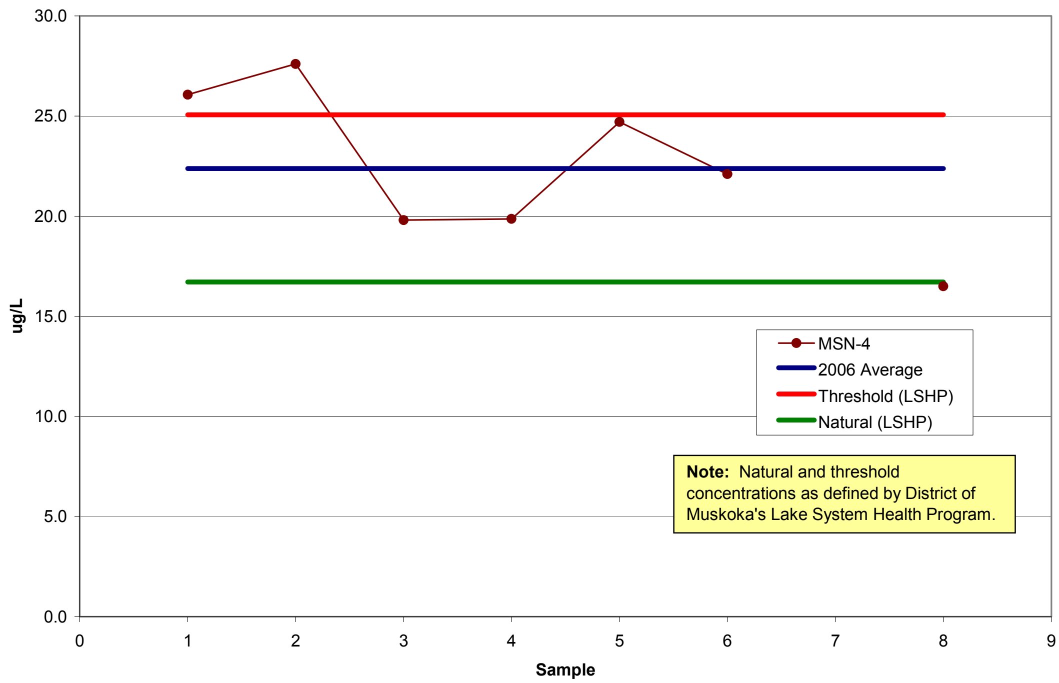

Figure B.24 - Whiteside Bay Total Phosphorus Concentration

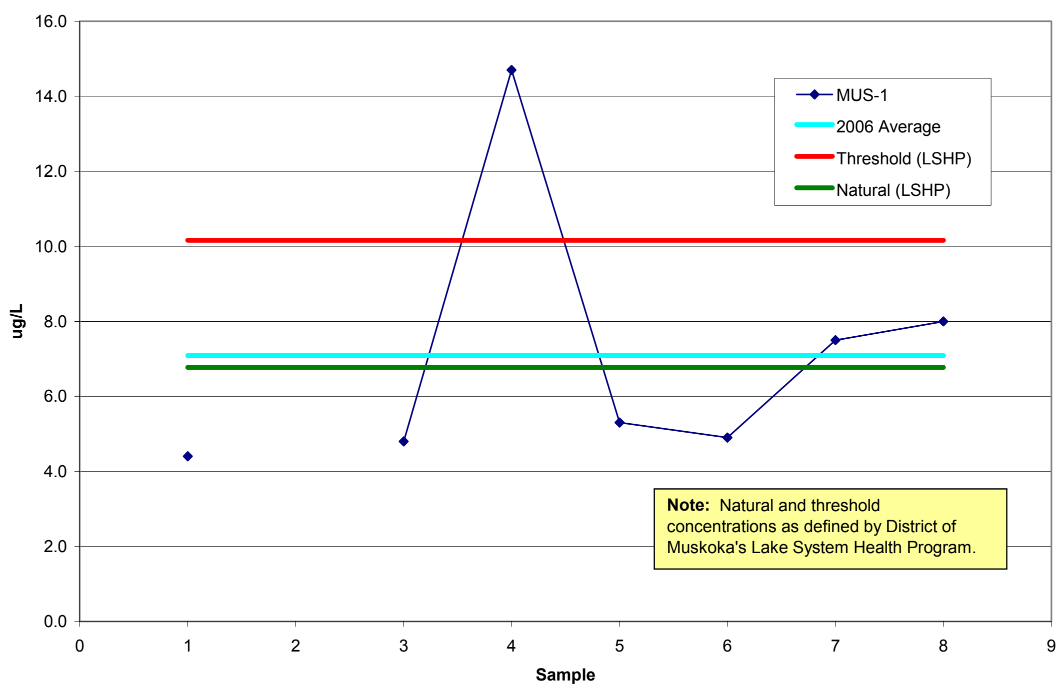

Figure B.25 - Dudley Bay Total Phosphorus Concentration

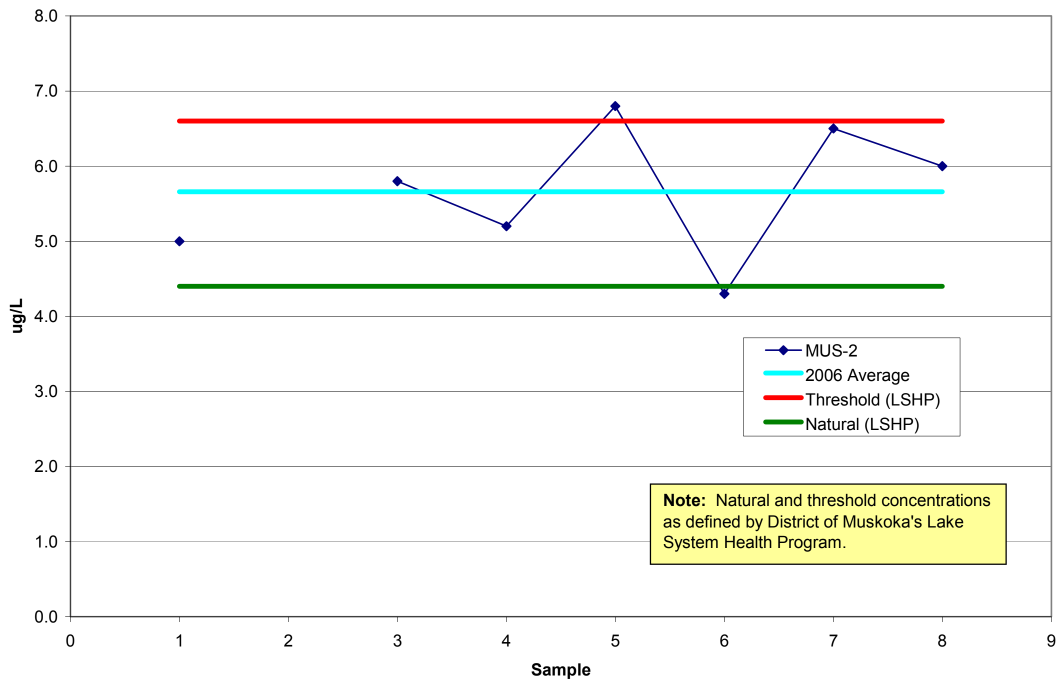

Figure B.26 - Lake Muskoka (South Basin) Total Phosphorus Concentration

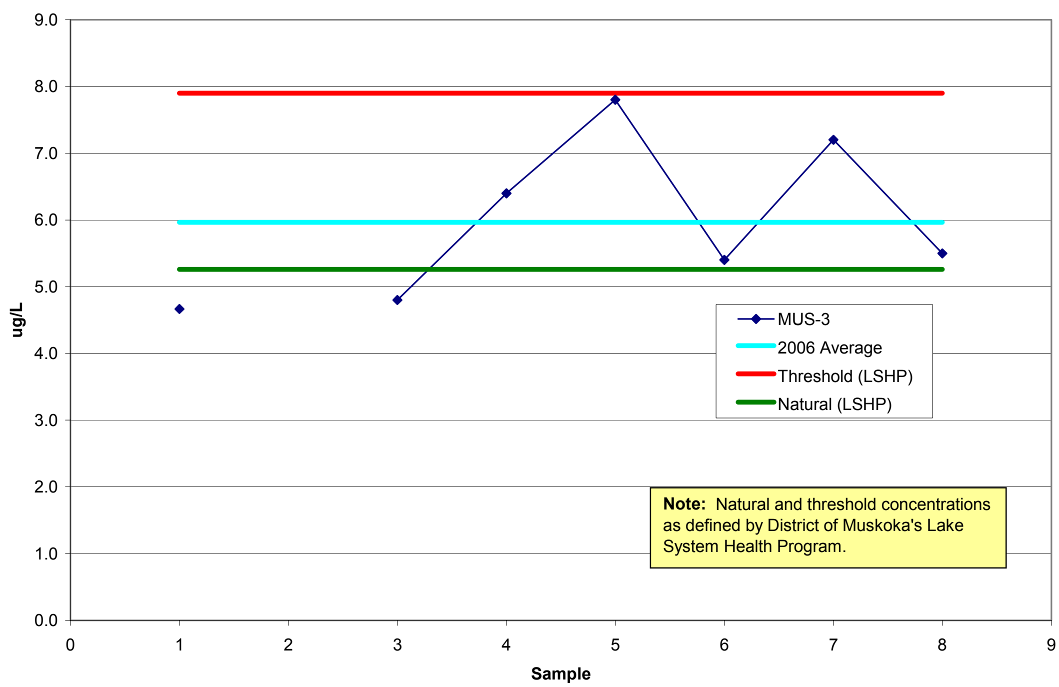

Figure B.27 - Portage Bay Total Phosphorus Concentration

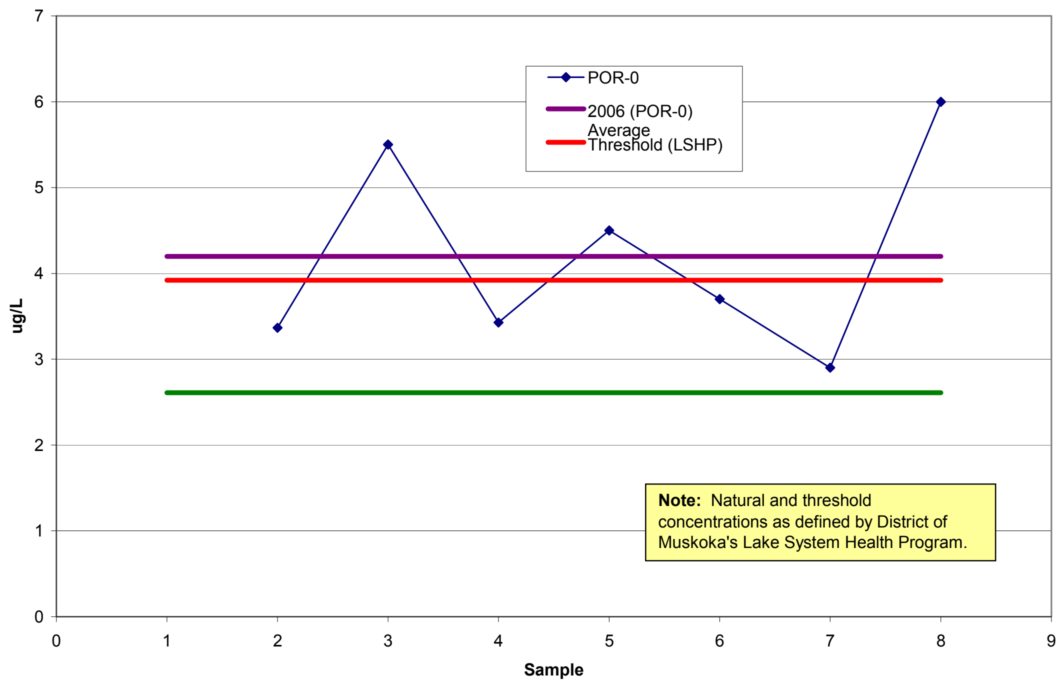

Figure B.28 - Lake Rosseau (Main Basin) Total Phosphorus Concentration

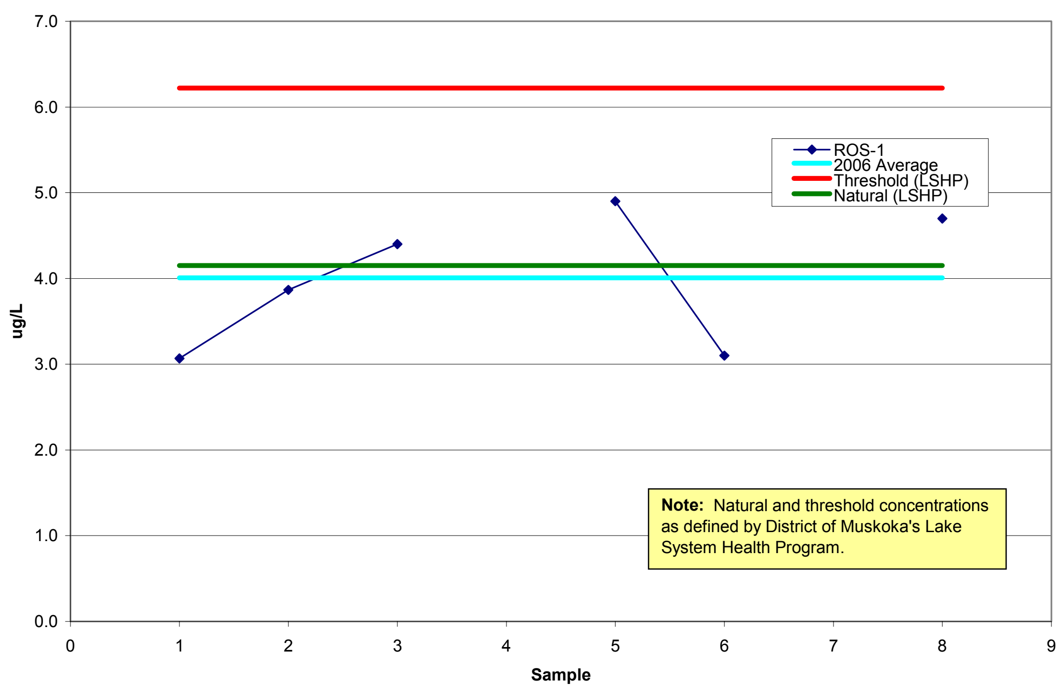

Figure B.29 - Skeleton Bay Total Phosphorus Concentration

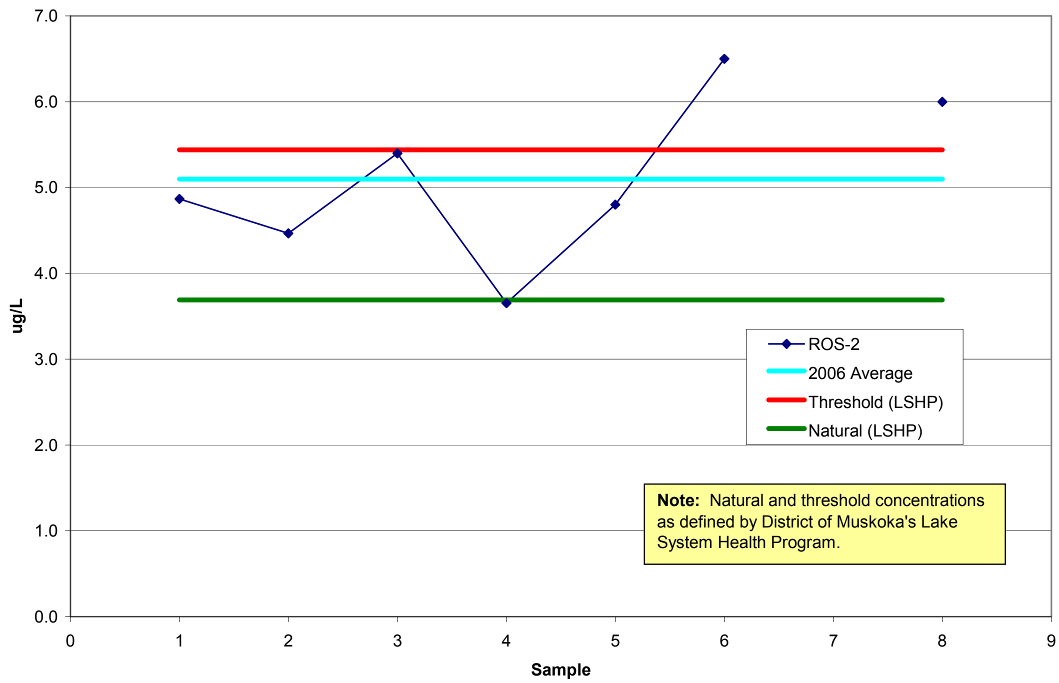

Figure B.30 - Joseph River Total Phosphorus Concentration

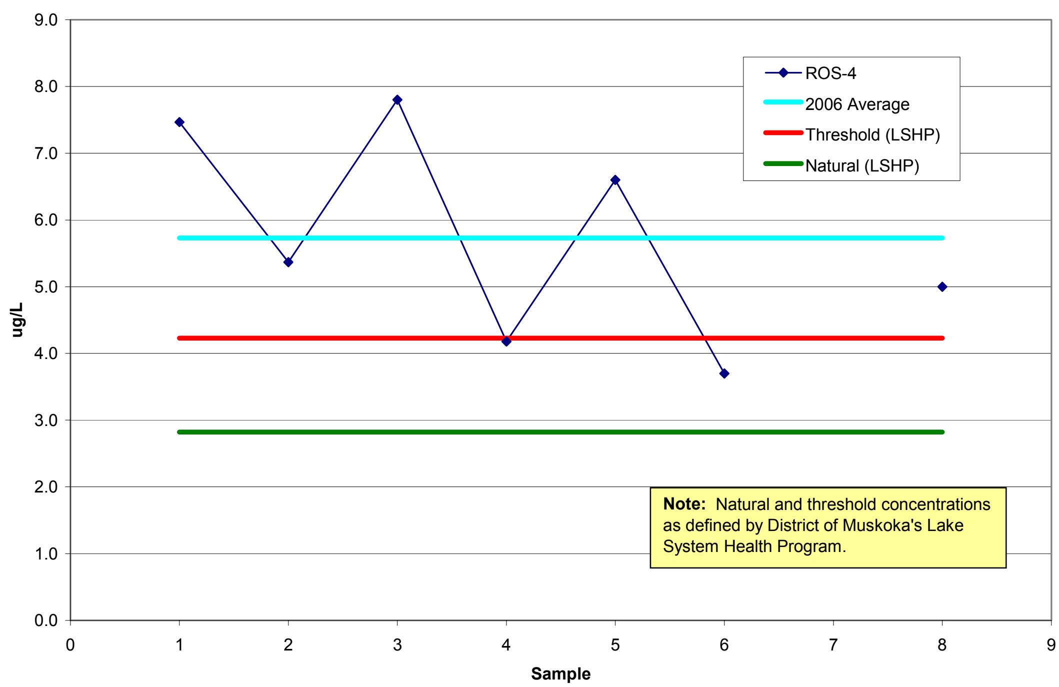

Figure B.31 - North Lake Rosseau Total Phosphorus Concentration

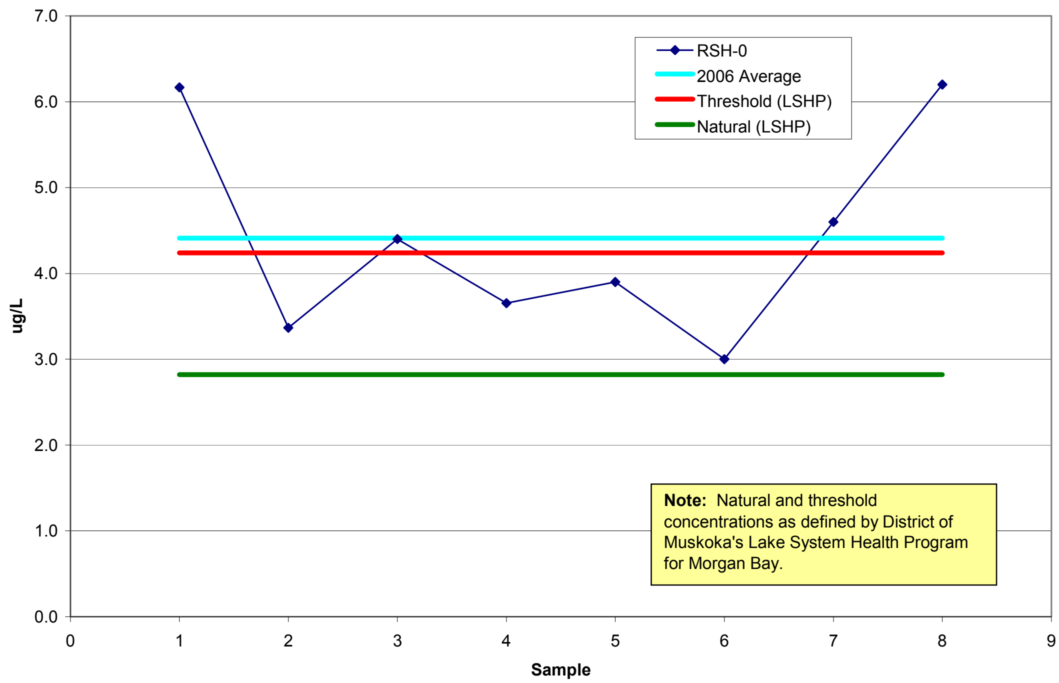

Figure B.32 - Skeleton Lake Total Phosphorus Concentration

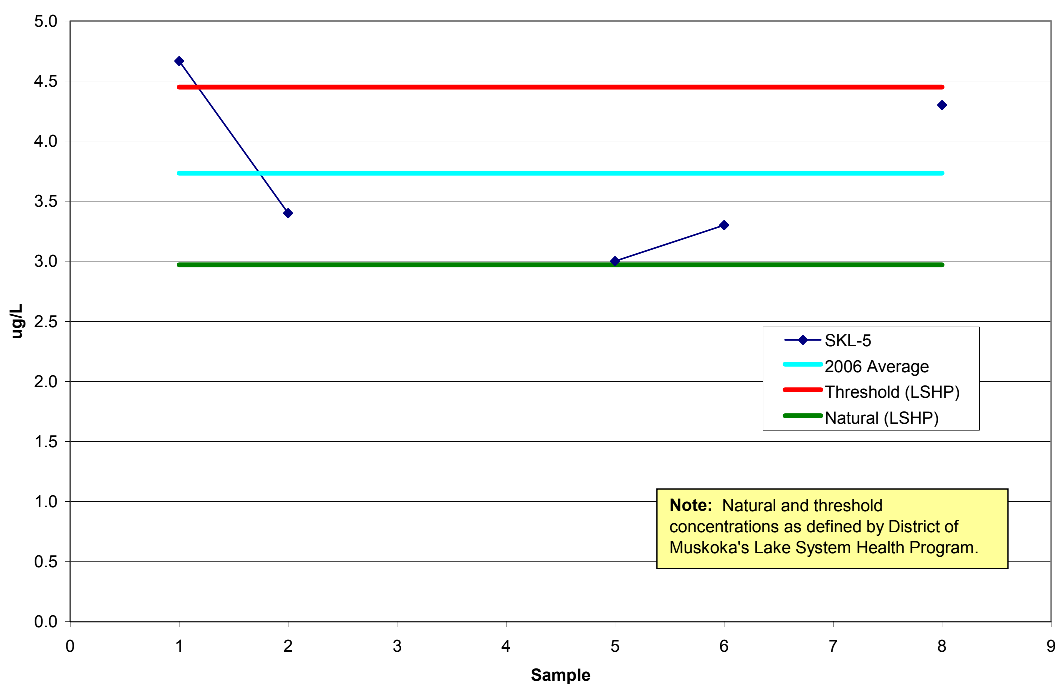

Figure B.33 - Silver Lake (Muskoka Lakes) Total Phosphorus Concentration

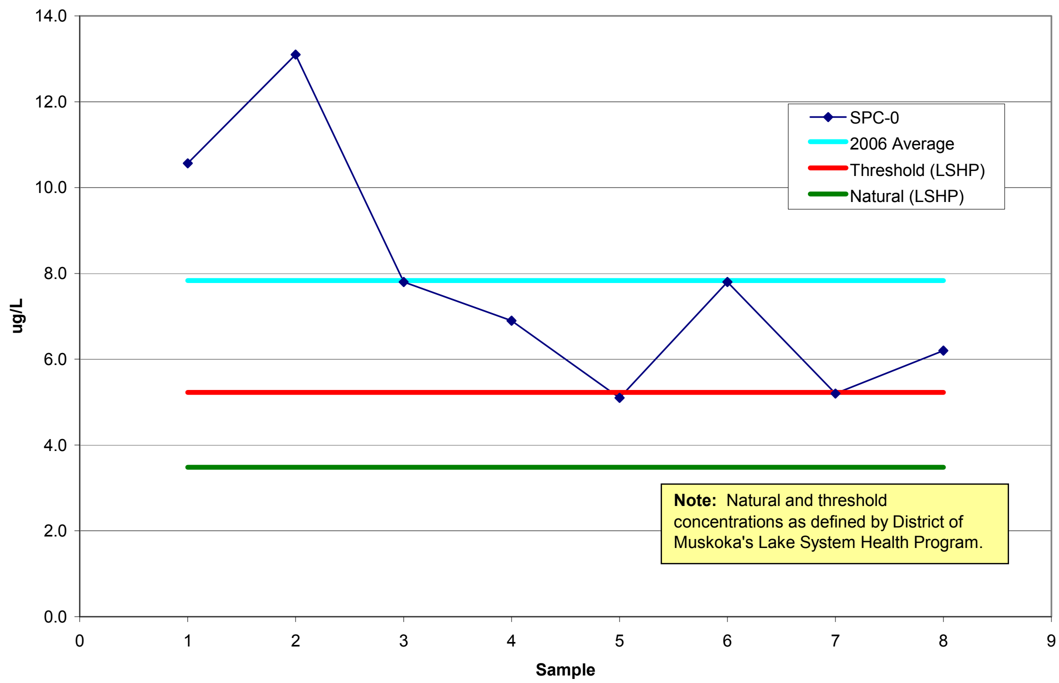

Figure B.34 - Still's Bay Total Phosphorus Concentration

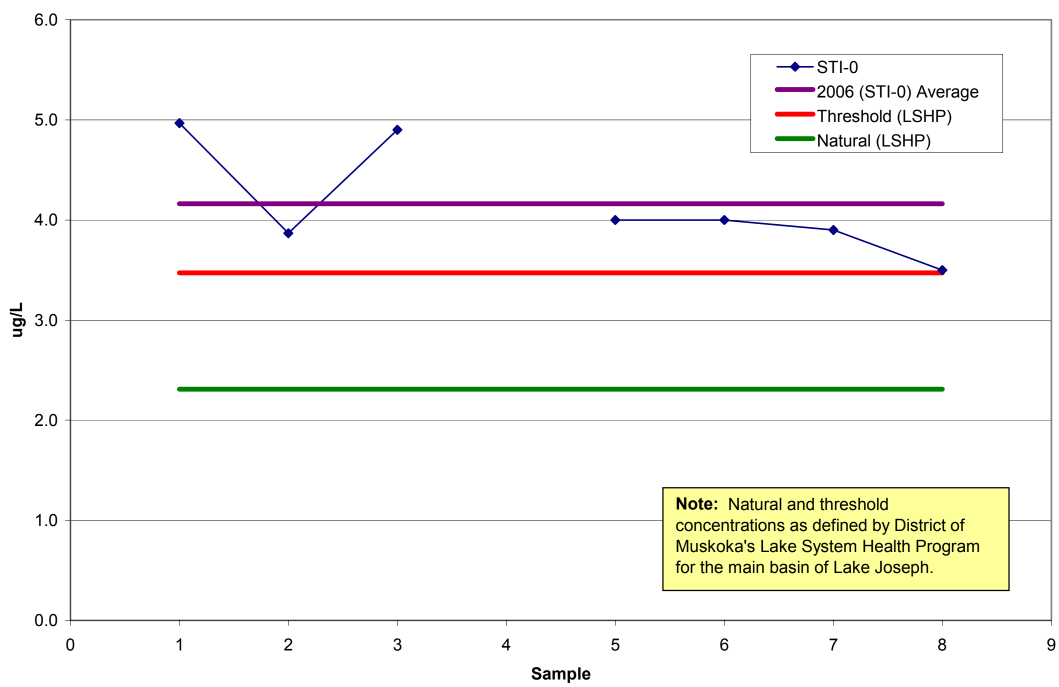

Figure B.35 - Stanley Bay Total Phosphorus Concentration

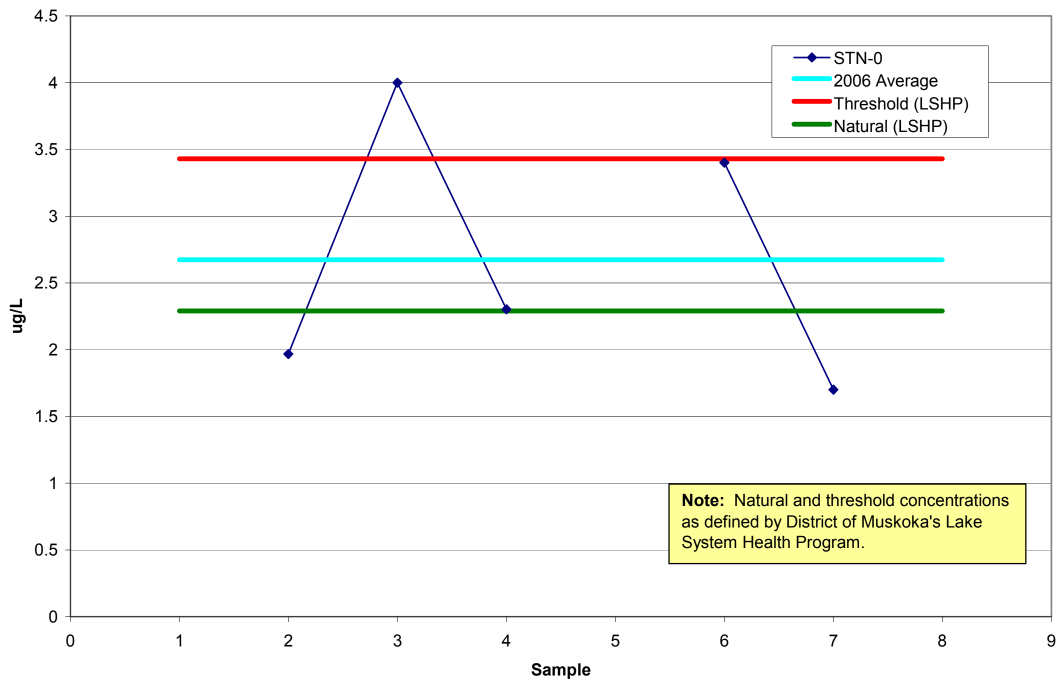

Figure B.36 - Silver Lake (Gravenhurst) Total Phosphorus Concentration

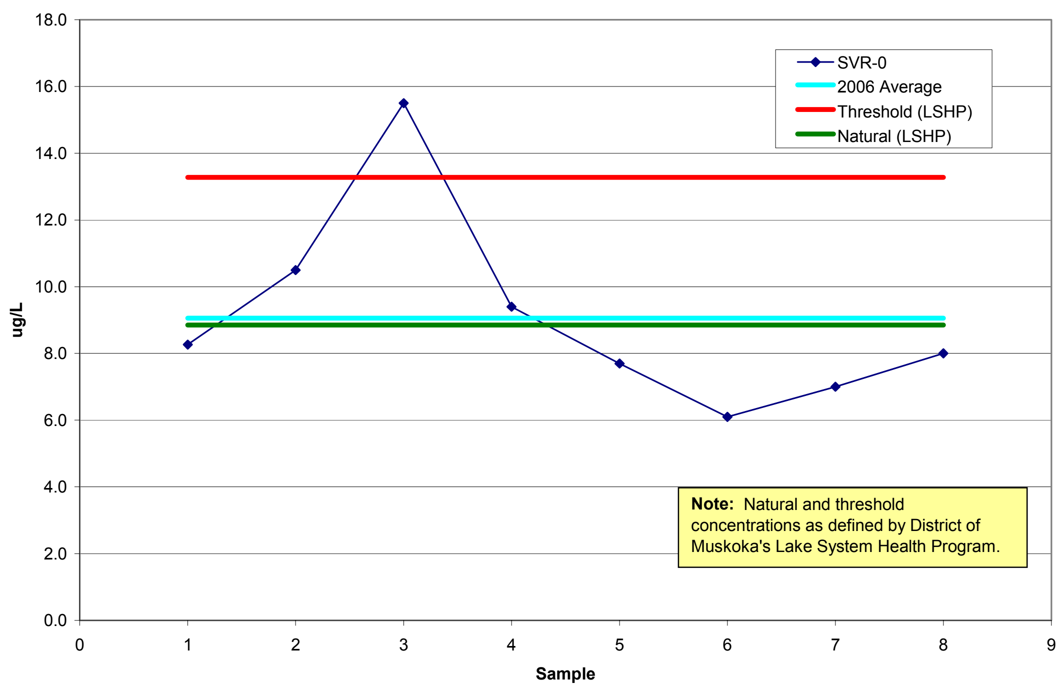

Figure B.37 - Tobin's Island Total Phosphorus Concentration

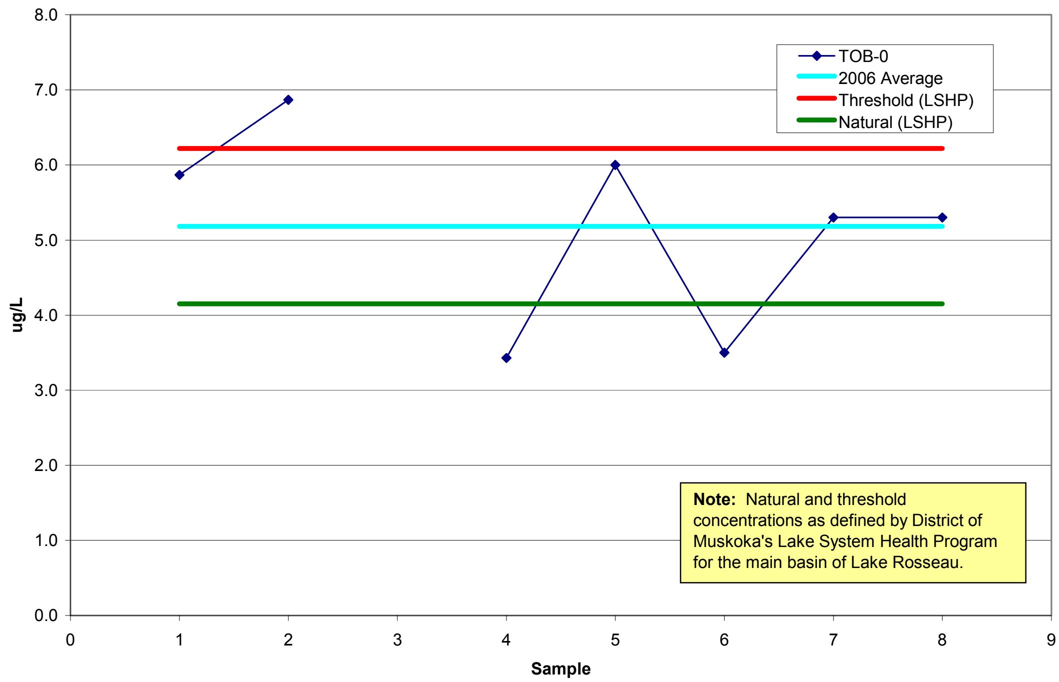

Figure B.38 - Walker's Point Total Phosphorus Concentration

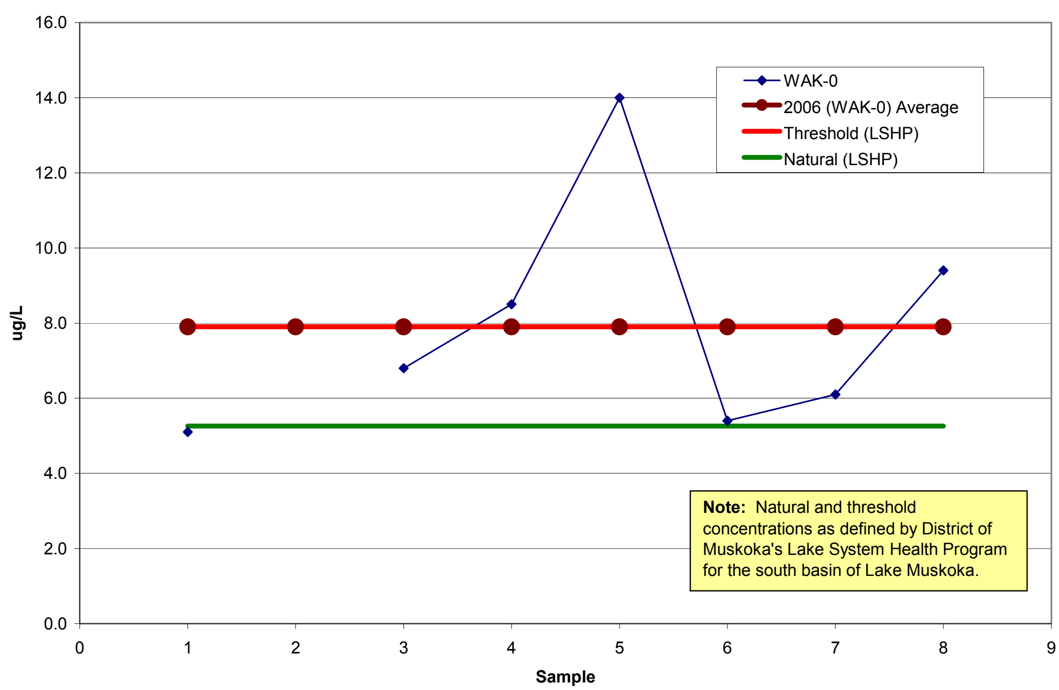

Figure B.39 - Windermere Total Phosphorus Concentration

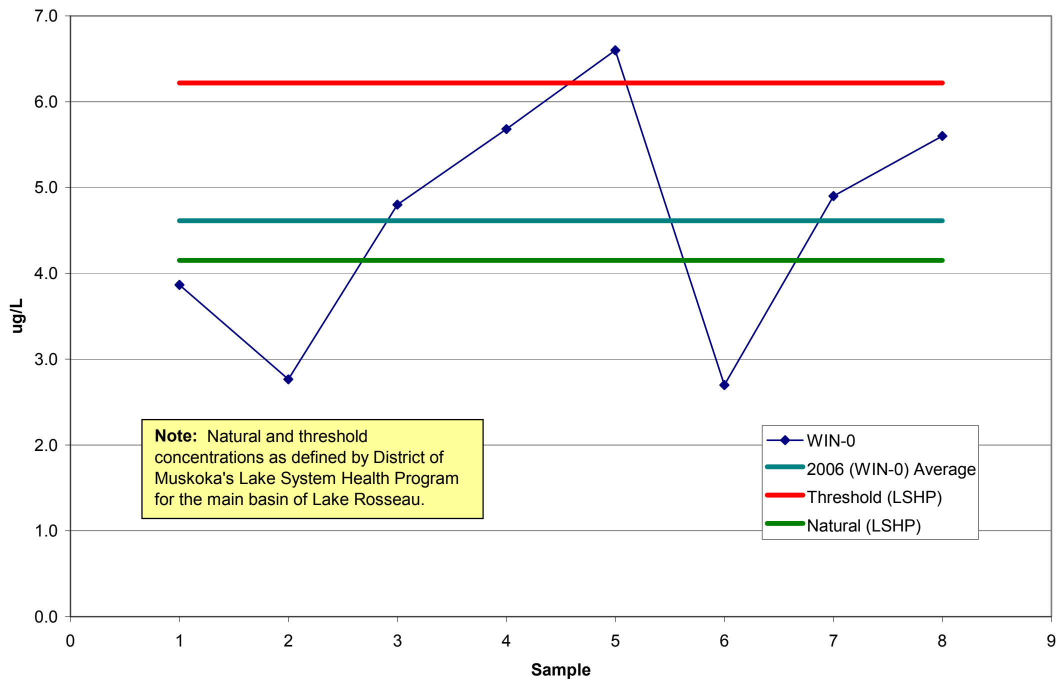

Figure B.40 - Willow Beach Total Phosphorus Concentration