FINAL REPORT

HENVEY INLET PHOSPHORUS SAMPLING PROJECT-LAKE SIMCOE/ SOUTHEASTERN GEORGIAN BAY CLEANUP FUND

Submitted to:

Henvey Inlet First Nation
Pickerel River, Ontario.
POG IJO

Submitted by:

BluMetric Environmental Inc.
102-957 Cambrian Heights Drive
Sudbury, ON P3C 5S5

Project Number: 160524

November23, 2016

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4916 49th Street, Second Floor
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Project Number: 160524

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EXECUTIVE SUMMARY

BluMetric Environmental Inc. (BluMetric™) was retained by Henvey Inlet First Nation to complete surface water quality sampling in the vicinity of Sandy Bay as part of funding obtained under the Lake Simcoe/Southeastern Georgian Bay Cleanup Fund (Environment and Climate Change Canada). Sandy Bay is situated in eastern Georgian Bay, northwest of Byng Inlet, and the community of Britt. It can be accessed via Wright's Marina which is situated on the northern shoreline of Byng Inlet. A general map of the area illustrates the location of Sandy Bay (Figure 1). The northern shoreline of Sandy Bay is part of Henvey Inlet Reserve No. 2. The shoreline includes a large sandy beach which is used for recreational purposes by boaters on Georgian Bay. This use is not authorized by Henvey Inlet First Nation. Human and animal excrement has been observed on the beach and it is possible that the unauthorized uses are detrimentally affecting the water quality of Sandy Bay.

The objectives of the study were to complete water quality monitoring of Sandy Bay in response to community concerns and to meet the objectives outlined as part of the Lake Simcoe/Georgian Bay Cleanup Fund with respect to phosphorus monitoring.

Polycyclic aromatic hydrocarbons (PAH's) and PCB's exceeded Provincial Water Quality Guidelines at Station 1 and Station 5. All other water quality parameters were within established guidelines and other than these exceedances the water quality in Sandy Bay was determined to be good.

Additional recommendations were made to enhance Henvey Inlet's ability to monitor water quality in waters adjacent to their reserve and on inland lakes within their reserve in the future.

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1. SCOPE OF WORK

The scope of the project included collecting surface water samples at five locations within Sandy Bay and collecting temperature and oxygen profiles at each of the five stations.
The objectives of the Lake Simcoe/South-eastern Georgian Bay cleanup fund as cited by Environment and Climate Change Canada (2016) include:

a) to improve environmental monitoring, assessment and scientific information required to measure the effectiveness of control strategies, and identify and assess alternative approaches to reducing phosphorous discharges;
b) to conserve critical aquatic habitat and associated species through targeted aquatic habitat protection, restoration and creation projects;
c) to reduce rural and urban non-point sources of phosphorous / nutrients, including implementation of BMPs for the management of soil, crops, livestock, and water use, septic systems and creating and rehabilitating wetlands and naturalizing watercourses to attenuate phosphorous discharges;
d) to reduce discharge of phosphorous from point sources including sewage, combined sewer overflows and urban stormwater systems including support to development and testing of innovative approaches to manage urban stormwater and wastewater.

(https://www.ec.gc.ca/eau-water/default.asp?lang=En&n=85C54DAE-1)

2. SAMPLING METHODOLOGY

BluMetric Environmental followed the methodology outlined in the Enclosed Bays and Inland Lakes Phosphorus Monitoring Guideline (Georgian Bay Biosphere Reserve, State of the Bay Water Quality Indicator, March 2016) located in Appendix A and the Lake Partner Program Volunteer Instructions (Appendix B). Five sampling locations were established in Sandy Bay. The GPS coordinates of the sampling locations are as follows and they are illustrated in Figure 1, at the back of this report:

Table 1: GPS Coordinates of Samples Obtained (NAD 83)

Station	Northing	Easting
1	N 5072955	E0526352
2	N 5072977	E0525377
3	N 5073238	E0525176
4	N 5073005	E0525654
5	N 5072891	E0524792

2.1 Temperature and Oxygen Profiles

Temperature and oxygen profiles and water samples were obtained at 5 locations within Sandy Bay using a YSI Oxygen and Temperature Meter with a 15 m cord during the first sampling round. Field records can be reviewed in Appendix C. Temperature and oxygen profiles were completed on August 26th, 2016. A duplicate sample for QA/QC was taken at Sites 4 and 5. A second sampling even was completed on October 12, 2016. During this sampling round a duplicate sample was obtained at Site 4.

2.2 Sampling Methodology

Water quality samples were obtained using a weighted bottle as outlined in the Lake Partner Program Volunteer Instructions. Composite samples were obtained at the secchi depth and were tested for total and dissolved phosphorus, Ecoli and total coliforms were collected at all stations. Additional water quality parameters were tested at Station 1 during the first round of sampling in August (as reported in Appendix D) and during the second round of sampling in October (as reported in Appendix E) at Station 5. Other observations recorded included the weather, water depth and secchi depth. General observations were made regarding recreational use in the area and any noticeable water quality observations were noted such as the presence of algal blooms. All samples were kept in a cooler with ice packs until their arrival at the analyzing laboratory on the same day, along with corresponding Chain of Custody documentation (Appendix E). All water samples were submitted to Testmark Laboratories in Garson, Ontario for analysis.

2.3 Regulatory Framework

Results were compared to Provincial Water Quality Objectives which are applicable to all waters of the province except in areas influenced by MOECC approved point source discharges. PWQO's represent a desirable level of water quality that MOECC strives to maintain in the surface waters of the Province. They are set at a level of water quality which is protective of all forms of aquatic life and all aspects of the aquatic life cycle (MOECC Blue Book, 1994).

Ontario does not currently set water quality objectives for phosphorus in the Great Lakes, but has been active in the binational effort to reduce Great Lakes phosphorus loadings. Ontario is supporting the review of the Canada-U.S. Great Lakes Water Quality Agreement which includes phosphorus targets.

Results were also compared to the CCME Guidelines (Canadian Counsel of Ministers of the Environment). CCME is the primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern and is comprised of the environment ministers from the federal, provincial and territorial governments. The organization develops Canadian Water Quality Guidelines for surface and groundwater quality.

3. RESULTS AND DISCUSSION

Results for phosphorus (total and dissolved), E. coli and total coliforms are presented in Table 2.

Table 2: Parameters tested at all Stations

	Date Sample Obtained	Station 1	Station 2	Station 3	Station 4	Station 5
Dissolved Total Phosphorus (As P) mg/L	Aug 26th 2016	0.0069	0.007	0.006	0.0071 0.0072 (duplicate)	0.0073 0.006 (duplicate)
	Oct 12th 2016	0.004	Less than 0.004	Less than 0.004	Less than 0.004 Less than 0.004 (duplicate)	Less than 0.004
Total Phosphorus (As P) mg/L	Aug 26th 2016	0.011	0.009	0.011	0.012 0.01	0.008
	Oct 12th 2016	0.0065	0.0071	0.004	0.008 0.0099 (duplicate)	0.0062
Escherichia coli CFU/100mL	Aug 26th 2016	<100	<100	<100	<100	<100
	Oct 12th 2016	4	4	<2	2, <2 (duplicate)	<2
Total Coliform (R10) CFU/100mL	Aug 26th 2016	<100	<100	<100	<100	<100
	Oct 12th 2016	34	16	28	36 20 (duplicate)	10
Station Depth (m)	Aug 26th 2016	4.27	9.27	14.76	5.9	9.54
	Oct 12th 2016	2.3	6.1	2.41	5.28	6.55
Secchi depth	Aug 26th 2016	3.7	3.2	2.4	3.3	3.1
pH	Aug 26th 2016	7.43	7.9	7.87	8.01	7.99
pH-Ranges of between 5 to 9 are acceptable*	Oct 12th 2016	8.32	8.32	8.36	8.35	8.45
Conductivity	Aug 26th 2016	176	178	177	177	178
	Oct 12th 2016	182	184	193	188	212
Field ORP	Aug 26th 2016	221	205.1	218.3	197.8	204.8
(Oxygen reduction potential)	Oct 12th 2016	117	108	90	92	81

*Recreational water quality guidelines (CCME, 2016) indicate a pH range of between 5 to 9 is acceptable.

3.1 PHOSPHORUS

Total phosphorus (TP) concentrations control the growth of algae in Ontario lakes (MOECC, December 2013) and are used to interpret lake nutrient status. Increases in phosphorus may decrease water clarity and stimulate algal growth. Algal blooms affect lake aesthetics and may cause changes to the water quality including changes in odour and/or taste. Natural processes leading to excess phosphorus in water include weathering of rocks, soil erosion, decay of organic material or atmospheric deposition. Human activities leading to phosphorus enrichment include erosion and runoff from agricultural lands that have been treated with phosphorus-containing fertilizers, discharges from sewage treatment plants and septic systems, stormwater runoff from urban areas and atmospheric deposition from the burning of fossil fuels (Water Quality in Ontario, 2010). In the past, laundry detergents were a major source of phosphorus, however government regulations now control this. Excessive phosphorus inputs can result in nutrient enrichment of waters (eutrophication).

Lakes are normally classified as either oligotrophic (less than 10 µg/L), mesotrophic (10-20 µg/L) or eutrophic (greater than 20 µg/L) and may exhibit persistent algal blooms (Lake Partner Program, 2013)..
Ontario has set an Interim Provincial Water Quality Objective (PWQO) for total phosphorus of 20 µg/L (micrograms per litre, or parts per billion) for inland lakes. Ontario does not currently set water quality objectives for phosphorus in the Great Lakes, but has been active in the binational effort to reduce Great Lakes phosphorus loadings. Ontario is supporting the review of the Canada-U.S. Great Lakes Water Quality Agreement which includes phosphorus targets.

Our results indicate that as expected, Sandy Bay exhibited oligotrophic conditions during August of 2016. Dissolved total phosphorus readings ranged from a low of 6.0 µg/L at Station 3 to a high of 7.3 µg/L at Station 5. Total phosphorus (as P) ranged from 0.008 mg/L at Station 5 to 0.012 mg/L at Station 4.

During the October sampling round, dissolved total phosphorus readings ranged from less than detectable to 0.004 mg/L (4 ug/L). Total phosphorus readings ranged from 0.004 µg/L to 0.0071 µg/L (4 ug/L to 7.1 ug/L at Station 2 which reflected oligotrophic conditions.

These results were compared with results from the Georgian Bay Biosphere Reserve water quality samples obtained from Sandy Bay (Sites 1A and IB) in 2003. Values here ranged from 1.8 to 4.9 ug/L. These values were obtained from Georgian Bay Biophere Reserve's online database and were obtained as part of the Great Lakes Nearshore Assessment.

3.2 MICROBIOLOGICAL PARAMETERS

3.2.1 E. Coli

The presence of E. coli indicates recent faecal contamination and the potential presence of microorganisms capable of causing gastrointestinal illnesses; pathogens in human and animal faeces pose the most immediate danger to public health. E. coli is used as an indicator of the microbiological safety of drinking water. If it is detected, enteric pathogens may be present. E. coli monitoring should be used as part of a multi-barrier approach to producing drinking water of acceptable quality. (Guidelines for Canadian Drinking Water Summary Table, 2014).

E.coli readings at all Stations did not exceed the water quality guideline of none detectable per 100 ml during the first sampling round. This demonstrates that there did not appear to be any faecal contamination occurring in Sandy Bay during the time of the sampling in August.

E.coli was detected at Stations 1, 2 and 4 during the second sampling round in October. The readings ranged from 2 CFU/100mL at Station 4 to 4 CFU/100mL at Stations 1 and 2. The source of E. coli contamination was unknown. Potential sources could include faecal contamination from humans or animals using the surrounding area.

The CCME Guidelines (Canadian Council on Ministers of the Environment) for Recreational Water Quality (Appendix H) indicate that an average of at least 5 samples taken within a 30 day period should not exceed 2000 E. coli/L and that resampling should be performed when samples exceed 4000 E. coli/L. The exceedances of E. coli in Sandy Bay range from 20 E. coli per L to 40 E. coli per L when the values are converted. Therefore the levels in Sandy Bay are well within water quality standards for recreational activities (swimming, windsurfing, waterskiing, etc) and should not be of concern for residents of Henvey Inlet First Nation or the general public.

3.2.2 Total Coliforms

Total coliforms are bacteria that comprise three groups, *Escherichia, Klebsiella, Enterobacte, Citrobacter, Serratia,* and many others. Common sources of total coliforms include human and animal faeces, and they are also naturally occurring in water, soil and vegetation. The presence of any total coliform bacteria in water leaving a treatment plant or in any treated water immediately post treatment signifies inadequate treatment and is unacceptable and will require corrective action. (Government of Ontario, June 2003, rev. June 2006.)Total coliforms are used as a tool to determine how well a drinking water treatment system is operating and to indicate water quality changes in water distribution systems. Detection of total coliforms from consecutive samples from the same site or from more than 10% of the samples collected in a

given sampling period should be investigated (Guidelines for Canadian Drinking Water Quality, 2014).

The guideline for drinking water is for a maximum allowable concentration of none detectable per 100 mL in water leaving a treatment plant.

Total coliforms results for Sandy Bay were less than 100 at all Stations tested indicating that total coliforms in Sandy Bay fell within drinking water guidelines at the time of the August sampling event.

Total coliforms were detected at all Stations during the October sampling round. The values ranged from 10 CFU/100mL at Station 5 to a high of 36 CFU/100mL at Station 4. The source of contamination was unknown. Total coliform values still fell within drinking water guidelines at the time of the October sampling event and therefore use of the waters of Sandy Bay for recreational uses should present a problem.

3.3 Physical Parameters

During the August 26, 2016 sampling event, temperature and oxygen profiles were obtained from all 5 stations.
The weather was clear and a strong prevailing wind was coming from the west, blowing water into Sandy Bay. Photographs of the sampling stations are provided in Appendix C, Field Records. No individuals were present on the Sandy Bay beach located on the north side of the bay, however some larger yachts were observed in nearby bays, seeking shelter from the strong winds.

Temperature and oxygen profile information indicated that oxygen was plentiful at the lake bottom and the lake was not stratified in Sandy Bay and was exhibiting the characteristics of fall turnover. Table 3 outlines the depths and water temperature/oxygen profiles for all stations.

Table 3: Temperature and Oxygen Profile Information, Sandy Bay, August 26, 2016.

	Station 1		Station 2		Station 3		Station 4		Station 5	
	Temp (C)	Oxygen (mg/L)	Temp (C)	Oxygen (mg/L)	Temp (C)	Oxygen (mg/L)	Temp (C)	Oxygen (mg/L)	Temp (C)	Oxygen (mg/L)
1 m	22.96	8.76	22.63	8.74	22.71	8.9	22.79	8.84	22.53	8.84
2 m	22.95	8.94	22.63	8.7	22.7	8.81	22.77	8.81	22.54	8.85
3 m	22.93	8.88	22.63	8.7	22.7	8.82	22.72	8.95	22.54	8.8
4 m	22.88	9.01	22.62	8.73			22.66	8.82	22.55	8.77
5 m			22.61	8.69			22.65	8.78		

Temperature and oxygen profiles were not obtained during the second sampling round, since it was assumed that stratification was continuing into the fall.

3.3.1 Secchi Depth

Secchi depth readings are used to measure the water clarity of the lake. Dissolved organic carbon (DOC), turbidity and/or invading species such as zebra mussels may result in impacts on water clarity. Water clarity readings are valuable to track changes in the lake that might be occurring that would not normally be noticed by monitoring total phosphorus (Lake Partner Program, 2013).

Secchi depth readings ranged from 2.4 at Station 3 to 3.7 at Station 1 and indicate good water clarity in Sandy Bay. Secchi depths were not obtained during the October sampling round.

3.4 Additional Chemical Parameters

Additional water quality parameters were tested at Station 1, in response to community concerns regarding a foul odour in the Bay during the summer of 2016. Appendix D lists the additional water quality parameters that were tested at this location. Table 4 illustrates the parameters where exceedances of Provincial Water Quality Standards were detected.

Table 4: List of Exceeded Parameters at Station 1 and 5

Method	Parameter	Unit	PWQA	Water Quality Guidelines for the Protection of Aquatic Life (Environment Canada, 1998)	Station 1	Station 5
PAH	Anthracene	ug/L	0.0008	0.012	<0.02	<0.01
PAH	Benzo(ghi)perylene	ug/L	0.00002		<0.05	<0.02
PAH	Benzo(k)fluoranthene	ug/L	0.0002		<0.05	<0.02
PAH	Chrysene	ug/L	0.0001	No recommended guideline	<0.06	<0.03
PAH	Dibenz(a,h)anthracene	ug/L	0.002		<0.05	<0.02
PAH	Fluoranthene	ug/L	0.0008	0.04*	<0.04	<0.02
PAH	Phenanthrene	ug/L	0.03	0.4*	<0.04	_
PCBs in Water	Total PCBs	ug/L	0.001		<0.06	<0.06

*Interim guideline

3.5 POLYCYCLIC AROMATIC HYDROCARBONS

The first seven parameters listed in Table 4 are classified as PAH's (Polycyclic Aromatic Hydrocarbons). Provincial Water Quality Guidelines were exceeded for anthracene, Benzo(ghi)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, and Phenanthrene. The comparison guideline is listed in Table 4 for reference. The source of contamination of the water sample at Stations 1 and 5 is unknown.

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds which are non-essential for the growth of plants, animals or humans; yet, they are ubiquitous in the environment. When present in sufficient quantity in the environment, certain PAHs are toxic and carcinogenic to plants, animals and humans (BC Environment, 2016). Polycyclic aromatic hydrocarbons (also known as polynuclear aromatic hydrocarbons) are composed of two or more aromatic (benzene) rings which are fused together when a pair of carbon atoms is shared between them. Environmentally significant PAHs are those molecules which contain two (e.g., naphthalene) to seven benzene rings. PAHs can be divided into two groups based on their physical, chemical, and biological characteristics. The lower molecular weight of PAHs (e.g., 2 to 3 ring group of PAHs such as naphthalenes, fluorenes, phenanthrenes, and anthracenes) have significant acute toxicity to aquatic organisms.

Anthracene is used as a dye or chemical intermediary for dyes, diluent for wood preservatives and is non-carcinogenic (BC Environment, 2016).

PAHs entering the aquatic environment exhibit a high affinity for suspended particulates in the water column. As PAHs tend to sorb to these particles, they are eventually settled out of the water column onto the bottom sediments. PAHs are degraded through the process of photo-oxidation and are subject to biodegradation by microorganisms present in soil, sewage, and water (BC Environment, 2016).

PAH's may occur naturally in the environment, as a result of forest fires, release of fossil fuels, and volcanic activity. Anthropogenic sources may include vehicular exhaust, heat and electrical generating facilities that burn fossil fuels, the production of coke, the production of coal tars, the incineration of waste, and the production of treated wood. The sources of PAHs which may discharge directly into aquatic environment include: accidental spillage and/or leakage of PAH-containing fluids (e.g. waste oils, gasoline, etc.), industrial and domestic wastewaters, urban runoff, discharges originating from landfills, and use of creosoted pilings for docks and other shoreline structures. PAH production may also be atmospheric and may originate from a wide range of stationary and non-stationary sources (BC Environment, 2016).

Since the source(s) of the exceedances are unknown, the location of Sandy Bay should be considered with respect to watershed (ie. Direction of flow of water in the surrounding tributaries) and any potential for point and non-point source receptors should be considered. (BC Environment, 2016). The largest two atmospheric sources of PAH's are forest fires and agricultural burning. The largest two major source of annual input of PAH's to aquatic environments are petroleum spillage and atmospheric deposition.

Figure 2 illustrates the location of Sandy Bay in relation to the tertiary and quaternary watersheds. The watershed area that flows into Sandy Bay is largely undeveloped and includes the Henvey Inlet First Nation Reserve No. 2 and the North Georgian Bay Shoreline and Islands Conservation Reserve which is undeveloped, protected land. It is unlikely that any contamination is arising from within this largely undeveloped area and more likely that the source of contamination is from atmospheric deposition.

3.6 PCBs (Polychlorinated Biphenyls)

Total PCB's exceeded the PWQO value of 0.001 ug/L at Station 1 and with a value of <0.06 ug/L.at Station 5.

PCBs are among the most ubiquitous and persistent pollutants in the global ecosystem. In the past, PCBs have been marketed extensively for a wide variety of purposes but are no longer manufactured or used. The available information suggests that drinking water containing PCB, at a concentration of 0.003 mg/L or less, does not pose a health risk (Government of Ontario, rev. 2006).

4. RECOMMENDATIONS

Henvey Inlet First Nation should consider the following recommendations with respect to the findings of this report:

1. Henvey Inlet Lands and Resources may consider becoming involved in the Lake Partner Program which would enable the community to continue phosphorus sampling in the spring of 2017 in Sandy Bay and in other inland lakes situated on their reserve(s). This would enable them to participate in future years for a minimal cost. Contact information for the Lake Partner Program and additional information on the program can be reviewed in Appendix F. Established sampling locations should be included in the monitoring program to establish a trend over time of seasonal/monthly phosphorus concentrations in Sandy Bay. BluMetric has provided the Lake Partner Program registration information for Henvey Inlet's site at Sandy Bay and a package with materials

to complete phosphorus sampling will be sent to the community. (See Appendix F for additional information).

2. Henvey Inlet could liaise with nearby communities including but not limited to Magnetawan First Nation who are completing phosphorus monitoring in Bying Inlet to compare and share results.
3. Henvey Inlet may wish to consider providing the data compiled within this report to the Georgian Bay Biosphere Reserve online water quality monitoring database (Appendix G).
4. Henvey Inlet may wish to consider partnering with the Dorset Environmental Science Centre and/or the Ontario Benthos Biomonitoring Network.
5. Henvey Inlet may wish to consider additional surface water quality sampling to determine whether exceedances of the PAH and PCB values are present in surface waters at other locations inside or outside of Sandy Bay that may be determined through additional study.
6. Henvey Inlet may wish to consider educational programs to raise awareness of water pollution aimed at membership and cottage owners in the local area or to enhance the capacity of membership to complete water quality monitoring or other forms of environmental monitoring through BluMetric's Environmental Monitoring training program or other capacity-building endeavors.

5. CLOSURE

The conclusions presented in this report represent our professional opinion and are based on the work described in this report and any limiting conditions in the scope of work or conditions noted herein.

The findings presented in this report are based on conditions observed at the specific dates and locations noted, the analysis of samples for the specified parameters and information obtained for this project. Unless otherwise stated, the findings cannot be extended to previous or future site conditions, locations that were not investigated diretly, or types of analysis not performed.

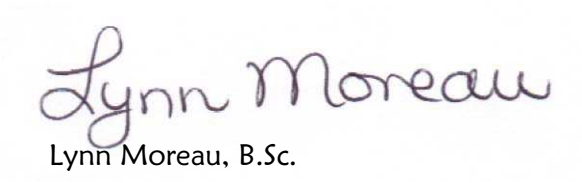
BluMetric makes no warranty as to the accuracy and completeness of the information provided by others, or of conclusions and recommendations predicated on the accuracy of that information.

This report has been prepared for Henvey Inlet First Nation, and for Environment Canada (the funder). Any use a third party makes of this report, any reliance on the report, or decisions based upon the report, are the responsibility of those third parties unless authorization is received from BluMetric in writing. BluMetric accepts no responsibility for any loss or damages suffered

by any unauthorized third party as a result of decisions made or actions taken based on this report.

Thank you for the opportunity to provide services to Henvey Inlet First Nation.

Respectfully submitted,
BluMetric Environmental Inc.



Lynn Moreau, B.Sc.
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Senior Hydrogeologist

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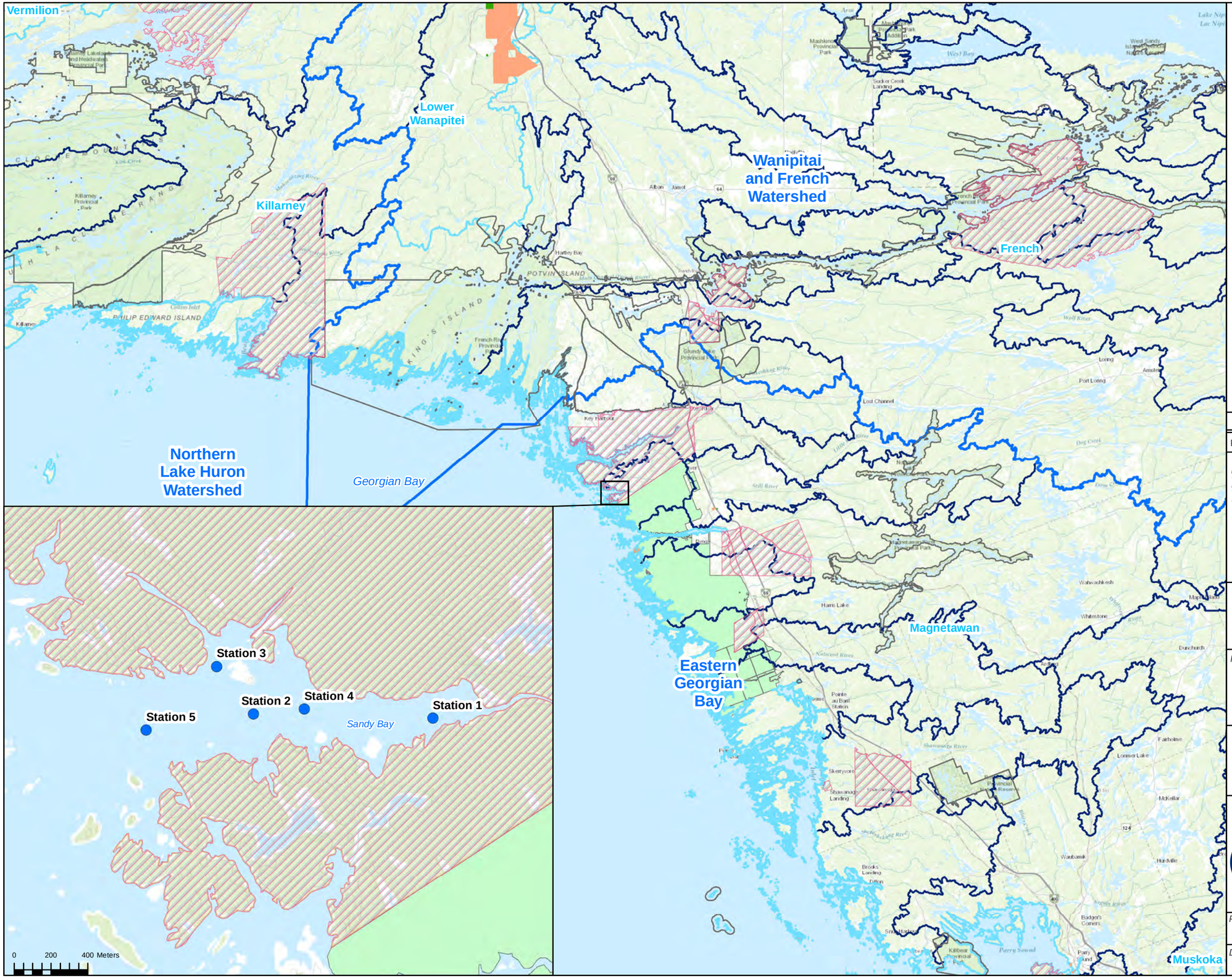
FIGURES



LEGEND

- Station Location
- Indian Reserve
- Regulated Provincial Park
- Crown Leased Land
- Federal Land
- Secondary Watershed
- Tertiary Watershed
- Quaternary Watershed
- North Georgian Bay Shoreline and Islands Conservation Reserve

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
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REFERENCES

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N W E S

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CLIENT

Henvey Inlet First Nation

PROJECT

Sandy Bay Water Quality Sampling

TITLE

Sandy Bay Sampling Station Locations

BluMetric™ Environmental

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Ottawa, Ontario K0A 1L0
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FAX: (613) 839-5376
Email: info@blumetric.ca
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PROJECT #	DATE
160524-00-03	November 08, 2016

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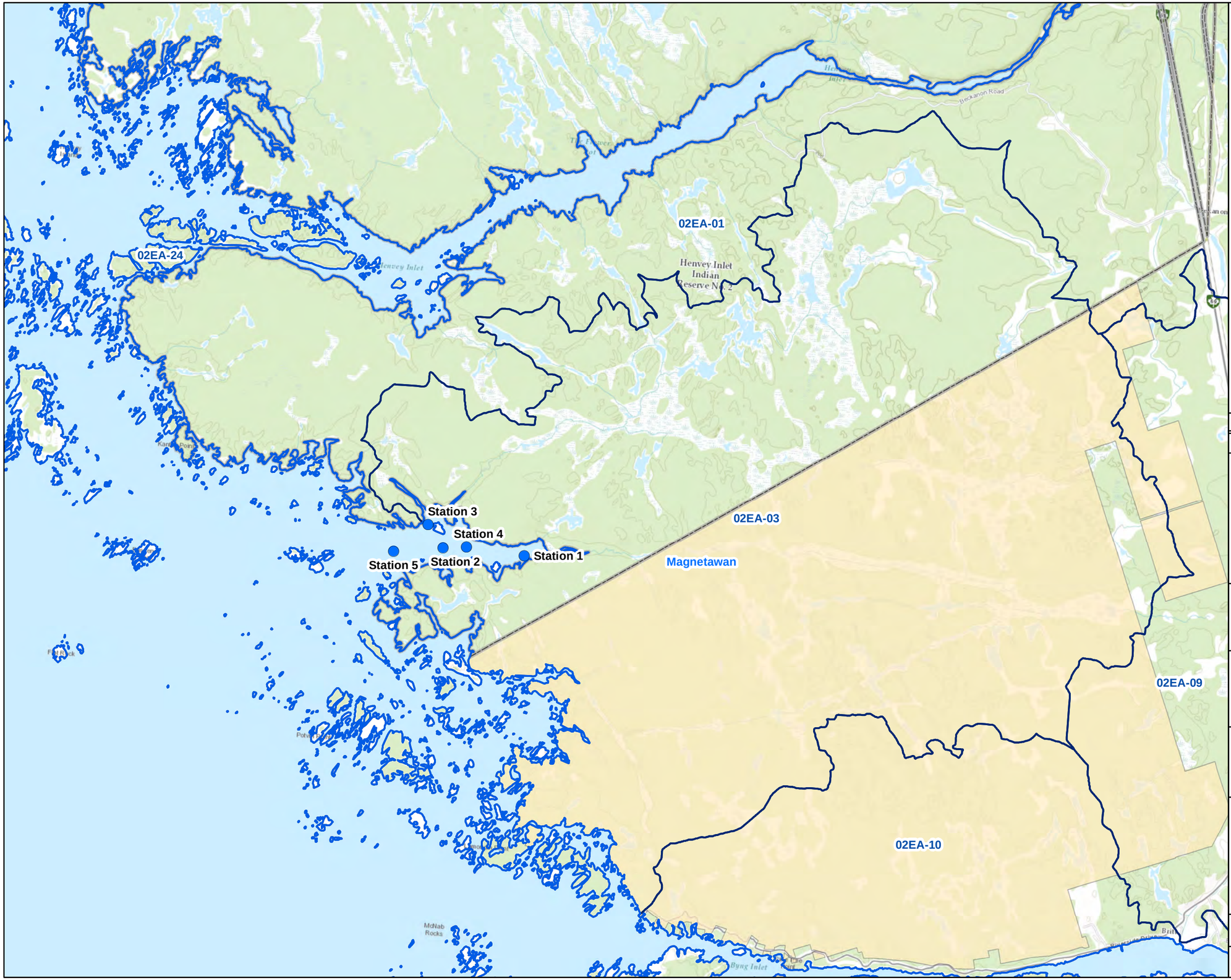

LEGEND

- Station Location
- Tertiary Watershed
- Quaternary Watershed
- Indian Reserve
- North Georgian Bay Shoreline and Islands Conservation Reserve

REV.	DESCRIPTION	YY/MM/DD	BY	CHK
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CLIENT

Henvey Inlet First Nation

PROJECT

Sandy Bay Water Quality Sampling

TITLE

Sandy Bay Watershed

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PROJECT #	DATE		
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Appendix A

Enclosed Bays and Inland Lakes Phosphorus Monitoring Guidelines

State of the Bay

Water Quality Indicator Update

Enclosed Bays and Inland Lakes Phosphorus Monitoring Guideline

Photo credit: Meg Wallace Photography

Final Version – March 2016

Prepared by:

Bev Clark
David Bywater
Becky Pollock
Greg Mason

Government of Canada / Gouvernement du Canada

With support from Environment Canada's Lake Simcoe/South-eastern Georgian Bay Clean-Up Fund (LSGBCUF)

FINAL VERSION

Summary

Designated by UNESCO in 2004, the Georgian Bay Biosphere Reserve (GBBR) is an area of 347,000 hectares that stretches 200 km along the eastern coast of Georgian Bay from Port Severn to the French River, in the world's largest freshwater archipelago, also known as the '30,000 Islands' (Figure 1).

In 2015, GBBR facilitated a review of nutrient monitoring programs within its boundaries (Clark et al., 2015). The review determined that current federal and provincial monitoring programs are well established and effectively collect the data needed for open water and most nearshore areas of eastern Georgian Bay. Recommendations from that review included the need for increased monitoring in enclosed bays that are often inaccessible to larger monitoring vessels, as well as at enclosed bays and inland lakes where there are no long-term programs in place. The review also determined that there are current monitoring programs in place for most areas of eastern Georgian Bay where there are existing water quality concerns (Clark et al., 2015).

While there are numerous active monitoring locations within the GBBR (Clark et al., 2015), there remain many enclosed bays and inland lakes that lack current nutrient monitoring programs. The guideline outlines how townships, ratepayer associations and/or volunteers can initiate nutrient monitoring in these areas. Nutrient monitoring refers to total phosphorus (TP) monitoring, as it is the nutrient that controls the growth of algae and most living biota in the aquatic environment. Total phosphorus data can be useful for detecting trends, identifying internal loading and providing information to help avoid or reverse harmful algal blooms.

The easiest way for ratepayer associations and/or volunteers to get involved with phosphorus and water clarity monitoring is to participate in the Ministry of the Environment and Climate Change's (MOECC) Lake Partner Program (LPP). The LPP provides monitoring equipment and samples are collected once per year in the spring for most sites and monthly for sites that are not on the Canadian Shield. Volunteers must use their own boats to collect samples.

Spring sampling (following LPP protocols) will be sufficient for most locations in the GBBR, as there are few areas that experience fall algal blooms (Clark et al., 2015). However, in some locations further monitoring (beyond LPP) may be required. A decision tree (Figure 3) outlines how additional monitoring would occur under several scenarios. The collection of additional water quality data should be recommended on a case by case basis following a review of existing data.

This guideline includes suggested nutrient monitoring locations for enclosed bays and inland lakes. Our approach identifies potential monitoring locations and then seeks to find volunteers to sample them. Whenever possible, volunteers are encouraged to contact GBBR prior to sampling if they have any comments or concerns about the suggested monitoring locations.

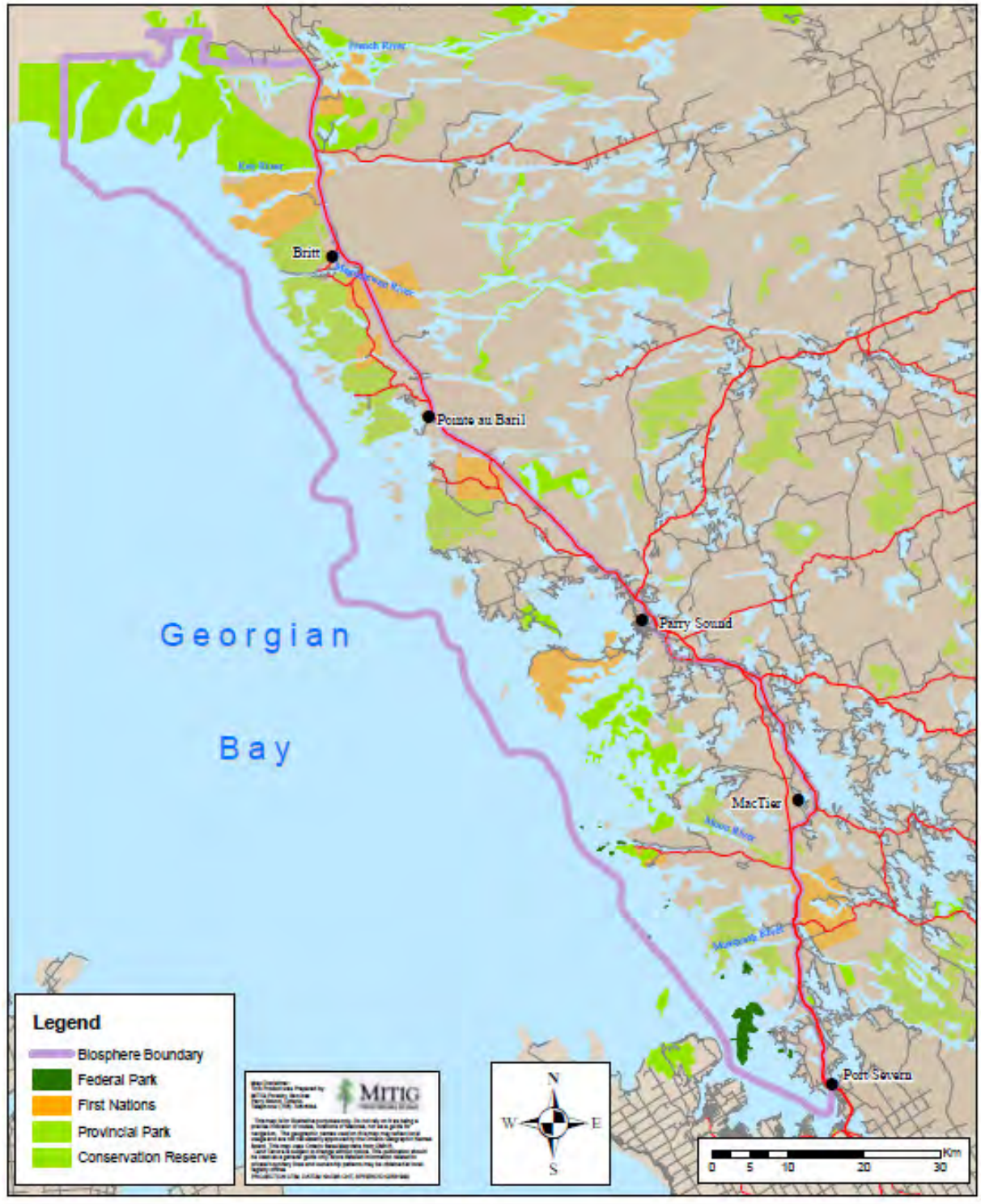


Figure 1 – Georgian Bay Biosphere Reserve

Why Monitor Total Phosphorus (TP)?

Nutrient monitoring refers to total phosphorus (TP) monitoring, as it is the nutrient that controls the growth of algae and most living biota in the aquatic environment. Total phosphorus data can be useful for detecting trends, identifying internal loading and providing information to help avoid or reverse harmful algal blooms.

Why Monitor TP in Enclosed Bays?

Enclosed bays that are connected to Georgian Bay, and have limited exchange of water due to convoluted connections or constricted openings, will have water chemistry characteristics that are mostly subject to influences from the upstream watershed. This will be especially true if there are major inflows or shoreline development within the bay. Even in cases where the bay is considered to be 'natural' there are multiple stressors associated with all ecosystems that occur as a result of climate change, long-range transport of pollutants and the influx of invading species. Monitoring in these areas will help to understand the impacts of these stressors and support federal and provincial monitoring in nearby nearshore areas.

Finally, there are many areas of eastern Georgian Bay where no background data exist. For example, shallow nearshore areas inaccessible to federal and/or provincial monitoring vessels (i.e. MOECC and EC boats). Also, the paucity of data is more pronounced in areas that are further north where the impacts of future development are uncertain.

Why Monitor TP in Inland Lakes?

Inland lakes require total phosphorus data to help assess background concentrations relative to present day concentrations. These data are often used to assess development capacity (Paterson et al., 2006).

Figure 2 – Water quality is important to residents, cottagers and visitors in GBBR

Steps towards a Nutrient Monitoring Program

Lake Partner Program

The easiest way for ratepayer associations and/or volunteers to get involved with phosphorus and water clarity monitoring is to participate in the Ministry of the Environment and Climate Change's (MOECC) Lake Partner Program (LPP). The LPP provides monitoring equipment and samples are collected once per year in the spring for most sites and monthly for sites that are not on the Canadian Shield. Volunteers must use their own boats to collect samples. Details are available at: http://desc.ca/programs/LPP

Additional Water Quality Monitoring

Spring sampling (following LPP protocols) will be sufficient for most locations in the GBBR, as there are few areas that experience fall algal blooms (Clark et al., 2015). However, in some locations further monitoring (beyond LPP) may be required. Generally, the 'trigger' to consider additional monitoring relates to high TP and/or algal blooms. A decision tree shown in Figure 3 outlines how additional monitoring would occur under several scenarios. In these scenarios, further water quality parameters can be obtained with only a few additional pieces of equipment, most notably oxygen meters and specialized bottles to collect samples at distinct depths. It is important to bear in mind that the scenarios outlined in the decision tree pertain only to aspects of total phosphorus monitoring.

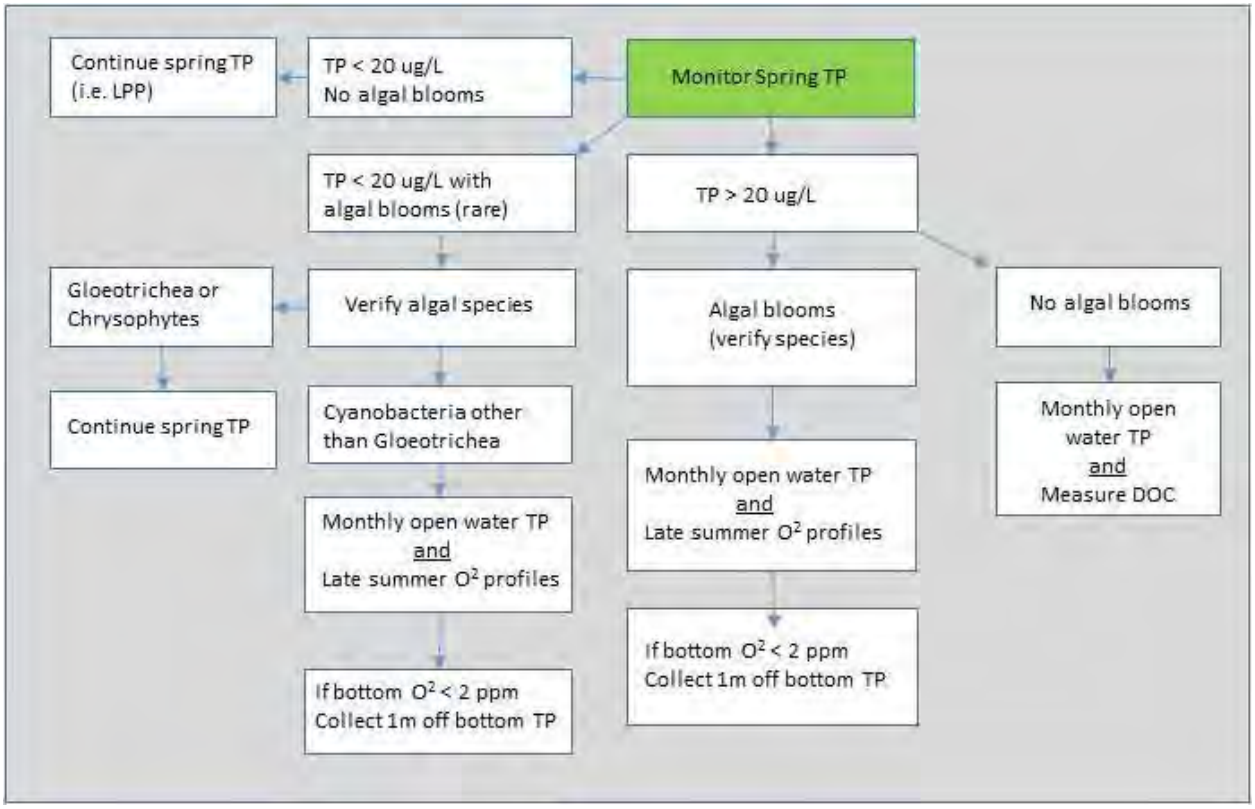


Figure 3 – Simplified Decision Tree to Assess the Need for Additional Monitoring

Additional water quality data are often collected to help interpret any results from a spring nutrient monitoring program that prove difficult to interpret. Tests such as dissolved organic carbon (DOC) can help to determine whether or not high TP concentrations are from natural sources. The collection of additional water quality data should be recommended on a case by case basis following a review of existing data. Additional costs are associated with analysis which must be outsourced to a private lab. General water chemistry suites are available from most private labs and these often include: pH, alkalinity, conductivity, nitrogen (specifically nitrate, NO^3), phosphorus, dissolved organic carbon (DOC), chloride, sulphate, silica and sometimes cations and anions.

Several municipalities undertake additional water quality monitoring by partnering with the MOECC's LPP. Municipalities typically collect samples using their own equipment and staff, with sample analysis provided by the LPP. These types of science partner programs must be pre-arranged with MOECC. Factors influencing data collection requirements include and are not limited to, planning (e.g. lake capacity model), by-laws, and local water quality conditions. Other groups use volunteers to collect samples which are submitted to the Trent University Lab (fee for service) at the Dorset Environmental Science Centre. In some cases consultants are used to complete the sampling each year.

Costing Estimates

Nutrient monitoring programs range from volunteer and donated equipment to the use of salaried field staff and purchased equipment (boats, vehicles, sample equipment). Program scope will depend on the number of lakes or bays that are sampled and whether there is a need for sampling in months other than in the spring. Spring sampling will be sufficient for most locations in the GBBR (Clark et al., 2015). The range in costs will depend on the extent to which volunteers and donated equipment are used, as well as other factors such as accessibility and/or distance to a site. Table 1 shows general costing estimates for a wide range of program activities.

Table 1 – Approximate costs for different types of nutrient monitoring programs

Program Type	Staff	Equipment	Analysis	~ Cost per site	Comments
Volunteer	Volunteer	Donated	Free if LPP	Free	May lack long-term commitment due to volunteer fatigue.
In-House (municipal or local group)	Student(s) or staff	Purchased	~$50/site Free if combined with LPP	Wages + capital costs divided by the number of sites.	High level of oversight and flexibility to conduct additional work. Best for multiple sites. Not suitable for small number of sites.
Consultant	Fees	Typically provided (best to confirm)	~$50/site	Usually based on hourly fees: $400 to $800/day to do several lakes/sites	Better for small number of sites if volunteer program is not feasible. More cost effective if lakes are close together.

Monitoring Protocols

Nutrient Monitoring

In this case *nutrient monitoring* refers to total phosphorus (TP) monitoring. This is the nutrient that controls the growth of algae and most living biota in the aquatic environment.

Sample Location **–** Sample locations to characterize water quality in enclosed bays should be in open, deep-water areas. Sample locations near to inflows, close to shore, in shallow areas or in areas where there is significant water exchange with Georgian Bay should be avoided (Figure 4). While we have focused our sampling location advice on enclosed bays, the same principles apply to other bodies of water and the LPP instructions also include sample location selection.

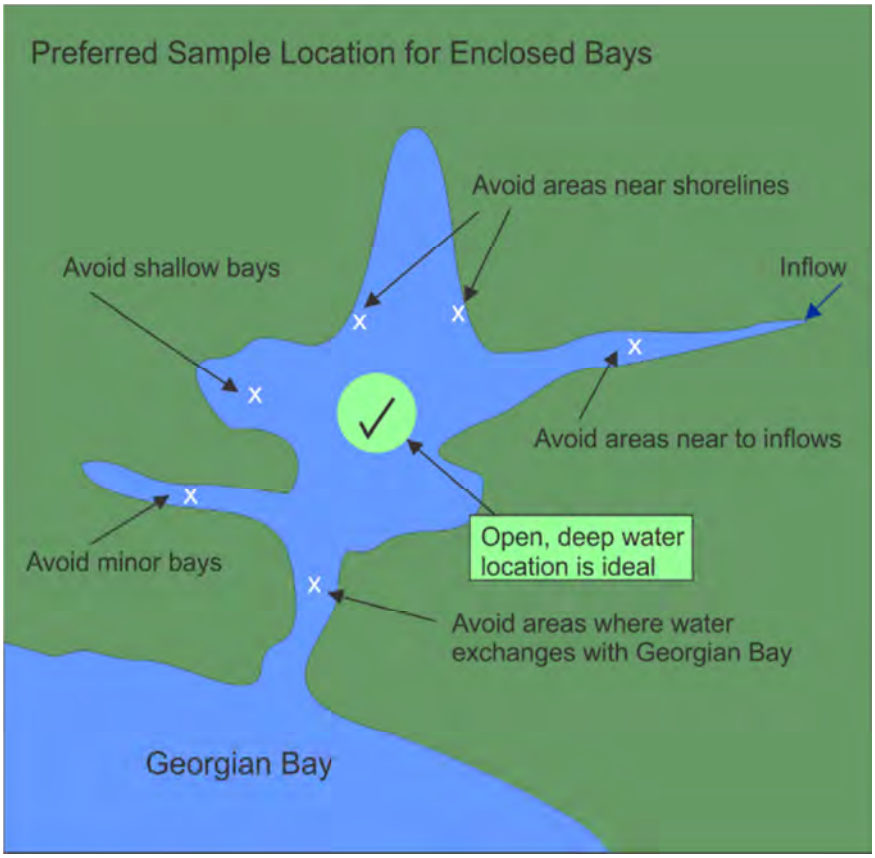


Figure 4 – Diagram to illustrate preferred sample locations for enclosed bays

Sample Timing **–** Spring turnover is the period when a body of water is well mixed from the surface to the bottom such that samples will be representative of the entire water body. It is better to wait for 7 to 10 days after ice out to avoid unmixed conditions. Samples taken a bit later in the season after the water has stratified will still be acceptable since the water, which is now thermally stratified, will not immediately begin to show variations in chemistry with depth. In summary, it is best to take samples in May (Clark et al., 2010).

Sample Methods – The Lake Partner Program and the Trent University Lab provide 35mL borosilicate glass tubes for sample collection. Composite samples are collected and coarse filtered directly into the borosilicate sample tubes that will be used to digest the samples for analysis. The key aspect of low level phosphorus analysis is to collect the samples into the same container that will be used to digest the sample. This eliminates problems associated with transfer between sample containers and eliminates sample perishability problems.

There are many protocols for mixed layer sampling that include composite bottles or bottles that are simply held below the surface to fill. Most protocols suggest a composite whereby a bottle fills as it is being lowered and sample bottom depths are often specified as the Secchi depth or 5m. LPP volunteers collect a composite sample from the surface down to the Secchi depth using a weighted plastic drinking water bottle. Studies by Clark (unpublished data) to assess various sample methods found no difference in results for samples collected by a wide range of protocols. Only the samples collected to 2x the Secchi depth showed some difference. It is very important to avoid getting floating surface material into the sample and to avoid contact with the water by any foreign material other than the sample bottle, the filter and the borosilicate tube. Likewise, stirring up bottom sediment and getting this into the sample should be avoided. Sampling directions are provided by the LPP.

Sample Analysis - The most important aspect of a TP monitoring program is to ensure that samples are submitted to a lab that can conduct precise, low-level analysis. Specifically, it is important to maintain detection limits around 0.1 µg/L and standard deviation between duplicate analyses of less than 1 µg/L in order to detect change at the extremely low ambient concentrations that are currently being observed in Georgian Bay. These methods are currently being used by the MOECC labs at the Dorset Environmental Science Centre (DESC) to analyse samples from the Lake Partner Program and by the Trent University Lab at the DESC to analyse fee for service samples for many groups.

In the past, TP data was affected by poor precision in analysis, but these problems were corrected in 2002 when low-level analysis was adopted by the LPP and other groups. Therefore, historical TP trends typically use data from 2002 onwards.

Identifying Areas that Require Monitoring

Enclosed Bays

A set of priorities was developed to help identify enclosed bays that would benefit from nutrient monitoring programs. Enclosed bays should be identified with preference according to the following order:

1. Enclosed bays with development and large watershed influences (i.e. inflows).
2. Enclosed bays with development and influenced by local watershed.
3. Enclosed bays with little or no development and large watershed influences (i.e. inflows).
4. Enclosed bays with little or no development and influenced by local watershed.

Note: In all cases, enclosed bays where MOECC collects data are recommended for LPP monitoring as these locations would support ongoing MOECC research. Furthermore, locations inland from these

enclosed bays, that MOECC cannot access, have been prioritized in order to better understand watershed influences.

Inland Lakes

Inland lakes should be sampled in all cases where there are no previous data being collected. Developed lakes should be sampled before undeveloped lakes in the case where resources are limited.

In most cases one sample location near the deepest area of the lake is sufficient. More locations may be sampled if there are compelling reasons to suspect variations on water chemistry due to inflows or areas of significant development.

Suggested Monitoring Locations

There are numerous active monitoring locations within the GBBR (Clark et al., 2015), but there remain many enclosed bays and inland lakes that lack current monitoring programs. Appendix 1 contains maps by township with tables to describe suggested monitoring locations. Digital files are available for ratepayer associations and/or volunteers interested in uploading the suggested locations to a GPS unit (please contact: David Bywater, GBBR, 705-774-0978, conservation@gbbr.ca)

It is important to remember that further monitoring is proposed not to address existing problems, but rather to expand our understanding of the GBBR ecosystem. For example, to better understand the multiple stressor effects on nutrients (e.g. climate change, long range transport, invasive species, etc.).

In addition to the priorities listed above, suggested sampling locations (provided in Appendix 1) have been chosen based on a range of factors, such as: input from earlier workshops; sample locations used by current federal and/or provincial monitoring programs; sample locations upstream from current federal and/or provincial monitoring programs to better understand watershed influences; and sample locations that are inaccessible to federal and provincial monitoring vessels.

Our approach identifies potential monitoring locations and then seeks to find volunteers to sample them. In many cases, however, volunteers may wish to sample elsewhere. In addition, existing programs with advanced knowledge of currents and water levels may also choose to move some of the locations proposed in Appendix 1. Whenever possible, volunteers are encouraged to contact GBBR prior to sampling if they have any comments or concerns about the suggested monitoring locations.

The number of monitoring locations have been selected in order to provide good regional coverage, thus the list is not exhaustive. Therefore other unmarked locations exist that could fulfill the criteria listed above. Ratepayer associations and/or townships with the capacity to monitor more locations (than those recommended in Appendix 1) are encouraged to contact the GBBR for assistance with sample site selection.

Existing Lake Partner Program Data

It is important to note that there are many locations where data have been collected by the Lake Partner Program that may not be currently monitored. This does not mean that there is insufficient data to accurately characterise water quality with respect to TP in these locations. There may be

sufficient data to assess long term means (>3-5 years). Locations that have been sampled by the LPP are shown in Figure 3. It would be worthwhile in the cases where sample sites are no longer being sampled to try to find volunteers to continue the monitoring. Sample location details are available by zooming in on the map on the LPP website.

Many sample locations such as those shown in Killarney Park represent federal, provincial and/or university research project sample locations indicating the presence of significant additional water quality data. In many cases these data have not been summarized; which is a shortcoming for many of the datasets that pertain to water bodies in the GBBR.

Existing LPP data is available online at the MOECC's website (link below), as well as on GBBR's nutrient monitoring website.

- GBBR's website (click on the 'Water Quality' tab): http://ow.ly/10B5n2
- LPP website: www.ontario.ca/data/ontario-lake-partner

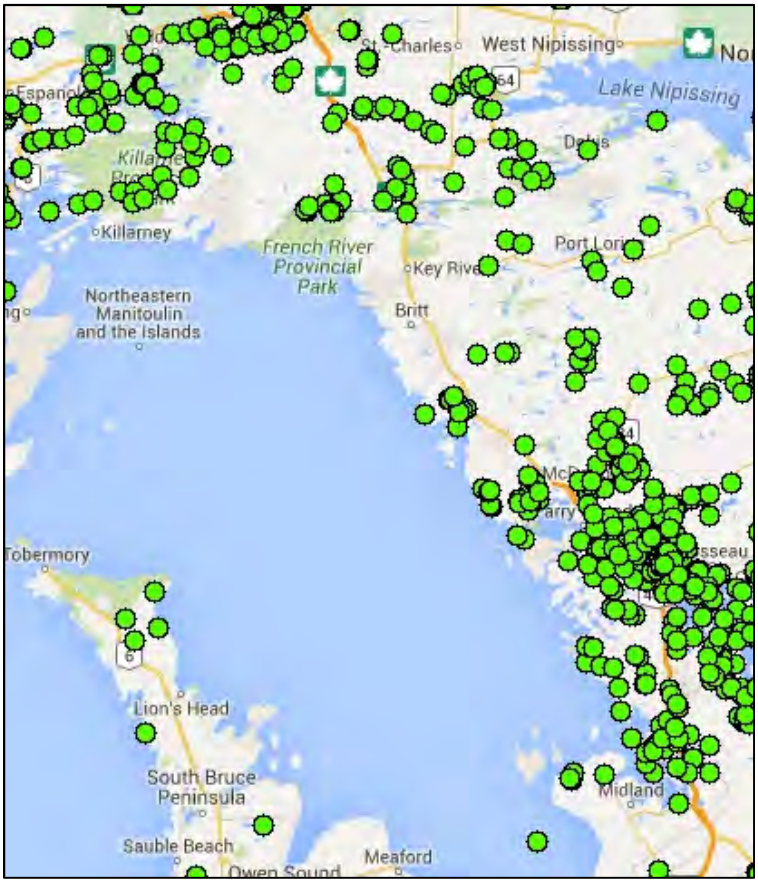


Figure 5 – Past and present Lake Partner Program sample locations within the GBBR and surrounding area

References

Clark, B., D. Bywater, B. Pollock, and G. Mason. 2015. Nutrient Monitoring in the Georgian Bay Biosphere Reserve.

Clark, B.J., A.M. Paterson, A. Jeziorski, and S. Kelsey. 2010. Assessing variability in total phosphorus measurements in Ontario lakes, Lake and Res. Man. 26(1): 63-72.

Ministry of the Environment and Climate Change. 2015. LPP website - www.ontario.ca/data/ontario-lake-partner.

Paterson, A. M., P. J. Dillon, N. J. Hutchinson, M. N. Futter, B.J. Clark, R. B. Mills
R. A. Reid and W. A. Scheider. 2006. A review of the components, coefficients, and technical assumptions of Ontario's Lakeshore Capacity Model. Lake and Res. Man. 22(1): 7-18.

Nutrient Monitoring Website

Do you want to learn more about water quality along eastern Georgian Bay? Have you ever wondered who monitors the water around your house or cottage? We have developed a searchable map to show the major monitoring programs and activities in each area of the Biosphere Reserve. Start at this link and make sure to select the 'WATER QUALITY' tab from the top left menu: http://ow.ly/10B5n2

The website has several different features and tools, allowing the user to explore nutrient conditions along the Bay. The 'Summary' page allows the user to review the Ministry of Environment and Climate Change's Lake Partner Program data. You can simply view the total phosphorus results for your area, or more advanced users might wish to use the "Query" and/or "Chart" tools to analyze the data. The 'Advanced' page allows the user to review and compare three different nutrient monitoring programs.

Nutrient Monitoring Reports

As noted in the Summary section, this guideline is part of GBBR's 'Coordinated Nutrient Strategy for eastern Georgian Bay' project. Previous reports referenced in this guideline are available online at:

- www.gbbr.ca/our-environment/state-of-the-bay-report

Appendix 1 – Potential locations for additional monitoring

Interpreting the Maps and Tables

Maps

 Red square = MOECC site

 Blue circle = TGB site

 Green triangle = LPP site

 Yellow star = Recommended sampling site

Tables

- IL = inland lake
- EB = enclosed bay
- MOECC = Ministry of the Environment and Climate Change
- LPP = Lake Partner Program

Township of Georgian Bay

Recommended sample locations are shown on Map A and listed in Table A. Areas in the south portion are well monitored by SSEA.

Map A

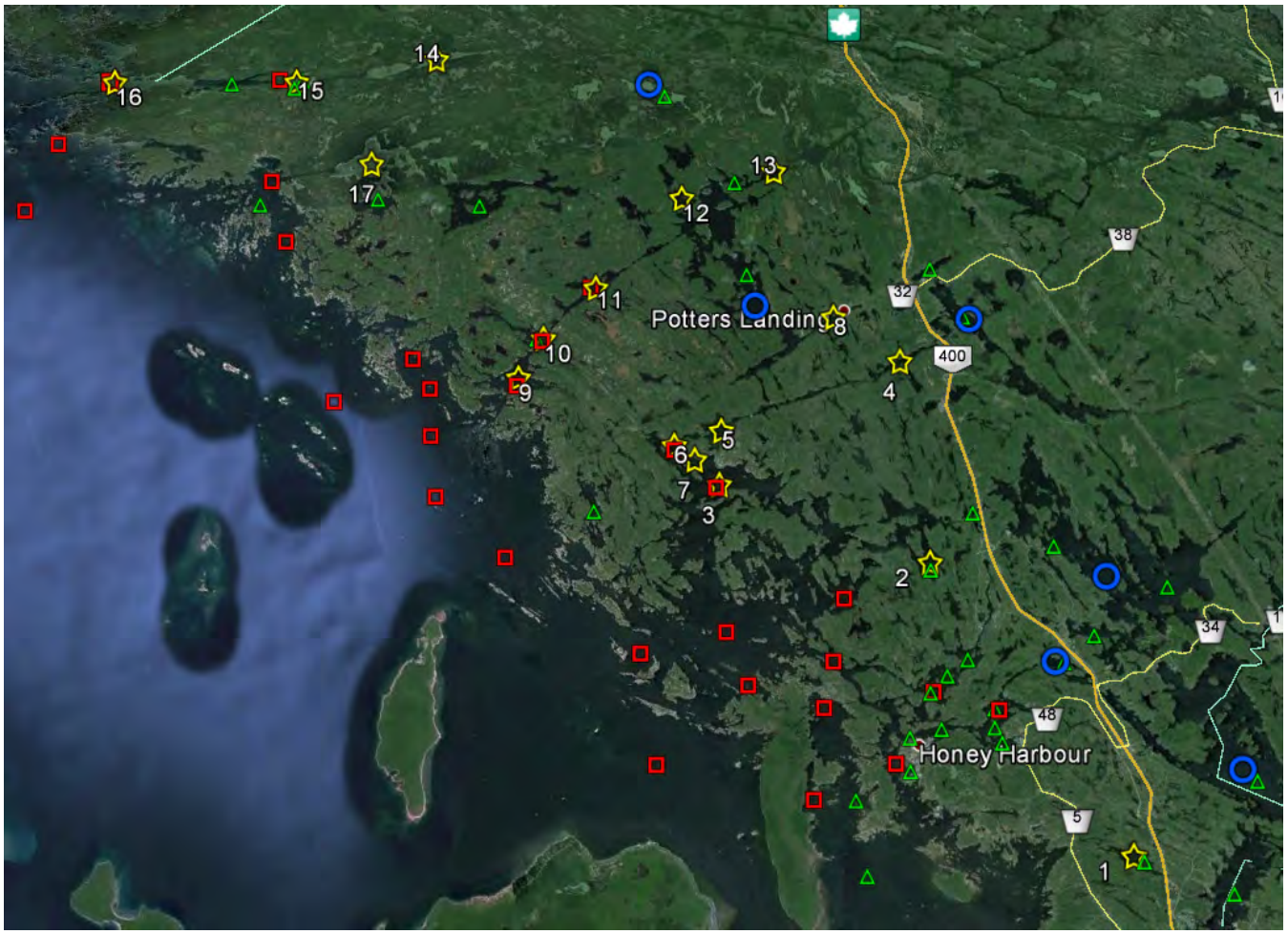


Table A

	Township of Georgian Bay (17)						
Site #	Location	Lat	Long	Type	Existing Data	Action	Rationale
1	Barron's Lake	44 49 51	79 44 51	Large IL	No current LPP	LPP	Continue LPP
2	McCrae Lake	44 55 04	79 47 53	Large IL	No current LPP	LPP	Continue LPP
3	Musquash mouth	44 57 00	79 52 13	EB	MOECC	LPP	MOECC support
4	Gibson Lake Outflow	44 58 23	79 47 34	EB/River	no	LPP	MOECC support
5	Near Gibson Mouth	44 57 52	79 51 56	EB/River	no	LPP	MOECC support
6	Musquash Gibson Mouth	44 57 47	79 53 03	EB/River	MOECC	LPP	MOECC support
7	Sawdust Bay	44 57 30	79 52 39	EB hotspot	no	LPP	hotspot
8	Potters Landing	44 59 20	79 48 51	EB/River	no	LPP	MOECC support
9	Go Home OUT near mouth	44 59 24	79 56 15	EB/River	MOECC	LPP	MOECC support
10	Go Home OUT near Go Home	44 59 57	79 55 30	EB/River	MOECC	LPP	MOECC support
11	Go Home River	45 00 37	79 54 05	EB/River	MOECC	LPP	MOECC support
12	Mannings Bay	45 01 48	79 51 43	EB	no	LPP	MOECC support
13	Flatrock Lake	45 01 56	79 49 29	EB	no	LPP	MOECC support
14	Twelve Mile Bay E	45 04 57	79 56 41	EB	no	LPP	MOECC support
15	Twelve Mile Bay Mid	45 05 03	80 00 01	EB	MOECC	LPP	MOECC support
16	Twelve Mile Bay W	45 05 40	80 04 13	EB	MOECC	LPP	MOECC support
17	Tadenac	45 03 25	79 58 39	EB	no	LPP	EB no data

Township of the Archipelago (southern portion) and Seguin Township

Recommended sample locations are shown on Map B and listed in Table B. Note that Seguin Township is well sampled (by the municipality) using Dorset protocols such that no further sampling is required. However, any lakes in Seguin with no data could still join the LPP.

Map B

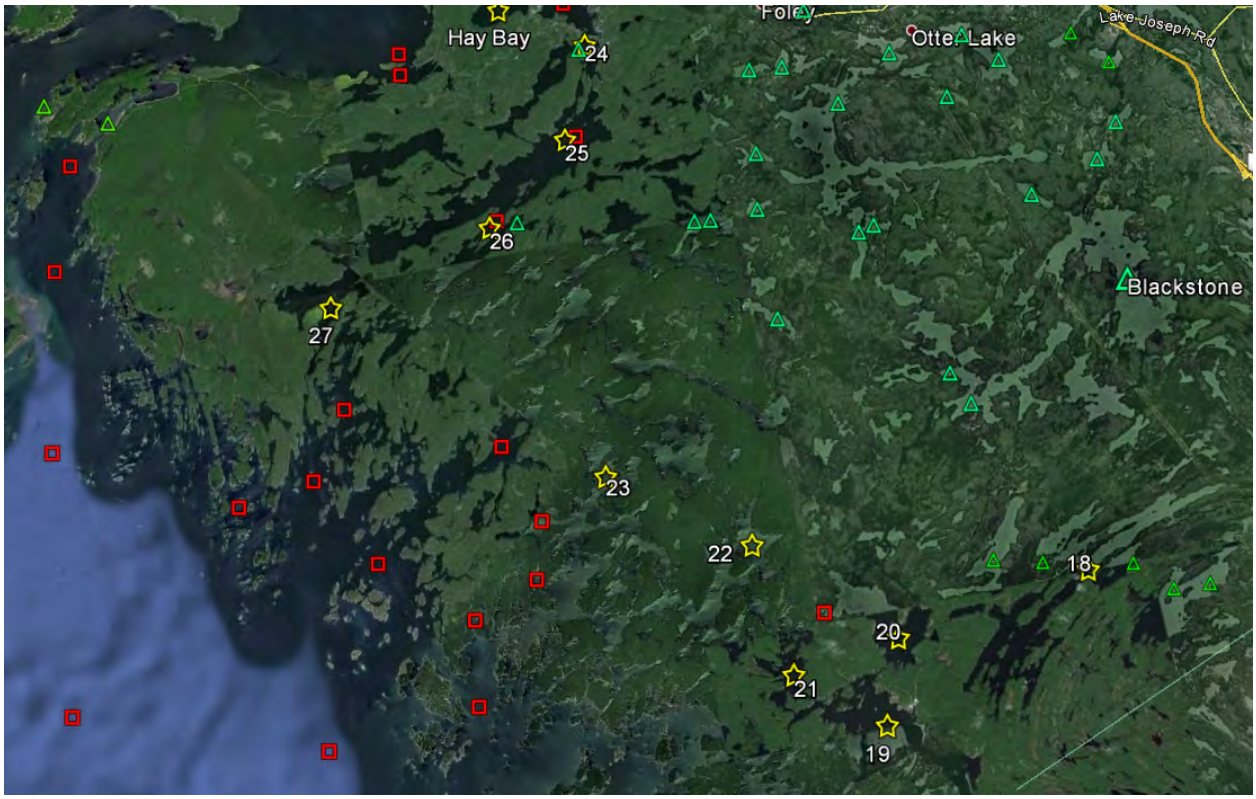


Table B

	Township of the Archipelago (South) (10)						
Site #	Location	Lat	Long	Type	Existing Data	Recommendation	Rationale
18	Healey Lake	45 09 52	79 55 01	IL	No	LPP	more locations
19	Woods Bay	48 08 20	79 59 39	EB	No	LPP	Developed EB
20	Blackstone Harbour	45 09 29	79 59 02	EB	No	LPP	Developed EB
21	North Channel	45 09 17	80 01 15	EB	No	LPP	Developed EB
22	Port Rawson Bay	45 11 10	80 01 31	EB	No	LPP	Developed EB
23	Ruddy Island	45 12 32	80 04 06	EB	No	LPP	Developed EB
24	Near Rose Point	45 18 45	80 02 43	EB	no	LPP	Support fo MOECC
25	South Channel	45 17 26	80 03 31	EB	MOECC	LPP	Support fo MOECC
26	Seven Mile Narrows	45 16 23	80 05 24	EB	MOECC	LPP	Support fo MOECC
27	W end Five Mile Bay	45 15 43	80 08 54	EB	no	LPP	Support fo MOECC

Town of Parry Sound and Township of Carling

Recommended sample locations are shown on Map C and in Table C.

Map C

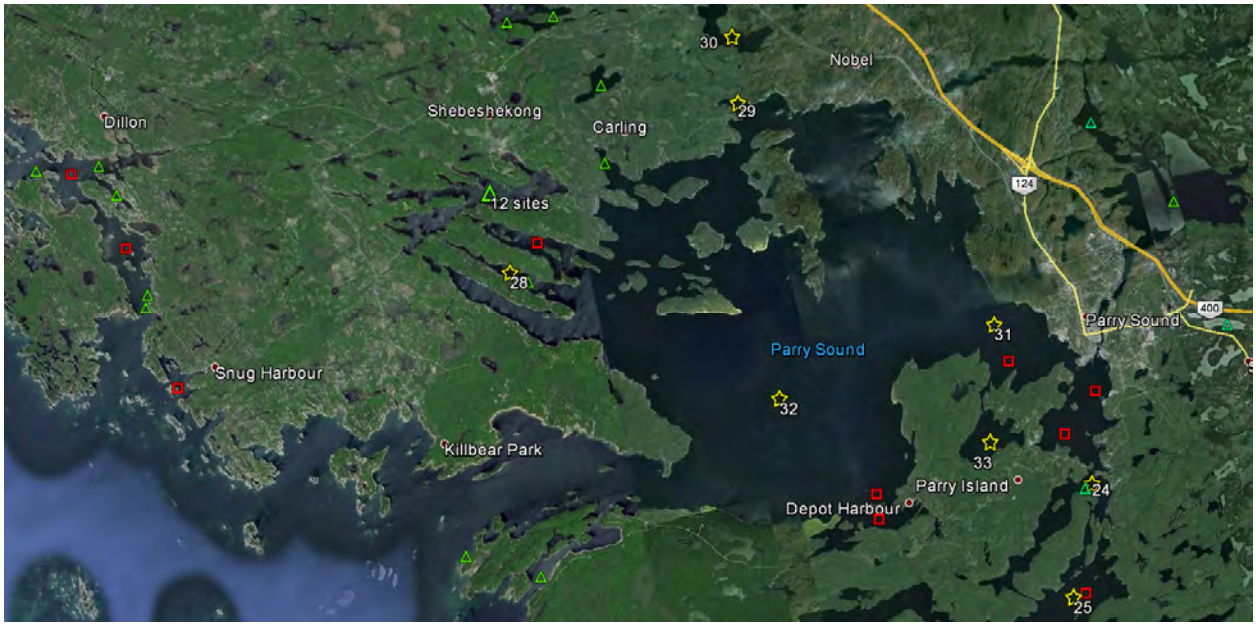


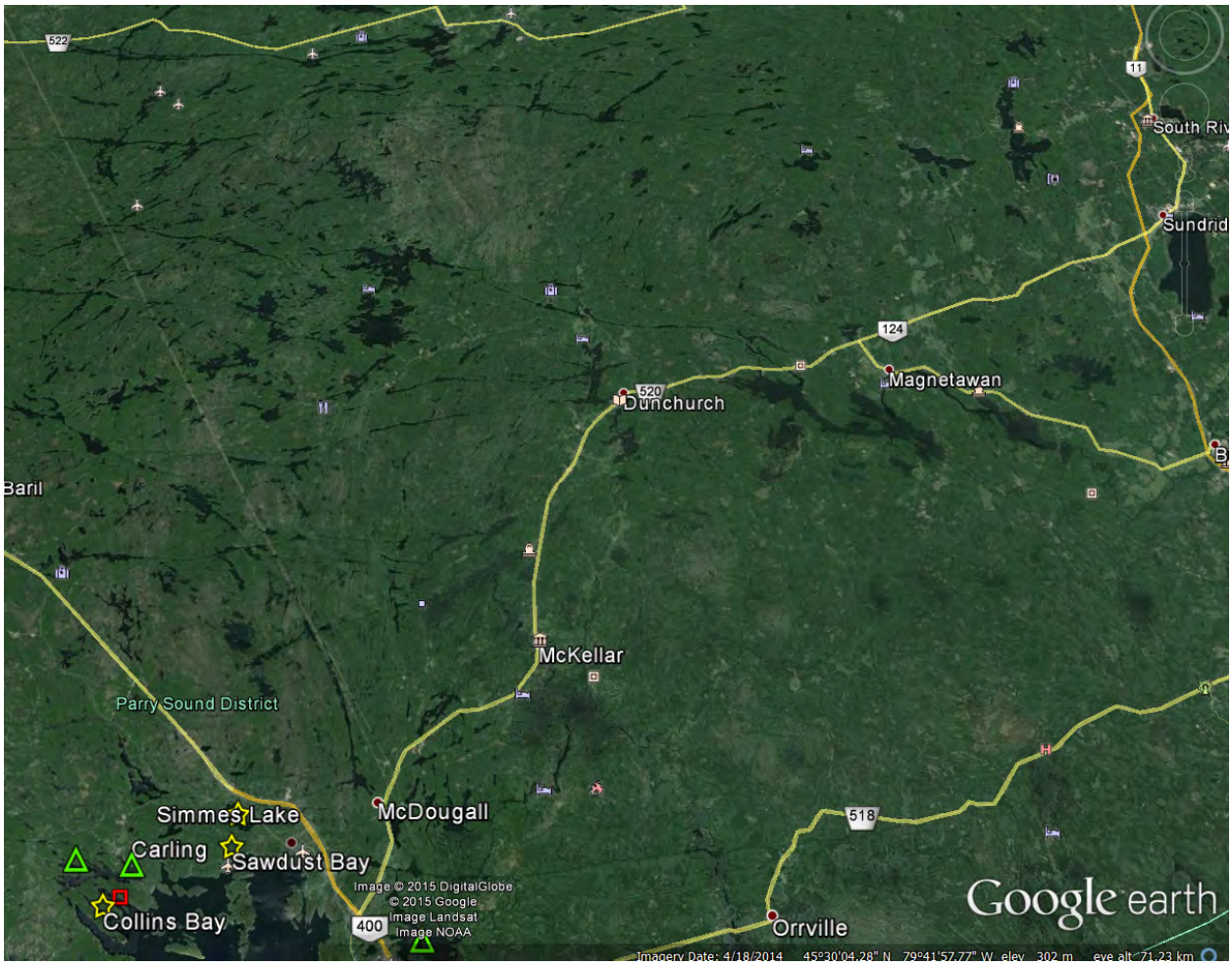
Table C

	Parry Sound and Carling Township (6)						
Site #	Location	Lat	Long	Type	Existing Data	Recommendation	Rationale
28	Collins Bay	45 22 54	80 12 11	EC	no?	LPP	EB Outflow
29	Sawdust Bay	45 24 30	80 07 26	EB	no	LPP	EB with issue
30	Simmes Lake	45 25 23	80 07 16	IL feeds EB	no	LPP	Outflow to EB
31	PS near Parry Sound	45 20 59	80 03 45	EB	MOECC	LPP	support for MOECC
32	Parry Sound Mid	45 20 37	80 07 52	EB	no	LPP	no data
33	Hay Bay	45 19 32	80 04 19	EB	no	LPP	EB with no data

Township of McKellar, Municipalities of McDougall and Whitestone

These large areas bordering the GBBR have several active LPP locations, but would benefit from increased monitoring of inland lakes.

Map D



Township of the Archipelago (northern portion) to Key River

Recommended sample locations are shown on Map E and in Table E.

Map E

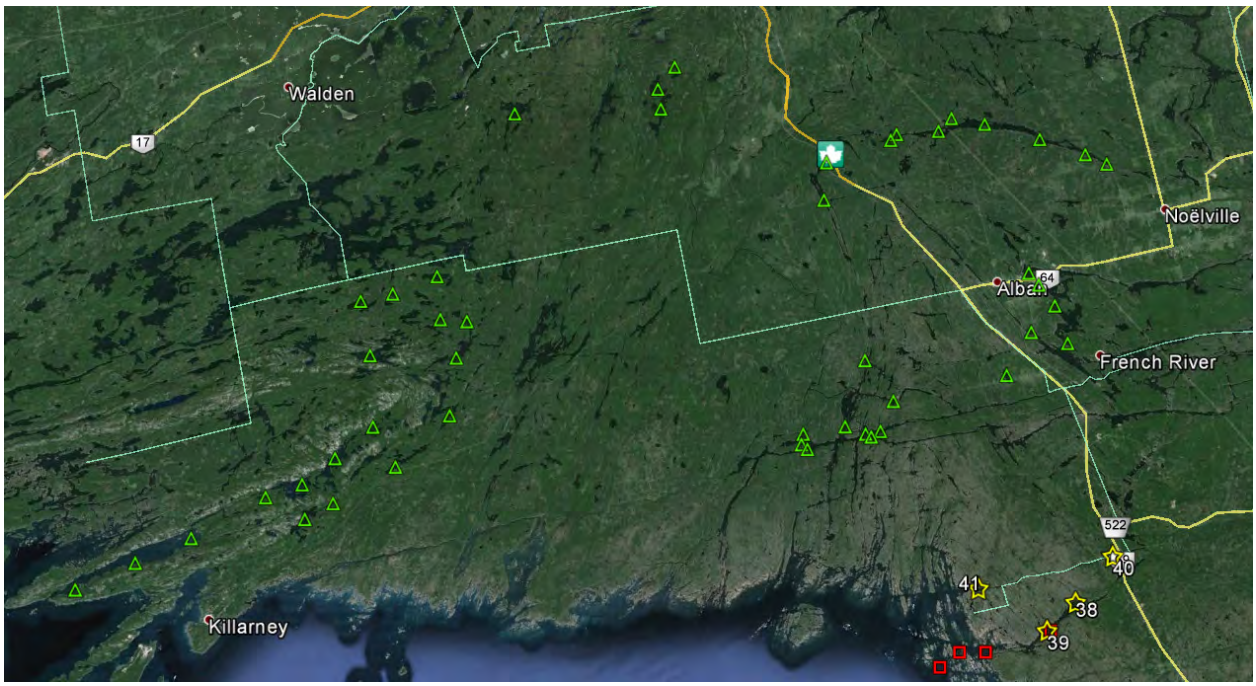
Table E

	Archipelago North (8)						
Site #	Location	Lat	Long	Type	Existing Data	Recommendation	Rationale
34	EB Sof P au B	45 33 43	80 21 38	EB	no	LPP	**EB**
35	Byng 1	45 46 16	80 31 33	EB	EC	LPP	MOECC support
36	Byng 2	45 46 07	80 34 06	EB	EC	LPP	MOECC support
37	Byng 3	45 45 57	80 35 50	EB	EC	LPP	MOECC support
38	Henvey E	45 51 48	80 37 27	EB	no	LPP	EB no data
39	Henvey Mid	45 50 52	80 39 36	EB	no	LPP	EB no data
40	Key R at 69	45 53 25	80 34 30	EB	no	LPP	EB no data
41	Key R at Key R.	45 53 13	80 43 12	EB	no	LPP	EB no data

Unincorporated, French River, and Killarney Area

There are many locations in the unincorporated and Killarney/Sudbury/French River area that have samples processed by the LPP. Many of these locations represent science partners that collect data in cooperation with universities or with regional MOECC staff. As a result there is a large amount of additional data available for these areas. Therefore it is recommended that inland lakes and enclosed bays without LPP data are monitored using the LPP. The French River delta has been identified as a potential water quality problem area (Clark et al. 2015 and Table G) and is discussed in the section below.

Map F



Areas with Concerns Identified in Previous Reports

Table G lists areas where water quality or biota concerns have been mentioned in previous reports as summarized by Clark *et al.* 2015. Most of these areas are either being monitored or are studied through research initiatives.

The one area that is not being monitored is the French River delta and this is likely due to the remoteness of the near mouth areas (Map F). There have been studies conducted between the Lake Nipissing outflow to the French River and the mouth, however the data is unpublished. Current water quality concerns relate to algal blooms and these may be due to the areas being poorly flushed. More work is required to more clearly identify any existing problems, including a better understanding of the areas of concern.

Table G – Areas with water quality or biota related concerns that have been mentioned or identified in previous reports/studies.

Legend for '*Source*' column

- 1 = Environment Canada Science and Monitoring Synthesis
- 2 = Township of Georgian Bay/Georgian Bay Forever 2011 Water Quality program report
- 3 = Georgian Bay Forever Coastal Monitoring Review 2011

Area	Concern(s)	Source(s)	Status
Cognashene Bay	Cognashene Lake: phosphorus from the sediment, low conductivity, anoxia	1,2,3,	Monitored by TGB/GBF TP = 5-10 (anoxia)
Go Home Bay	Reduced clarity within the inner bay due to elevated phosphorus	1,2,3	Monitored by TGB/GBF TP = 4-8 (anoxia)
Severn Sound	Remedial Action Plan	SSEA and MOECC	Well studied, research continues
North Bay	Increase in rooted aquatic plants and periphyton over past 10-15 years, anoxia	2,3	Well studied, research continues
South Bay	Degradation of water quality between inflow from Baxter Lake and outflow, periphyton, anoxia	2,3	Well studied, research continues
Sturgeon Bay	Eutrophication and excessive cyanobacteria blooms, low DO	1	Well studied
Twelve Mile Bay	Elevated phosphorus, anoxia	1,2,3	Monitored by TGB/GBF TP = 5-10 (anoxia)
Honey Harbour	Decreased water clarity, elevated bacteria and phosphorus	1,2	Well studied, research continues
Church Bay	Changing invertebrate and phytoplankton communities; aquatic plants and periphyton	1,2	Some studies, degradation links to sedimentation

Area	Concern(s)	Source(s)	Status
Severn River	Severn River / Port Severn: elevated phosphorus and macrophytes	1	Monitored by TGB
French River	French River: elevated phosphorus levels, cyanobacteria blooms	1	Unknown, research required
Parry Sound (Deep Bay)	Occasional algal blooms	1	Some monitoring by MOECC

Appendix B

Lake Partner Program Volunteer Instructions

LAKE PARTNER PROGRAM – detailed instructions

General

Lakes within the Canadian Shield are sampled for total phosphorus **once per year** during May at the deep spot of your lake or bay. The instructions for taking the water sample for total phosphorus are provided on page 2 of this sheet.

Because the transparency of a lake may vary through the year, Secchi disk observations are made, ideally, twice per month from May to October. Refer to the **sampling instructions** on the reverse side of the Secchi observation sheet for instructions on how to take a Secchi disk measurement. **Record** the Secchi depths on the enclosed observation sheet. **In November,** return the Secchi observation sheet to the Dorset Environmental Science Centre in the pre-paid envelope provided.

Please read these detailed instructions and the Secchi observation sheet before you sample.

Before You Sample

Water Sampling Materials include:

- one 80 micron filter with funnel **(1)**
- one 100mL sample jar (blue or orange cap)**(2)**
- one sample collection bottle **(3)**
- two glass sample tubes **(4)**
- Secchi observation sheet and return envelope
- return postage for samples with Dorset mailing address

NOTE: You will need to supply some materials to complete the collection bottle and Secchi Disk (explained below).

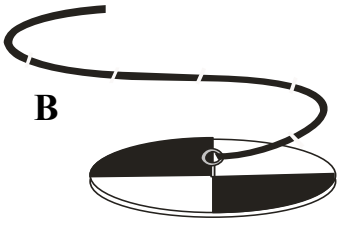
1. Prepare the **collection bottle** by attaching about 6 meters of clean rope to the neck ring (**photo A**). Mark the rope off in metres. Duct tape a suitable clean weight to the bottom of the bottle. Choose a weight heavy enough to sink the bottle (approximately 2Lbs/900g). A metal *pipe cap is shown in the photo below* (**A**). *Keep your ropes and weights to attach to a new bottle that is supplied each year.*

2. Assemble the **Secchi disk**. Attach a rope to the Secchi disk enclosed in your kit (for new volunteers). The rope length will depend on how transparent the lake is, but in general, lakes in Ontario have up to 10 metres of water clarity (usually 4-6 m). Mark the rope off in tenths of a metre (**photo B**). You will need to add an eye bolt (for the rope) and a few large washers, or other suitable weight, to the bottom (**photo C**). Some stores carry large square "dock hardware" washers that are ideal to use as weights.

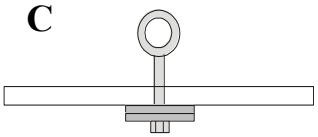
A

Please keep your Secchi Disk to use in following years. With time, some rope material will stretch. Each year check that the metre markings on the collection bottle rope and the tenths of a metre markings on the Secchi disk rope are still accurate.

B



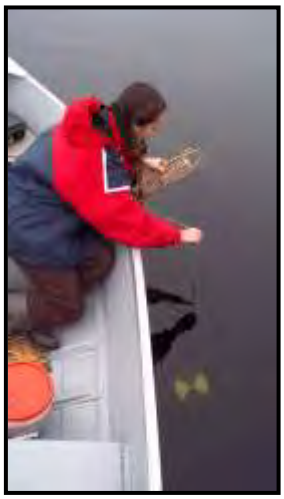
C



At the Lake

*Secchi transparency readings and water samples must be taken at the **off-shore deep spot** of the lake or bay. It is best to sample when lake conditions are calm, between the hours of 10 am and 4 pm.*

Step 1. *Secchi Transparency Readings*



- Use your Secchi disk to measure water clarity. Record the depth (in **metres**) on the observation sheet (see instructions on how to take a Secchi measurement on the back of the field observation sheet).
- **Keep** your observation sheet to make Secchi readings once or twice per month and return it to Dorset in November in the envelope provided.

Step 2. *Collect the Water Samples*

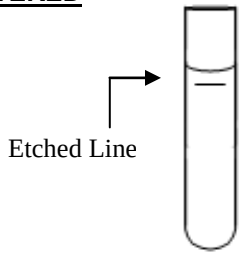
- **First, write the sampling date on the two glass tube labels and on the 100mL sample jar label (blue or orange cap)**
- Rinse the weighted sample bottle twice with lake water (does not need to be filtered). Next, lower the weighted sample bottle down to the Secchi depth and back up to the surface to fill it. In shallow lakes, lower the bottle no closer than approximately **1 metre** from the lake bottom.

Step 3. *Fill the 100mL sample jar (blue or orange cap)*

- Pour the water through the filter and rinse the small sample jar **THREE TIMES** with **FILTERED** water. Fill the small sample jar with filtered water.
- **The funnel components are held together by friction. If they come apart, reassemble the two halves with the filter screen between the upper and lower sections.**

Step 4. *Fill both Glass Phosphorus Tubes*

- Rinse both glass tubes and caps **THREE TIMES** with **FILTERED** water
- **Using filtered water, fill both tubes to *1 cm above* the etched line on the glass sample tube** (if you run out of water, repeat S*tep 2 by collecting another water sample with the weighted sample bottle*)
- Make sure the lids are screwed on snugly.



Step 5. *Mail the samples to Dorset*

- Place the **funnel, sample collection bottle, 100mL jar and glass tubes** back into the box.
- Make sure the lids are securely screwed on and insert into the protective pipe wrap. Attach the return address label and postage provided to the outside of the box. Seal the ends of the box with tape and mail to Dorset.

Questions? Call 1-800-470-8322 (or 705-766-1294 if outside Ontario) or email *lakepartner@ontario.ca*

Note: *Please keep the samples refrigerated until the kit is mailed. Thanks!*

Appendix C

Field Records

Henvey Inlet Phosphorus Sampling Methodology

Date: Aug 26, 2016 Sampling Crew: D. Peuk / Jones

Station No: 1 Weather: clear, warm, choppy.

Easting: 0526352 Northing: 5072955

Station Depth (m): 4.27

Secchi Depth (m): 3.70

Field pH: 7.43

Field Conductivity (µs): ~~0~~176

Field ORP: 221.0

Duplicate collected: no

Sample Collection (check one):

___ Surface Water

___ 1 m from bottom

___ 5 m from bottom

~~4~~ Secchi depth

✓ Composite: secchi depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
1	~~22.48~~ 22.96	~~9.001~~ 8.76 ~~9.01~~
2	22.95	8.94
3	22.93	8.88
4	22.88	9.01
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

General Description of Location: End of Bay straight out from beach

General Observations (algal blooms, etc) Isolated, choppy no evidence of blooms

Henvey Inlet Phosphorus Sampling Methodology

Date: Aug 26, 2016 Sampling Crew: D. Peck, D. Jones

Station No: 2 Weather: Clear, Windy, Choppy

Easting: 0525379 Northing: 5072977

Station Depth (m): 9.29m

Secchi Depth (m): 3.20

Field pH: 7.90

Field Conductivity (µs): 177

Field ORP: 205.1

Duplicate collected: NO

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: secchi depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
1	22.63	8.74
2	22.63	8.70
3	22.63	8.70
4	22.62	8.73
5	22.61	8.69
6		
7		
8		
9		
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16		
17		
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19		
20		

General Description of Location: _____

_____

_____

General Observations (algal blooms, etc) _____

_____

Henvey Inlet Phosphorus Sampling Methodology

Date: Aug 24, 2016 Sampling Crew: D. Peck, D. Jones

Station No: 3 Weather: clear, windy, choppy

Easting: 0525116 Northing: 5073238

Station Depth (m): 95'

Secchi Depth (m): 2.4

Field pH: 7.87

Field Conductivity (µs): 177

Field ORP: 218.3

Duplicate collected: No

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

✓ Composite: secchi depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
1	22.71	8.90
2	22.70	8.81
~~3~~ 2.4	22.70	8.82
4		
5		
6		
7		
8		
9		
10		
11		
12		
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16		
17		
18		
19		
20		

General Description of Location: _____

General Observations (algal blooms, etc) _____

Henvey Inlet Phosphorus Sampling Methodology

Date: Aug 26, 2016 Sampling Crew: D. Peck, D. Jones

Station No: 4 Weather: clear, windy, choppy

Easting: 0525654 Northing: 5073005

Station Depth (m): 5.79

Secchi Depth (m): 3.30

Field pH: 8.01

Field Conductivity (µs): 177

Field ORP: 197.8

Duplicate collected: Station-4D (12:25)

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

~~✓~~ ___Secchi depth

✓ Composite: secchi depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
1	22.79	8.84
2	22.77	8.81
3	22.72	8.95
4	22.66	8.82
5	22.65	8.78
6		
7		
8		
9		
10		
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18		
19		
20		

General Description of Location: _____

General Observations (algal blooms, etc) Choppy

Henvey Inlet Phosphorus Sampling Methodology

Date: Aug 24, 2016 Sampling Crew: D. Peck / D. Jones

Station No: 5 Weather: clear, windy very choppy

Easting: 0524792 Northing: 5072891

Station Depth (m): 9.1'

Secchi Depth (m): 0.1 m

Field pH: 7.09

Field Conductivity (µs): 178

Field ORP: 204.8

Duplicate collected: NO

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: secchi depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
1	22.53	8.84
2	22.54	8.85
3	22.54	8.90
4	22.55	8.77
5		
6		
7		
8		
9		
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General Description of Location: _____

General Observations (algal blooms, etc) _____

Henvey Inlet Phosphorus Sampling Methodology

Date: 12-Oct-16 Sampling Crew: Dave Jones + Dixie

Station No: 1 Weather: sunny, windy

Easting: 526324.09 Northing: 5072963.65

Station Depth (m): 2.3m

Secchi Depth (m): n/a.

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
composite X 1	15.1	n/a.
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
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15		
16		
17		
18		
19		
20		

Field pH: 8.32

Field Conductivity (µs): 182

Field ORP: 117

Duplicate collected: ~~X~~ no.

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: ~~secchi~~ depth to surface

General Description of Location: back (eastern extent) of bay; west of marsh.

General Observations (algal blooms, etc)

Sample time: 10:00am

Henvey Inlet Phosphorus Sampling Methodology

Date: 12-Oct-16 Sampling Crew: Dave Jane + Dixie

Station No: 2 Weather: sunny, windy

Easting: 525432.27 Northing: 5072979.45

Station Depth (m): 6.10 m

Secchi Depth (m): n/a

Field pH: 8.32

Field Conductivity (µs): 184

Field ORP: 108

Duplicate collected: NO

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: ~~secchi~~ depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
composite X 1	15.4	
2		
3		
4		
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6		
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General Description of Location: off southern shore, across bay from beach area

General Observations (algal blooms, etc)

sample time: 10:30am

Henvey Inlet Phosphorus Sampling Methodology

Date: 12-Oct-16 Sampling Crew: Dave Jones + Dixie.

Station No: 3 Weather: sunny, windy.

Easting: 525200.54 Northing: 5073254.27

Station Depth (m): 2.41 m

Secchi Depth (m): n/a.

Field pH: 8.36

Field Conductivity (µs): 193

Field ORP: 90

Duplicate collected: no

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: ~~secchi~~ depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
composite 1	15.4	n/a.
2		
3		
4		
5		
6		
7		
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General Description of Location: west of small island, north side of bay.

General Observations (algal blooms, etc)

Sample time: 11:00am

Henvey Inlet Phosphorus Sampling Methodology

Date: 12-Oct-16 Sampling Crew: Dave Jones + Dixie

Station No: 4 Weather: sunny, windy.

Easting: 525560.82 Northing: 5073089.19

Station Depth (m): 5.28m

Secchi Depth (m): n/a.

Field pH: 8.35

Field Conductivity (µs): 188

Field ORP: 92

Duplicate collected: yes

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: ~~secchi~~ depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
composite 1	15.6.	n/a.
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

General Description of Location: southeast of island, south of marsh, north side of bay.

duplicate sample collected.

General Observations (algal blooms, etc)

sample time: 11:30am

duplicate time: 11:35am

Henvey Inlet Phosphorus Sampling Methodology

Date: 12-Oct-16 Sampling Crew: Dave Jones + Dixie.

Station No: 5 Weather: Sunny + windy.

Easting: 524774.48 Northing: 5072877.72

Station Depth (m): 6.55m

Secchi Depth (m): n/a.

Field pH: 8.45

Field Conductivity (µs): 212

Field ORP: 81

Duplicate collected: no

Sample Collection (check one):

___Surface Water

___1 m from bottom

___5 m from bottom

___Secchi depth

X Composite: ~~secchi~~ depth to surface

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
composite. 1	15.4	n/a.
2		
3		
4		
5		
6		
7		
8		
9		
10		
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17		
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19		
20		

General Description of Location: @ mouth of bay, west end.

General Observations (algal blooms, etc)

Sample time: 12:00pm

Station Photographs

Station 1

Station 2

Station 3

Station 4

Station 5

Beach on north shore of Sandy Bay

Bay overview looking east

Appendix D

Laboratory Results

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CERTIFICATE OF ANALYSIS

Client:	Dixie Ortiz	Work Order Number:	283013
Company:	BluMetric	PO #:	160524
Address:	957 Cambrian Heights Dr Sudbury, ON, P3C 5S5	Regulation: Project #:	PWQO Sand Bay Water Quality Monitoring
Phone/Fax:	(705) 525-6075 / (705) 525-6077	DWS #:	
Email:	dortiz@blumetric.ca	Sampled By:	David Peck & David Jones
Date Order Received:	8/26/2016	Analysis Started:	8/28/2016
Arrival Temperature:	14 °C	Analysis Completed:	9/7/2016

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
Station #1	807498	Surface Water	None	SAMPLE CONTAINED RESULT EXCEEDENCES.	8/26/2016	11:00 AM
Station #2	807499	Surface Water	None		8/26/2016	12:40 PM
Station #3	807500	Surface Water	None		8/26/2016	1:00 PM
Station #4	807501	Surface Water	None		8/26/2016	12:20 PM
Station #4D	807502	Surface Water	None		8/26/2016	12:25 PM
Station #5	807503	Surface Water	None		8/26/2016	1:30 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
A07-Reactive Si/W	Mississauga	Determination of Reactive Silica in Waters	Modified from EPA 366.0
A23-DTP Water	Garson	Determination of Dissolved Total Phosphorus in Water	Based on APHA-4500P
A23-TP Water	Garson	Determination of Total Phosphorus in Water	Based on APHA-4500P
Alka	Garson	Determination of Alkalinity	Based on APHA-2320B
Ammonia Water	Garson	Determination of Ammonia/Ammonium in Water	Based on APHA-4500NH3 H
Anions Water	Garson	Determination of Anions by Ion Chromatography	Based on SW846-9056A
Chlorophyll A	Garson	Determination of Chlorophyll A in water	Based on APHA-10200H
Ecoli (DC-R10)	Garson	Determination of E. coli in Water by Membrane Filtration	Based on MOE E3407

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Method	Lab	Description	Reference
ICPMS Tot. Water	Garson	Determination of Total Metals in Water by ICP/MS with Digestion	Based on SW846-6020A
OCPs Water	Garson	Determination of Organochlorine Pesticides in Water by GC/ECD	Based on SW846-8081B
PAH Water SIM	Garson	Determination of PAH in Water by GC/MS	Based on SW846-8270D
PCBs Water	Garson	Determination of Polychlorinated Biphenyls in Water by GC/ECD	Based on SW846-8082A
pHWater	Garson	Determination of Water pH by Ion Selective Electrode	Based on APHA-4500H+ B
TKN Water Dig.	Garson	Determination of Total Kjeldahl Nitrogen in Waters with Block Digestion	Based on APHA-4500NORG
TN Water	Garson	Determination of Total Nitrogen in Water	Based on APHA-4500N
TOC Water	Garson	Determination of Total Organic Carbon in Water	Based on APHA-5310C
Total Coliform (R10)	Garson	Determination of Total Coliforms in Water by Membrane Filtration	Based on MOE E3407A

This report has been approved by:

Khaled Omari, Ph.D.
Laboratory Director

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

WORK ORDER RESULTS

Sample Description	Station #1
Lab ID	807498

Anions	Result	MDL	Units	Criteria: PWQO
Bromide	<0.1	0.1	mg/L	~
Chloride	5.26	0.2	mg/L	~
Fluoride	<0.1	0.1	mg/L	~
Nitrate (as N)	<0.1	0.1	mg/L	~
Nitrite (as N)	<0.03	0.03	mg/L	~
Sulphate	10.3	1	mg/L	~

Sample Description	Station #1
Lab ID	807498

Chlorophyll A	Result	MDL	Units	Criteria: PWQO
Chlorophyll A	<0.5	0.5	ug/L	~

Sample Description	Station #1		Station #2		Station #3		Station #4			
Lab ID	807498		807499		807500		807501			
General Chemistry	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units	Criteria: PWQO
Ammonia (as N)	0.01	0.01							mg/L	~
Dissolved Total Phosphorus (as P)	0.0069	0.002	0.007	0.002	0.006	0.002	0.0071	0.002	mg/L	~
M-Alkalinity (pH 4.5)	62.3	1							mg/L as CaCO3	~
pH	7.98	N/A							pH	~
Reactive Silica	1.34 [1.33]	0.02							mg/L	~
Total Kjeldahl Nitrogen	0.63	0.2							mg/L	~
Total Nitrogen (as N)	<1	1							mg/L	~
Total Organic Carbon	3.7	0.4							mg/L	~
Total Phosphorus (as P)	0.011	0.002	0.009	0.002	0.011	0.002	0.012	0.002	mg/L	~

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #4D		Station #5			
Lab ID	807502		807503			
General Chemistry	Result	MDL	Result	MDL	Units	Criteria: PWQO
Dissolved Total Phosphorus (as P)	0.0072	0.002	0.0073 [0.006]	0.002	mg/L	~
Total Phosphorus (as P)	0.01	0.002	0.008	0.002	mg/L	~

Sample Description	Station #1			
Lab ID	807498			
Metals (Total)	Result	MDL	Units	Criteria: PWQO
Total Aluminum	28.7	1	ug/L	75
Total Antimony	<0.5	0.5	ug/L	20
Total Arsenic	1	1	ug/L	100
Total Barium	13.9	1	ug/L	~
Total Beryllium	<0.5	0.5	ug/L	11
Total Bismuth	<1	1	ug/L	~
Total Boron	19	2	ug/L	200
Total Cadmium	<0.1	0.1	ug/L	0.2
Total Calcium	16000	50	ug/L	~
Total Cerium	<1	1	ug/L	~
Total Cesium	<1	1	ug/L	~
Total Chromium	<1	1	ug/L	~
Total Cobalt	<0.1	0.1	ug/L	0.9
Total Copper	1	1	ug/L	5
Total Europium	<1	1	ug/L	~
Total Gallium	<1	1	ug/L	~
Total Iron	40	20	ug/L	300
Total Lanthanum	<1	1	ug/L	~
Total Lead	<1	1	ug/L	5
Total Lithium	<5	5	ug/L	~

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #1
Lab ID	807498

Metals (Total)	Result	MDL	Units	Criteria: PWQO
Total Magnesium	4880	4	ug/L	~
Total Manganese	5.5	1	ug/L	~
Total Mercury	<0.1	0.1	ug/L	~
Total Molybdenum	<1	1	ug/L	40
Total Nickel	1	1	ug/L	25
Total Niobium	<1	1	ug/L	~
Total Potassium	790	100	ug/L	~
Total Rubidium	1	1	ug/L	~
Total Scandium	<1	1	ug/L	~
Total Selenium	<1	1	ug/L	100
Total Silicon	600	600	ug/L	~
Total Silver	<0.1	0.1	ug/L	0.1
Total Sodium	5130	100	ug/L	~
Total Strontium	76.5	1	ug/L	~
Total Sulphur	2000	800	ug/L	~
Total Tellurium	<1	1	ug/L	~
Total Thallium	<0.1	0.1	ug/L	0.3
Total Thorium	<1	1	ug/L	~
Total Tin	<1	1	ug/L	~
Total Titanium	<1	1	ug/L	~
Total Tungsten	<1	1	ug/L	30
Total Uranium	<1	1	ug/L	5
Total Vanadium	<1	1	ug/L	6
Total Yttrium	<1	1	ug/L	~
Total Zinc	2	1	ug/L	30
Total Zirconium	<1	1	ug/L	4

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #1		Station #2		Station #3		Station #4			
Lab ID	807498		807499		807500		807501			
Microbiology	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units	Criteria: PWQO
Escherichia coli	<100 [<100]	100	<100	100	<100	100	<100	100	CFU/100mL	~
Total Coliform	<100 [<100]	100	<100	100	<100	100	<100	100	CFU/100mL	~

Sample Description	Station #4D		Station #5			
Lab ID	807502		807503			
Microbiology	Result	MDL	Result	MDL	Units	Criteria: PWQO
Escherichia coli	<100	100	<100	100	CFU/100mL	~
Total Coliform	<100	100	<100	100	CFU/100mL	~

Sample Description	Station #1			
Lab ID	807498			
OC Pesticides	Result	MDL	Units	Criteria: PWQO
2,4'-DDD	<0.0006	0.0006	ug/L	~
2,4'-DDE	<0.0006	0.0006	ug/L	~
2,4'-DDT	<0.0002	0.0002	ug/L	~
4,4'-DDD	<0.0006	0.0006	ug/L	0.003
4,4'-DDE	<0.0002	0.0002	ug/L	0.003
4,4'-DDT	<0.0003	0.0003	ug/L	0.003
Aldrin	<0.0003	0.0003	ug/L	0.001
DDD (Total)	<0.0003	0.0003	ug/L	~
DDE (Total)	<0.0002	0.0002	ug/L	~
DDT (Total)	<0.0006	0.0006	ug/L	~
Decachlorobiphenyl (Surr.)	64	N/A	% Rec	~
Dieldrin	<0.0008	0.0008	ug/L	0.001
Endosulfan I	<0.0004	0.0004	ug/L	0.003

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #1
Lab ID	807498

OC Pesticides	Result	MDL	Units	Criteria: PWQO
Endosulfan I + II	<0.0006	0.0006	ug/L	~
Endosulfan II	<0.0006	0.0006	ug/L	~
Endosulfan sulfate	<0.0008	0.0008	ug/L	~
Endrin	<0.0006	0.0006	ug/L	0.002
Endrin aldehyde	<0.0004	0.0004	ug/L	~
Heptachlor	<0.0004	0.0004	ug/L	0.001
Heptachlor epoxide	<0.0004	0.0004	ug/L	0.001
Hexachlorobenzene	<0.0005	0.0005	ug/L	0.0065
Hexachlorobutadiene	<0.0006	0.0006	ug/L	0.009
Hexachloroethane	<0.0006	0.0006	ug/L	1
Methoxychlor	<0.0008	0.0008	ug/L	0.04
Mirex	<0.0005	0.0005	ug/L	0.001
Oxychlordane	<0.0005	0.0005	ug/L	~
ß-BHC	<0.0005	0.0005	ug/L	~
α - Chlordane	<0.0003	0.0003	ug/L	~
α + γ -Chlordane	<0.0006	0.0006	ug/L	~
α-BHC	<0.0006	0.0006	ug/L	~
γ - Chlordane	<0.0004	0.0004	ug/L	~
γ-BHC (Lindane)	<0.0003	0.0003	ug/L	~
δ-BHC	<0.0004	0.0004	ug/L	~

Sample Description	Station #1
Lab ID	807498

PAH	Result	MDL	Units	Criteria: PWQO
1+2-Methylnaphthalene	<0.05	0.05	ug/L	~
1-Methylnaphthalene	<0.04	0.04	ug/L	2

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #1
Lab ID	807498

PAH	Result	MDL	Units	Criteria: PWQO
2-Methylnaphthalene	<0.02	0.02	ug/L	2
3,3'-Dichlorobenzidine	<0.06	0.06	ug/L	0.6
Acenaphthene	<0.05	0.05	ug/L	~
Acenaphthylene	<0.05	0.05	ug/L	~
Anthracene	<0.02	0.02	ug/L	0.0008
Benzo(a)anthracene	0.05	0.02	ug/L	~
Benzo(a)pyrene	0.035	0.01	ug/L	~
Benzo(b)fluoranthene	<0.07	0.07	ug/L	~
Benzo(ghi)perylene	<0.05	0.05	ug/L	2e-005
Benzo(k)fluoranthene	<0.05	0.05	ug/L	0.0002
Chrysene	<0.06	0.06	ug/L	0.0001
Dibenz(a,h)anthracene	<0.05	0.05	ug/L	0.002
Fluoranthene	<0.04	0.04	ug/L	0.0008
Fluorene	<0.05	0.05	ug/L	0.2
Fluorobiphenyl (Surr.)	54	N/A	% Rec	~
Indeno(1,2,3-c,d)pyrene	<0.04	0.04	ug/L	~
Naphthalene	<0.06	0.06	ug/L	7
Phenanthrene	<0.04	0.04	ug/L	0.03
p-Terphenyl-d14 (Surr)	78.6	N/A	% Rec	~
Pyrene	<0.06	0.06	ug/L	~

Sample Description	Station #1
Lab ID	807498

PCBs	Result	MDL	Units	Criteria: PWQO
Aroclor 1242	<0.06	0.06	ug/L	~
Aroclor 1248	<0.06	0.06	ug/L	~

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Sample Description	Station #1
Lab ID	807498

PCBs	Result	MDL	Units	Criteria: PWQO
Aroclor 1254	<0.06	0.06	ug/L	~
Aroclor 1260	<0.06	0.06	ug/L	~
Decachlorobiphenyl (Surr.)	100	N/A	% Rec	~
Total PCBs	<0.06	0.06	ug/L	0.001

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

[ ]: Results for laboratory replicates are shown in square brackets immediately below the associated sample result for ease of comparison.

% Rec: Surrogate compounds are added to the sample in some cases and the recovery is reported as a % recovered.

~: In a criteria column indicates the criteria is not applicable for the parameter row..

Quality Control: All associated Quality Control data is available on request.

LCL: Lower Control Limit.

UCL: Upper Control Limit.

QAQCID: This is a unique reference to the quality control data set used to generate the reported value. Contact our lab for this information, as it is traceable through our LIMS.

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

QUALITY CONTROL DATA

THIS SECTION REPORTS QC RESULTS ASSOCIATED WITH THE TEST BATCH; THESE ARE NOT YOUR SAMPLE RESULTS

Anions

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Bromide	0.1	mg/L	0	<0.1	0.2	20160831.R5A
Chloride	0.2	mg/L	0	<0.2	0.3	20160831.R5A
Fluoride	0.1	mg/L	0	<0.1	0.2	20160831.R5A
Nitrate (as N)	0.1	mg/L	0	<0.1	0.2	20160831.R5A
Nitrite (as N)	0.03	mg/L	0	<0.03	0.04	20160831.R5A
Sulphate	1	mg/L	0	<1	1.1	20160831.R5A

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Bromide	N/A	% Rec	85	101	115	20160831.R5A
Bromide	N/A	% Rec	80	102	115	20160831.R5A
Chloride	N/A	% Rec	80	81	115	20160831.R5A
Chloride	N/A	% Rec	85	98.7	115	20160831.R5A
Fluoride	N/A	% Rec	85	102	115	20160831.R5A
Fluoride	N/A	% Rec	80	97.9	115	20160831.R5A
Nitrate (as N)	N/A	% Rec	75	93.1	115	20160831.R5A
Nitrate (as N)	N/A	% Rec	85	95.2	115	20160831.R5A
Nitrite (as N)	N/A	% Rec	85	101	115	20160831.R5A
Nitrite (as N)	N/A	% Rec	80	105	115	20160831.R5A
Sulphate	N/A	% Rec	80	83.3	115	20160831.R5A
Sulphate	N/A	% Rec	78	98.2	115	20160831.R5A

General Chemistry

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Ammonia (as N)	N/A	%	0	0.5	20	20160830.R42.1A
Dissolved Total Phosphorus (as P)	N/A	%	0	N/A	20	20160901.S23.3A

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CERTIFICATE OF ANALYSIS

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M-Alkalinity (pH 4.5)	N/A	%	0	1.7	20	20160831.R1A
pH	N/A	pH	0	0.03	0.2	20160831.R2B
Reactive Silica	N/A	%	0	0.7	20	20160831.T07A
Total Kjeldahl Nitrogen	N/A	%	0	N/A	20	20160901.R58A
Total Organic Carbon	N/A	%	0	0	20	20160829.R55.2A
Total Phosphorus (as P)	N/A	mg/L	0	0.6	20	20160901.S23.4A
Total Phosphorus (as P)	N/A	mg/L	0	N/A	20	20160901.S23.4B

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Ammonia (as N)	0.01	mg/L	0	<0.01	0.03	20160830.R42.1A

Blank Spike

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Organic Carbon	0.4	mg/L	17	20.7	23	20160829.R55.2A

CRM

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Reactive Silica	2	mg/L	2980	3520	4060	20160831.T07A

Method Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Dissolved Total Phosphorus (as P)	0.002	mg/L	0	0.0059	0.025	20160901.S23.3A
M-Alkalinity (pH 4.5)	1	mg/L	0	<1	5	20160831.R1A
Total Kjeldahl Nitrogen	1	mg/L	0	<1	1	20160901.R58A
Total Organic Carbon	0.4	mg/L	0	0.748	0.8	20160829.R55.2A
Total Phosphorus (as P)	0.002	mg/L	0	0.00461	0.01	20160901.S23.4B
Total Phosphorus (as P)	0.002	mg/L	0	0.0065	0.01	20160901.S23.4A

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Ammonia (as N)	0.01	mg/L	0.2	0.263	0.3	20160830.R42.1A
Ammonia (as N)	0.01	mg/L	0.4	0.471	0.6	20160830.R42.1A
Dissolved Total Phosphorus (as P)	0.002	mg/L	0.04	0.0433	0.06	20160901.S23.3A
Dissolved Total Phosphorus (as P)	0.002	mg/L	0.16	0.19	0.24	20160901.S23.3A

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M-Alkalinity (pH 4.5)	N/A	%	85	99.1	115	20160831.R1A
pH	N/A	pH	7.8	8.04	8.2	20160831.R2B
Reactive Silica	0.02	mg/L	1	1.62	2	20160831.T07A
Reactive Silica	0.02	mg/L	7	8	8	20160831.T07A
Total Kjeldahl Nitrogen	0.1	mg/L	8	8.68	12	20160901.R58A
Total Kjeldahl Nitrogen	1	mg/L	20	20.4	30	20160901.R58A
Total Phosphorus (as P)	0.002	mg/L	0.04	0.0424	0.06	20160901.S23.4A
Total Phosphorus (as P)	0.002	mg/L	0.04	0.0442	0.06	20160901.S23.4B
Total Phosphorus (as P)	0.002	mg/L	0.16	0.196	0.24	20160901.S23.4B
Total Phosphorus (as P)	0.002	mg/L	0.16	0.197	0.24	20160901.S23.4A

Sample Spike

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Ammonia (as N)	N/A	% Rec	75	97.4	125	20160830.R42.1A
Dissolved Total Phosphorus (as P)	N/A	% Rec	75	106	125	20160901.S23.3A
Total Kjeldahl Nitrogen	N/A	% Rec	80	101	120	20160901.R58A
Total Organic Carbon	N/A	% Rec	75	107	125	20160829.R55.2A
Total Phosphorus (as P)	N/A	% Rec	75	100	125	20160901.S23.4A
Total Phosphorus (as P)	N/A	% Rec	75	110	125	20160901.S23.4B

Metals (Total)

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Aluminum	N/A	%	0	1.1	20	20160829.R13-5o6
Total Antimony	N/A	%	0	N/A	20	20160829.R13-5o6
Total Arsenic	N/A	%	0	N/A	20	20160829.R13-5o6
Total Barium	N/A	%	0	4	20	20160829.R13-5o6
Total Beryllium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Bismuth	N/A	%	0	N/A	20	20160829.R13-5o6
Total Cadmium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Calcium	N/A	%	0	0	20	20160829.R13-5o6
Total Cerium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Cesium	N/A	%	0	N/A	20	20160829.R13-5o6

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CERTIFICATE OF ANALYSIS

BluMetric

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Total Chromium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Cobalt	N/A	%	0	N/A	20	20160829.R13-5o6
Total Copper	N/A	%	0	N/A	20	20160829.R13-5o6
Total Europium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Gallium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Iron	N/A	%	0	0.3	20	20160829.R13-5o6
Total Lanthanum	N/A	%	0	N/A	20	20160829.R13-5o6
Total Lead	N/A	%	0	N/A	20	20160829.R13-5o6
Total Lithium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Magnesium	N/A	%	0	1.1	20	20160829.R13-5o6
Total Manganese	N/A	%	0	2.3	20	20160829.R13-5o6
Total Mercury	N/A	%	0	N/A	20	20160829.R13-5o6
Total Molybdenum	N/A	%	0	N/A	20	20160829.R13-5o6
Total Nickel	N/A	%	0	N/A	20	20160829.R13-5o6
Total Niobium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Rubidium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Scandium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Selenium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Silver	N/A	%	0	N/A	20	20160829.R13-5o6
Total Strontium	N/A	%	0	4.1	20	20160829.R13-5o6
Total Thallium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Thorium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Tin	N/A	%	0	N/A	20	20160829.R13-5o6
Total Titanium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Tungsten	N/A	%	0	N/A	20	20160829.R13-5o6
Total Uranium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Vanadium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Yttrium	N/A	%	0	N/A	20	20160829.R13-5o6
Total Zinc	N/A	%	0	N/A	20	20160829.R13-5o6
Total Zirconium	N/A	%	0	N/A	20	20160829.R13-5o6

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Aluminum	1	ug/L	0	<1	1	20160829.R13-5o6
Total Antimony	1	ug/L	0	<1	1	20160829.R13-5o6
Total Arsenic	1	ug/L	0	<1	1	20160829.R13-5o6
Total Barium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Beryllium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Bismuth	1	ug/L	0	<1	1	20160829.R13-5o6
Total Boron	2	ug/L	0	<2	6	20160829.R13-5o6
Total Cadmium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Cerium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Cesium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Chromium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Cobalt	1	ug/L	0	<1	1	20160829.R13-5o6
Total Copper	1	ug/L	0	<1	1	20160829.R13-5o6
Total Europium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Gallium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Iron	20	ug/L	0	<20	60	20160829.R13-5o6
Total Lanthanum	1	ug/L	0	<1	1	20160829.R13-5o6
Total Lead	1	ug/L	0	<1	1	20160829.R13-5o6
Total Lithium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Magnesium	4	ug/L	0	<4	12	20160829.R13-5o6
Total Manganese	1	ug/L	0	<1	1	20160829.R13-5o6
Total Mercury	0.1	ug/L	0	<0.1	0.1	20160829.R13-5o6
Total Molybdenum	1	ug/L	0	<1	1	20160829.R13-5o6
Total Nickel	1	ug/L	0	<1	1	20160829.R13-5o6
Total Niobium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Rubidium	0.1	ug/L	0	<0.1	0.1	20160829.R13-5o6
Total Selenium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Silver	5	ug/L	0	<5	5	20160829.R13-5o6
Total Sodium	100	ug/L	0	<100	300	20160829.R13-5o6
Total Strontium	1	ug/L	0	<1	1	20160829.R13-5o6

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CERTIFICATE OF ANALYSIS

BluMetric

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Total Thallium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Thorium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Tin	1	ug/L	0	<1	1	20160829.R13-5o6
Total Tungsten	1	ug/L	0	<1	1	20160829.R13-5o6
Total Uranium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Vanadium	1	ug/L	0	<1	1	20160829.R13-5o6
Total Yttrium	0.1	ug/L	0	<0.1	0.1	20160829.R13-5o6
Total Zinc	1	ug/L	0	<1	1	20160829.R13-5o6
Total Zirconium	0.1	ug/L	0	<0.1	0.1	20160829.R13-5o6

Blank Spike

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Aluminum	N/A	%	80	88.8	120	20160829.R13-5o6
Total Arsenic	N/A	%	80	97.9	120	20160829.R13-5o6
Total Barium	N/A	%	80	98.4	120	20160829.R13-5o6
Total Beryllium	N/A	%	80	91.2	120	20160829.R13-5o6
Total Boron	N/A	%	80	94.8	120	20160829.R13-5o6
Total Cadmium	N/A	%	80	83.7	120	20160829.R13-5o6
Total Calcium	N/A	%	80	93.8	120	20160829.R13-5o6
Total Chromium	N/A	%	80	96.2	120	20160829.R13-5o6
Total Cobalt	N/A	%	80	95.5	120	20160829.R13-5o6
Total Copper	N/A	%	80	91	120	20160829.R13-5o6
Total Iron	N/A	%	80	102	120	20160829.R13-5o6
Total Lead	N/A	%	80	92.3	120	20160829.R13-5o6
Total Magnesium	N/A	%	80	92.1	120	20160829.R13-5o6
Total Manganese	N/A	%	80	97.3	120	20160829.R13-5o6
Total Mercury	N/A	%	80	87.8	120	20160829.R13-5o6
Total Molybdenum	N/A	%	80	95.3	120	20160829.R13-5o6
Total Nickel	N/A	%	80	92.5	120	20160829.R13-5o6
Total Selenium	N/A	%	80	87.7	120	20160829.R13-5o6
Total Sodium	N/A	%	80	91.8	120	20160829.R13-5o6
Total Sulphur	N/A	%	80	80	120	20160829.R13-5o6
Total Thallium	N/A	%	80	90.5	120	20160829.R13-5o6

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CERTIFICATE OF ANALYSIS

BluMetric

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Total Vanadium	N/A	%	80	99.1	120	20160829.R13-5o6
Total Zinc	N/A	%	80	96.1	120	20160829.R13-5o6

Sample Spike

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Aluminum	N/A	% Rec	70	91.8	130	20160829.R13-5o6
Total Antimony	N/A	% Rec	70	80.2	130	20160829.R13-5o6
Total Arsenic	N/A	% Rec	70	78.3	130	20160829.R13-5o6
Total Barium	N/A	% Rec	70	96.4	130	20160829.R13-5o6
Total Beryllium	N/A	% Rec	70	80.3	130	20160829.R13-5o6
Total Cadmium	N/A	% Rec	70	80.4	130	20160829.R13-5o6
Total Chromium	N/A	% Rec	70	98.1	130	20160829.R13-5o6
Total Cobalt	N/A	% Rec	70	95.5	130	20160829.R13-5o6
Total Copper	N/A	% Rec	70	87.7	130	20160829.R13-5o6
Total Iron	N/A	% Rec	70	101	130	20160829.R13-5o6
Total Lead	N/A	% Rec	70	90.5	130	20160829.R13-5o6
Total Manganese	N/A	% Rec	70	101	130	20160829.R13-5o6
Total Molybdenum	N/A	% Rec	70	92.2	130	20160829.R13-5o6
Total Nickel	N/A	% Rec	70	90.8	130	20160829.R13-5o6
Total Selenium	N/A	% Rec	70	89.9	130	20160829.R13-5o6
Total Thallium	N/A	% Rec	70	89.9	130	20160829.R13-5o6
Total Vanadium	N/A	% Rec	70	98.9	130	20160829.R13-5o6
Total Zinc	N/A	% Rec	70	84.2	130	20160829.R13-5o6

Microbiology

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Escherichia coli	N/A	NA	0	N/A	0.30103	20160827.R10A
Total Coliform	N/A	NA	0	N/A	0.30103	20160827.R10A

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Coliform	1	CFU/100mL	0	0	0	20160827.R10A

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BluMetric

Work Order Number: 283013

Method Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Escherichia coli	1	CFU/100mL	0	0	0	20160827.R10A

OC Pesticides

Calibration Check

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
2,4'-DDT	0.0002	%	60	113	140	20160831.R19ocpw
4,4'-DDD	0.0006	%	60	85.1	140	20160831.R19ocpw
4,4'-DDE	0.0002	%	60	78.6	140	20160831.R19ocpw
4,4'-DDT	0.0003	%	60	114	140	20160831.R19ocpw
Aldrin	0.0003	%	60	71.5	140	20160831.R19ocpw
Decachlorobiphenyl (Surr.)	N/A	% Rec	50	54.8	140	20160831.R19ocpw
Dieldrin	0.0008	%	60	81.8	140	20160831.R19ocpw
Endosulfan I	0.0004	%	60	79.1	140	20160831.R19ocpw
Endosulfan II	0.0006	%	60	67.5	140	20160831.R19ocpw
Endosulfan sulfate	0.0008	%	60	94.3	140	20160831.R19ocpw
Endrin	0.0006	%	60	79.4	140	20160831.R19ocpw
Endrin aldehyde	0.0004	%	60	117	140	20160831.R19ocpw
Heptachlor	0.0004	%	60	65.9	140	20160831.R19ocpw
Heptachlor epoxide	0.0004	%	60	83.7	140	20160831.R19ocpw
Methoxychlor	0.0008	%	60	72.8	140	20160831.R19ocpw
Mirex	0.0005	%	60	91.1	140	20160831.R19ocpw
ß-BHC	0.0005	%	60	78.8	140	20160831.R19ocpw
α - Chlordane	0.0003	%	60	78.6	140	20160831.R19ocpw
α-BHC	0.0006	%	60	78.8	140	20160831.R19ocpw
γ - Chlordane	0.0004	%	60	80.4	140	20160831.R19ocpw
γ-BHC (Lindane)	0.0003	%	60	74.4	140	20160831.R19ocpw
δ-BHC	0.0004	%	60	81.5	140	20160831.R19ocpw

Method Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
2,4'-DDT	0.0002	ug/L	0	<0.0002	0.0006	20160831.R19ocpw

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4,4'-DDD	0.0006	ug/L	0	<0.0006	0.0018	20160831.R19ocpw
4,4'-DDE	0.0002	ug/L	0	<0.0002	0.0006	20160831.R19ocpw
4,4'-DDT	0.0003	ug/L	0	<0.0003	0.0009	20160831.R19ocpw
Aldrin	0.0003	ug/L	0	<0.0003	0.0009	20160831.R19ocpw
Decachlorobiphenyl (Surr.)	N/A	% Rec	50	54.1	140	20160831.R19ocpw
Dieldrin	0.0008	ug/L	0	<0.0008	0.0024	20160831.R19ocpw
Endosulfan I	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw
Endosulfan II	0.0006	ug/L	0	<0.0006	0.0018	20160831.R19ocpw
Endosulfan sulfate	0.0008	ug/L	0	<0.0008	0.0024	20160831.R19ocpw
Endrin	0.0006	ug/L	0	<0.0006	0.0018	20160831.R19ocpw
Endrin aldehyde	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw
Heptachlor	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw
Heptachlor epoxide	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw
Hexachlorobenzene	0.0005	ug/L	0	<0.0005	0.0024	20160831.R19ocpw
Methoxychlor	0.0008	ug/L	0	<0.0008	0.0024	20160831.R19ocpw
Mirex	0.0005	ug/L	0	<0.0005	0.0015	20160831.R19ocpw
ß-BHC	0.0005	ug/L	0	<0.0005	0.0015	20160831.R19ocpw
α - Chlordane	0.0003	ug/L	0	<0.0003	0.0009	20160831.R19ocpw
α-BHC	0.0006	ug/L	0	<0.0006	0.0018	20160831.R19ocpw
γ - Chlordane	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw
γ-BHC (Lindane)	0.0003	ug/L	0	<0.0003	0.0009	20160831.R19ocpw
δ-BHC	0.0004	ug/L	0	<0.0004	0.0012	20160831.R19ocpw

PAH

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Acenaphthene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Acenaphthylene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Anthracene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Benzo(a)anthracene	0.06	ug/L	0	<0.06	0.18	20160829.R41pw2
Benzo(a)pyrene	0.03	ug/L	0	0.03	0.04	20160829.R41pw2
Benzo(b)fluoranthene	0.06	ug/L	0	<0.06	0.18	20160829.R41pw2

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Benzo(ghi)perylene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Benzo(k)fluoranthene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Chrysene	0.05	ug/L	0	<0.05	0.15	20160829.R41pw2
Dibenz(a,h)anthracene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Fluoranthene	0.03	ug/L	0	<0.03	0.09	20160829.R41pw2
Fluorene	0.04	ug/L	0	<0.04	0.12	20160829.R41pw2
Fluorobiphenyl (Surr.)	N/A	% Rec	50	74.3	140	20160829.R41pw2
Indeno(1,2,3-c,d)pyrene	0.03	ug/L	0	<0.03	0.09	20160829.R41pw2
Naphthalene	0.05	ug/L	0	<0.05	0.15	20160829.R41pw2
Phenanthrene	0.08	ug/L	0	<0.08	0.24	20160829.R41pw2
p-Terphenyl-d14 (Surr)	N/A	% Rec	50	94.8	140	20160829.R41pw2
Pyrene	0.05	ug/L	0	<0.05	0.15	20160829.R41pw2

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Acenaphthene	N/A	% Rec	50	83.2	140	20160829.R41pw2
Acenaphthylene	N/A	% Rec	50	77	140	20160829.R41pw2
Anthracene	N/A	% Rec	50	104	140	20160829.R41pw2
Benzo(a)anthracene	N/A	% Rec	50	64.8	140	20160829.R41pw2
Benzo(a)pyrene	N/A	% Rec	50	57	140	20160829.R41pw2
Benzo(b)fluoranthene	N/A	% Rec	50	72.6	140	20160829.R41pw2
Benzo(ghi)perylene	N/A	% Rec	50	76.6	140	20160829.R41pw2
Benzo(k)fluoranthene	N/A	% Rec	50	96.8	140	20160829.R41pw2
Chrysene	N/A	% Rec	50	120	140	20160829.R41pw2
Dibenz(a,h)anthracene	N/A	% Rec	50	64	140	20160829.R41pw2
Fluoranthene	N/A	% Rec	50	91.8	140	20160829.R41pw2
Fluorene	N/A	% Rec	50	97	140	20160829.R41pw2
Fluorobiphenyl (Surr.)	N/A	% Rec	50	99.4	140	20160829.R41pw2
Indeno(1,2,3-c,d)pyrene	N/A	% Rec	50	73.6	140	20160829.R41pw2
Naphthalene	N/A	% Rec	50	86.8	140	20160829.R41pw2
Phenanthrene	N/A	% Rec	50	73.2	140	20160829.R41pw2
p-Terphenyl-d14 (Surr)	N/A	% Rec	50	108	140	20160829.R41pw2
Pyrene	N/A	% Rec	50	84.2	140	20160829.R41pw2

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

PCBs

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Aroclor 1242	N/A	%	0	N/A	30	20160906.R19pcbw
Aroclor 1248	N/A	%	0	N/A	30	20160906.R19pcbw
Aroclor 1254	N/A	%	0	N/A	30	20160906.R19pcbw
Aroclor 1260	N/A	%	0	N/A	30	20160906.R19pcbw
Total PCBs	N/A	%	0	N/A	30	20160906.R19pcbw

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Decachlorobiphenyl (Surr.)	N/A	% Rec	60	101	140	20160906.R19pcbw
Total PCBs	0.01	mg/L	0	<0.01	1	20160906.R19pcbw

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Decachlorobiphenyl (Surr.)	N/A	% Rec	60	103	140	20160906.R19pcbw
Total PCBs	0.000001	mg/L	0.005	0.00901	0.015	20160906.R19pcbw

THIS INDEX SHOWS HOW YOUR SAMPLES ARE ASSOCIATED TO THE CONTROLS INCLUDED IN THE IDENTIFIED BATCHES.

Sample Description	Lab ID	Method	QAQCID	Prep QAQCID
Station #1	807498	A07-Reactive Si/W	20160831.T07A	
Station #1	807498	A23-DTP Water	20160901.S23.3A	
Station #1	807498	A23-TP Water	20160901.S23.4A	
Station #1	807498	Alka	20160831.R1A	
Station #1	807498	Ammonia Water	20160830.R42.1A	
Station #1	807498	Anions Water	20160831.R5A	
Station #1	807498	Chlorophyll A	20160830.R73A	
Station #1	807498	Ecoli (DC-R10)	20160827.R10A	
Station #1	807498	ICPMS Tot. Water	20160829.R13-5o6	20160829.R52B
Station #1	807498	OCPs Water	20160831.R19ocpw	20160829.R00AA
Station #1	807498	PAH Water SIM	20160829.R41pw2	20160829.R00AA
Station #1	807498	PCBs Water	20160906.R19pcbw	20160829.R00AA
Station #1	807498	pHWater	20160831.R2B	

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 283013

Station #1	807498	TKN Water Dig.	20160901.R58A	
Station #1	807498	TN Water	20160902.R58A	
Station #1	807498	TOC Water	20160829.R55.2A	
Station #1	807498	Total Coliform (R10)	20160827.R10A	
Station #1	807498r	A07-Reactive Si/W	20160831.T07A	
Station #1	807498r	Ecoli (DC-R10)	20160827.R10A	
Station #1	807498r	Total Coliform (R10)	20160827.R10A	
Station #2	807499	A23-DTP Water	20160901.S23.3A	
Station #2	807499	A23-TP Water	20160901.S23.4A	
Station #2	807499	Ecoli (DC-R10)	20160827.R10A	
Station #2	807499	Total Coliform (R10)	20160827.R10A	
Station #3	807500	A23-DTP Water	20160901.S23.3A	
Station #3	807500	A23-TP Water	20160901.S23.4A	
Station #3	807500	Ecoli (DC-R10)	20160827.R10A	
Station #3	807500	Total Coliform (R10)	20160827.R10A	
Station #4	807501	A23-DTP Water	20160901.S23.3A	
Station #4	807501	A23-TP Water	20160901.S23.4B	
Station #4	807501	Ecoli (DC-R10)	20160827.R10A	
Station #4	807501	Total Coliform (R10)	20160827.R10A	
Station #4D	807502	A23-DTP Water	20160901.S23.3A	
Station #4D	807502	A23-TP Water	20160901.S23.4B	
Station #4D	807502	Ecoli (DC-R10)	20160827.R10A	
Station #4D	807502	Total Coliform (R10)	20160827.R10A	
Station #5	807503	A23-DTP Water	20160901.S23.3A	
Station #5	807503	A23-TP Water	20160901.S23.4B	
Station #5	807503	Ecoli (DC-R10)	20160827.R10A	
Station #5	807503	Total Coliform (R10)	20160827.R10A	
Station #5	807503r	A23-DTP Water	20160901.S23.3A	

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Regulation/Guideline Selection Criteria Menu:
PWQO

Method	Parameter	Unit	Reg Value	Sample # / Description / Sampling Date / Reg Unit	807498 Station #1 2016-08-26 Surface Water	807498 (Dup) Station #1 2016-08-26 Surface Water	807499 Station #2 2016-08-26 Surface Water	807500 Station #3 2016-08-26 Surface Water	807501 Station #4 2016-08-26 Surface Water	807502 Station #4D 2016-08-26 Surface Water	807503 Station #5 2016-08-26 Surface Water	807503 (Dup) Station #5 2016-08-26 Surface Water
A07-Reactive Si/W	Reactive Silica	mg/L			1.34	1.33						
A23-DTP Water	Dissolved Total Phosphorus (as P)	mg/L			0.0069		0.007	0.006	0.0071	0.0072	0.0073	0.006
A23-TP Water	Total Phosphorus (as P)	mg/L			0.011		0.009	0.011	0.012	0.01	0.008	
Alka	M-Alkalinity (pH 4.5)	mg/L as CaCO3			62.3							
Ammonia Water	Ammonia (as N)	mg/L			0.01							
Anions Water	Bromide	mg/L			<0.1							
Anions Water	Chloride	mg/L			5.26							
Anions Water	Fluoride	mg/L			<0.1							
Anions Water	Nitrate (as N)	mg/L			<0.1							
Anions Water	Nitrite (as N)	mg/L			<0.03							
Anions Water	Sulphate	mg/L			10.3							
Chlorophyll A	Chlorophyll A	ug/L			<0.5							
Ecoli (DC-R10)	Escherichia coli	CFU/100mL			<100	<100	<100	<100	<100	<100	<100	
ICPMS Tot. Water	Total Aluminum	ug/L	75	ug/L	28.7							
ICPMS Tot. Water	Total Antimony	ug/L	20	ug/L	<0.5							
ICPMS Tot. Water	Total Arsenic	ug/L	100	ug/L	1							
ICPMS Tot. Water	Total Barium	ug/L			13.9							
ICPMS Tot. Water	Total Beryllium	ug/L	11	ug/L	<0.5							
ICPMS Tot. Water	Total Bismuth	ug/L			<1							
ICPMS Tot. Water	Total Boron	ug/L	200	ug/L	19							
ICPMS Tot. Water	Total Cadmium	ug/L	0.2	ug/L	<0.1							
ICPMS Tot. Water	Total Calcium	ug/L			16000							
ICPMS Tot. Water	Total Cerium	ug/L			<1							
ICPMS Tot. Water	Total Cesium	ug/L			<1							
ICPMS Tot. Water	Total Chromium	ug/L			<1							
ICPMS Tot. Water	Total Cobalt	ug/L	0.9	ug/L	<0.1							
ICPMS Tot. Water	Total Copper	ug/L	5	ug/L	1							
ICPMS Tot. Water	Total Europium	ug/L			<1							
ICPMS Tot. Water	Total Gallium	ug/L			<1							
ICPMS Tot. Water	Total Iron	ug/L	300	ug/L	40							
ICPMS Tot. Water	Total Lanthanum	ug/L			<1							
ICPMS Tot. Water	Total Lead	ug/L	5	ug/L	<1							
ICPMS Tot. Water	Total Lithium	ug/L			<5							
ICPMS Tot. Water	Total Magnesium	ug/L			4880							
ICPMS Tot. Water	Total Manganese	ug/L			5.5							
ICPMS Tot. Water	Total Mercury	ug/L			<0.1							
ICPMS Tot. Water	Total Molybdenum	ug/L	40	ug/L	<1							
ICPMS Tot. Water	Total Nickel	ug/L	25	ug/L	1							
ICPMS Tot. Water	Total Niobium	ug/L			<1							
ICPMS Tot. Water	Total Potassium	ug/L			790							
ICPMS Tot. Water	Total Rubidium	ug/L			1							
ICPMS Tot. Water	Total Scandium	ug/L			<1							
ICPMS Tot. Water	Total Selenium	ug/L	100	ug/L	<1							
ICPMS Tot. Water	Total Silicon	ug/L			600							
ICPMS Tot. Water	Total Silver	ug/L	0.1	ug/L	<0.1							
ICPMS Tot. Water	Total Sodium	ug/L			5130							
ICPMS Tot. Water	Total Strontium	ug/L			76.5							
ICPMS Tot. Water	Total Sulphur	ug/L			2000							
ICPMS Tot. Water	Total Tellurium	ug/L			<1							
ICPMS Tot. Water	Total Thallium	ug/L	0.3	ug/L	<0.1							
ICPMS Tot. Water	Total Thorium	ug/L			<1							
ICPMS Tot. Water	Total Tin	ug/L			<1							
ICPMS Tot. Water	Total Titanium	ug/L			<1							
ICPMS Tot. Water	Total Tungsten	ug/L	30	ug/L	<1							
ICPMS Tot. Water	Total Uranium	ug/L	5	ug/L	<1							
ICPMS Tot. Water	Total Vanadium	ug/L	6	ug/L	<1							
ICPMS Tot. Water	Total Yttrium	ug/L			<1							
ICPMS Tot. Water	Total Zinc	ug/L	30	ug/L	2							
ICPMS Tot. Water	Total Zirconium	ug/L	4	ug/L	<1							
OCPs Water	2,4'-DDD	ug/L			<0.0006							
OCPs Water	2,4'-DDE	ug/L			<0.0006							
OCPs Water	2,4'-DDT	ug/L			<0.0002							
OCPs Water	4,4'-DDD	ug/L	0.003	ug/L	<0.0006							
OCPs Water	4,4'-DDE	ug/L	0.003	ug/L	<0.0002							
OCPs Water	4,4'-DDT	ug/L	0.003	ug/L	<0.0003							
OCPs Water	Aldrin	ug/L	0.001	ug/L	<0.0003							
OCPs Water	DDD (Total)	ug/L			<0.0003							
OCPs Water	DDE (Total)	ug/L			<0.0002							
OCPs Water	DDT (Total)	ug/L			<0.0006							
OCPs Water	Decachlorobiphenyl (Surr.)	% Rec			64							
OCPs Water	Dieldrin	ug/L	0.001	ug/L	<0.0008							
OCPs Water	Endosulfan I	ug/L	0.003	ug/L	<0.0004							
OCPs Water	Endosulfan I + II	ug/L			<0.0006							
OCPs Water	Endosulfan II	ug/L			<0.0006							
OCPs Water	Endosulfan sulfate	ug/L			<0.0008							
OCPs Water	Endrin	ug/L	0.002	ug/L	<0.0006							
OCPs Water	Endrin aldehyde	ug/L			<0.0004							
OCPs Water	Heptachlor	ug/L	0.001	ug/L	<0.0004							
OCPs Water	Heptachlor epoxide	ug/L	0.001	ug/L	<0.0004							
OCPs Water	Hexachlorobenzene	ug/L	0.0065	ug/L	<0.0005							
OCPs Water	Hexachlorobutadiene	ug/L	0.009	ug/L	<0.0006							
OCPs Water	Hexachloroethane	ug/L	1	ug/L	<0.0006							
OCPs Water	Methoxychlor	ug/L	0.04	ug/L	<0.0008							
OCPs Water	Mirex	ug/L	0.001	ug/L	<0.0005							
OCPs Water	Oxychlordane	ug/L			<0.0005							
OCPs Water	ß-BHC	ug/L			<0.0005							
OCPs Water	α - Chlordane	ug/L			<0.0003							
OCPs Water	α + γ -Chlordane	ug/L			<0.0006							
OCPs Water	α-BHC	ug/L			<0.0006							
OCPs Water	γ - Chlordane	ug/L			<0.0004							
OCPs Water	γ-BHC (Lindane)	ug/L			<0.0003							
OCPs Water	δ-BHC	ug/L			<0.0004							
PAH Water SIM	1+2-Methylnaphthalene	ug/L			<0.05							
PAH Water SIM	1-Methylnaphthalene	ug/L	2	ug/L	<0.04							
PAH Water SIM	2-Methylnaphthalene	ug/L	2	ug/L	<0.02							
PAH Water SIM	3,3'-Dichlorobenzidine	ug/L	0.6	ug/L	<0.06							
PAH Water SIM	Acenaphthene	ug/L			<0.05							
PAH Water SIM	Acenaphthylene	ug/L			<0.05							
PAH Water SIM	Anthracene	ug/L	0.0008	ug/L	<0.02							
PAH Water SIM	Benzo(a)anthracene	ug/L			0.05							
PAH Water SIM	Benzo(a)pyrene	ug/L			0.035							
PAH Water SIM	Benzo(b)fluoranthene	ug/L			<0.07							
PAH Water SIM	Benzo(ghi)perylene	ug/L	0.00002	ug/L	<0.05							
PAH Water SIM	Benzo(k)fluoranthene	ug/L	0.0002	ug/L	<0.05							

PAH Water SIM	Chrysene	ug/L	0.0001	ug/L	<0.06								
PAH Water SIM	Dibenz(a,h)anthracene	ug/L	0.002	ug/L	<0.05								
PAH Water SIM	Fluoranthene	ug/L	0.0008	ug/L	<0.04								
PAH Water SIM	Fluorene	ug/L	0.2	ug/L	<0.05								
PAH Water SIM	Fluorobiphenyl (Surr.)	% Rec			54								
PAH Water SIM	Indeno(1,2,3-c,d)pyrene	ug/L			<0.04								
PAH Water SIM	Naphthalene	ug/L	7	ug/L	<0.06								
PAH Water SIM	Phenanthrene	ug/L	0.03	ug/L	<0.04								
PAH Water SIM	p-Terphenyl-d14 (Surr)	% Rec			78.6								
PAH Water SIM	Pyrene	ug/L			<0.06								
PCBs Water	Aroclor 1242	ug/L			<0.06								
PCBs Water	Aroclor 1248	ug/L			<0.06								
PCBs Water	Aroclor 1254	ug/L			<0.06								
PCBs Water	Aroclor 1260	ug/L			<0.06								
PCBs Water	Decachlorobiphenyl (Surr.)	% Rec			100								
PCBs Water	Total PCBs	ug/L	0.001	ug/L	<0.06								
pHWater	pH	pH			7.98								
TKN Water Dig.	Total Kjeldahl Nitrogen	mg/L			0.63								
TN Water	Total Nitrogen (as N)	mg/L			<1								
TOC Water	Total Organic Carbon	mg/L			3.7								
Total Coliform (R10)	Total Coliform	CFU/100mL			<100	<100	<100	<100	<100	<100	<100		

Please note that the term Reg. Value in the context of this spreadsheet may refer to regulatory limits, regulatory guidelines, standards or objectives set out by government regulation, or site-specific requirements.
Highlighted results indicate a measured value that exceeds the reported Reg. Value.
Highlighted units indicate a discrepancy with the Reg. Unit. This may affect the functionality of the report to properly indicate an exceeded value. Measured values and units should be converted in order to compare criteria.
TESTMARK Laboratories Ltd. has included the criteria values set by the appropriate government agency as part of this spreadsheet for purposes of reference only.
These values may or may not accurately reflect the current values prescribed by government regulation and it is the Client's responsibility to compare the results reported herein with official government sources to ensure it meets the prescribed criteria.
Should any discrepancies be discovered or should you have any questions or comments regarding the information in this spreadsheet, please contact TESTMARK Laboratories Ltd. by phone or by e-mail at reports@testmark.ca.
This spreadsheet contains condensed and summarized material and is not intended to replace the Analytical Report, but to be used as a convenience and comparison tool only. For full analytical details including QA/QC data, please refer back to the Analytical Report in its e

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CERTIFICATE OF ANALYSIS

Client:	Dixie Ortiz	Work Order Number:	287413
Company:	BluMetric	PO #:	160524
Address:	957 Cambrian Heights Dr Sudbury, ON, P3C 5S5	Regulation: Project #:	PWQO Sandy Bay Water Quality Monitoring
Phone/Fax:	(705) 525-6075 / (705) 525-6077	DWS #:	
Email:	dortiz@blumetric.ca	Sampled By:	Dixie Ortiz
Date Order Received:	10/12/2016	Analysis Started:	10/14/2016
Arrival Temperature:	11 °C	Analysis Completed:	10/18/2016

WORK ORDER SUMMARY

ANALYSES WERE PERFORMED ON THE FOLLOWING SAMPLES. THE RESULTS RELATE ONLY TO THE ITEMS TESTED.

Sample Description	Lab ID	Matrix	Type	Comments	Date Collected	Time Collected
Station 1	820546	Surface Water	None		10/12/2016	10:00 AM
Station 2	820547	Surface Water	None		10/12/2016	10:30 AM
Station 3	820548	Surface Water	None		10/12/2016	11:00 AM
Station 4	820549	Surface Water	None		10/12/2016	11:30 AM
Station 4D	820550	Surface Water	None		10/12/2016	11:35 AM
Station 5	820551	Surface Water	None	SAMPLE CONTAINED RESULT EXCEEDENCES.	10/12/2016	12:00 PM

METHODS AND INSTRUMENTATION

THE FOLLOWING METHODS WERE USED FOR YOUR SAMPLE(S):

Method	Lab	Description	Reference
DTP Water	Garson	Determination of Dissolved Total Phosphorus in Water	Based on APHA-4500P
Ecoli (DC-R10)	Garson	Determination of E. coli in Water by Membrane Filtration	Based on MOE E3407
PAH+ Water SIM	Garson	Determination of PAH in Water by GC/MS	Based on SW846-8270D
PCBs Water	Garson	Determination of Polychlorinated Biphenyls in Water by GC/ECD	Based on SW846-8082A
Total Coliform (R10)	Garson	Determination of Total Coliforms in Water by Membrane Filtration	Based on MOE E3407A
TP Water	Garson	Determination of Total Phosphorus in Water	Based on APHA-4500P

REPORT COMMENTS

Lot #1547

7 Margaret Street, Garson, ON, P3L 1E1
Phone: (705) 693-1121 Fax: (705) 693-1124 Web: www.testmark.ca

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

This report has been approved by:

Khaled Omari, Ph.D.
Laboratory Director

7 Margaret Street, Garson, ON, P3L 1E1
Phone: (705) 693-1121 Fax: (705) 693-1124 Web: www.testmark.ca

CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

WORK ORDER RESULTS

Sample Description	Station 1		Station 2		Station 3		Station 4			
Lab ID	820546		820547		820548		820549			
General Chemistry	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units	Criteria: PWQO
Dissolved Total Phosphorus (as P)	0.004 [0.004]	0.004	<0.004	0.004	<0.004	0.004	<0.004	0.004	mg/L	~
Total Phosphorus (as P)	0.0065	0.002	0.0071	0.002	0.004	0.002	0.008	0.002	mg/L	~

Sample Description	Station 4D		Station 5			
Lab ID	820550		820551			
General Chemistry	Result	MDL	Result	MDL	Units	Criteria: PWQO
Dissolved Total Phosphorus (as P)	<0.004	0.004	<0.004	0.004	mg/L	~
Total Phosphorus (as P)	0.0099	0.002	0.0062	0.002	mg/L	~

Sample Description	Station 1		Station 2		Station 3		Station 4			
Lab ID	820546		820547		820548		820549			
Microbiology	Result	MDL	Result	MDL	Result	MDL	Result	MDL	Units	Criteria: PWQO
Escherichia coli	4	2	4	2	<2	2	2	2	CFU/100mL	~
Total Coliform	34	2	16	2	28	2	36	2	CFU/100mL	~

Sample Description	Station 4D		Station 5			
Lab ID	820550		820551			
Microbiology	Result	MDL	Result	MDL	Units	Criteria: PWQO
Escherichia coli	<2	2	<2	2	CFU/100mL	~
Total Coliform	20	2	10	2	CFU/100mL	~

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

Sample Description	Station 5			
Lab ID	820551			
PAH	Result	MDL	Units	Criteria: PWQO
1+2-Chloronaphthalene	<0.06	0.06	ug/L	~
1-Methylnaphthalene	<0.02	0.02	ug/L	2
2-Methylnaphthalene	<0.01	0.01	ug/L	2
3,3'-Dichlorobenzidine	<0.03	0.03	ug/L	0.6
Anthracene	<0.01	0.01	ug/L	0.0008
Benzo(ghi)perylene	<0.02	0.02	ug/L	2e-005
Benzo(k)fluoranthene	<0.02	0.02	ug/L	0.0002
Biphenyl	<0.06	0.06	ug/L	0.2
Chrysene	<0.03	0.03	ug/L	0.0001
Dibenz(a,h)anthracene	<0.02	0.02	ug/L	0.002
Fluoranthene	<0.02	0.02	ug/L	0.0008
Fluorene	<0.02	0.02	ug/L	0.2
Naphthalene	<0.03	0.03	ug/L	7
Phenanthrene	<0.02	0.02	ug/L	0.03

Sample Description	Station 5			
Lab ID	820551			
PCBs	Result	MDL	Units	Criteria: PWQO
Total PCBs	<0.06	0.06	ug/L	0.001

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

LEGEND

Dates: Dates are formatted as mm/dd/year throughout this report.

MDL: Method detection limit or minimum reporting limit.

[ ]: Results for laboratory replicates are shown in square brackets immediately below the associated sample result for ease of comparison.

~: In a criteria column indicates the criteria is not applicable for the parameter row..

Quality Control: All associated Quality Control data is available on request.

LCL: Lower Control Limit.

UCL: Upper Control Limit.

QAQCID: This is a unique reference to the quality control data set used to generate the reported value. Contact our lab for this information, as it is traceable through our LIMS.

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

QUALITY CONTROL DATA

THIS SECTION REPORTS QC RESULTS ASSOCIATED WITH THE TEST BATCH; THESE ARE NOT YOUR SAMPLE RESULTS

General Chemistry

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Dissolved Total Phosphorus (as P)	N/A	%	0	N/A	20	20161017.R23.2C
Total Phosphorus (as P)	N/A	%	0	N/A	20	20161017.R23.2A
Total Phosphorus (as P)	N/A	%	0	N/A	20	20161017.R23.2B

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Dissolved Total Phosphorus (as P)	0.004	mg/L	0	0.00426	0.025	20161017.R23.2C
Total Phosphorus (as P)	0.002	mg/L	0	0.00247	0.005	20161017.R23.2B
Total Phosphorus (as P)	0.002	mg/L	0	0.00377	0.005	20161017.R23.2A

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Dissolved Total Phosphorus (as P)	0.002	mg/L	0.04	0.0408	0.06	20161017.R23.2C
Total Phosphorus (as P)	0.002	mg/L	0.18	0.187	0.22	20161017.R23.2A
Total Phosphorus (as P)	0.002	mg/L	0.18	0.188	0.22	20161017.R23.2B
Total Phosphorus (as P)	0.005	mg/L	0.04	0.0462	0.06	20161017.R23.2A
Total Phosphorus (as P)	0.01	mg/L	0.04	0.0486	0.06	20161017.R23.2B
Total Phosphorus (as P)	0.02	mg/L	70.3	73.2	93.3	20161017.R23.2B
Total Phosphorus (as P)	0.02	mg/L	70.3	79.7	93.3	20161017.R23.2A

Sample Spike

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Dissolved Total Phosphorus (as P)	N/A	% Rec	75	103	125	20161017.R23.2C
Total Phosphorus (as P)	N/A	% Rec	75	100	125	20161017.R23.2A
Total Phosphorus (as P)	N/A	% Rec	75	97.6	125	20161017.R23.2B

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

Microbiology

%RPD

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Escherichia coli	N/A	NA	0	N/A	0.30103	20161013.R10D
Total Coliform	N/A	NA	0	N/A	0.30103	20161013.R10D

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total Coliform	1	CFU/100mL	0	0	0	20161013.R10D

Method Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Escherichia coli	1	CFU/100mL	0	0	0	20161013.R10D

PAH

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Anthracene	0.04	ug/L	0	<0.04	0.12	20161013.R41pw
Benzo(ghi)perylene	0.04	ug/L	0	<0.04	0.12	20161013.R41pw
Benzo(k)fluoranthene	0.04	ug/L	0	<0.04	0.12	20161013.R41pw
Chrysene	0.05	ug/L	0	<0.05	0.15	20161013.R41pw
Dibenz(a,h)anthracene	0.04	ug/L	0	<0.04	0.12	20161013.R41pw
Fluoranthene	0.03	ug/L	0	<0.03	0.09	20161013.R41pw
Fluorene	0.04	ug/L	0	<0.04	0.12	20161013.R41pw
Naphthalene	0.05	ug/L	0	<0.05	0.15	20161013.R41pw
Phenanthrene	0.08	ug/L	0	<0.08	0.24	20161013.R41pw

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Anthracene	N/A	% Rec	50	97.2	140	20161013.R41pw
Benzo(ghi)perylene	N/A	% Rec	50	112	140	20161013.R41pw
Benzo(k)fluoranthene	N/A	% Rec	50	120	140	20161013.R41pw
Chrysene	N/A	% Rec	50	116	140	20161013.R41pw
Dibenz(a,h)anthracene	N/A	% Rec	50	113	140	20161013.R41pw

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CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

Fluoranthene	N/A	% Rec	50	107	140	20161013.R41pw
Fluorene	N/A	% Rec	50	104	140	20161013.R41pw
Naphthalene	N/A	% Rec	50	96.8	140	20161013.R41pw
Phenanthrene	N/A	% Rec	50	123	140	20161013.R41pw

PCBs

Blank

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total PCBs	0.01	mg/L	0	<0.01	1	20161018.R19pcbw

Positive Control

Parameter	MDL	Units	LCL	Result	UCL	QAQCID
Total PCBs	0.000001	mg/L	0.005	0.0104	0.015	20161018.R19pcbw

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Phone: (705) 693-1121 Fax: (705) 693-1124 Web: www.testmark.ca

CERTIFICATE OF ANALYSIS

BluMetric

Work Order Number: 287413

THIS INDEX SHOWS HOW YOUR SAMPLES ARE ASSOCIATED TO THE CONTROLS INCLUDED IN THE IDENTIFIED BATCHES.

Sample Description	Lab ID	Method	QAQCID	Prep QAQCID
Station 1	820546	DTP Water	20161017.R23.2C	
Station 1	820546	Ecoli (DC-R10)	20161013.R10D	
Station 1	820546	Total Coliform (R10)	20161013.R10D	
Station 1	820546	TP Water	20161017.R23.2B	
Station 1	820546r	DTP Water	20161017.R23.2C	
Station 2	820547	DTP Water	20161017.R23.2C	
Station 2	820547	Ecoli (DC-R10)	20161013.R10D	
Station 2	820547	Total Coliform (R10)	20161013.R10D	
Station 2	820547	TP Water	20161017.R23.2A	
Station 3	820548	DTP Water	20161017.R23.2C	
Station 3	820548	Ecoli (DC-R10)	20161013.R10D	
Station 3	820548	Total Coliform (R10)	20161013.R10D	
Station 3	820548	TP Water	20161017.R23.2A	
Station 4	820549	DTP Water	20161017.R23.2C	
Station 4	820549	Ecoli (DC-R10)	20161013.R10D	
Station 4	820549	Total Coliform (R10)	20161013.R10D	
Station 4	820549	TP Water	20161017.R23.2A	
Station 4D	820550	DTP Water	20161017.R23.2C	
Station 4D	820550	Ecoli (DC-R10)	20161013.R10D	
Station 4D	820550	Total Coliform (R10)	20161013.R10D	
Station 4D	820550	TP Water	20161017.R23.2A	
Station 5	820551	DTP Water	20161017.R23.2C	
Station 5	820551	Ecoli (DC-R10)	20161013.R10D	
Station 5	820551	PAH+ Water SIM	20161013.R41pw	20161014.R00AA
Station 5	820551	PCBs Water	20161018.R19pcbw	
Station 5	820551	Total Coliform (R10)	20161013.R10D	
Station 5	820551	TP Water	20161017.R23.2A	

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Phone: (705) 693-1121 Fax: (705) 693-1124 Web: www.testmark.ca

Appendix E

Chain of Custody

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V-TM 2015-6.0

GENERAL CHAIN OF CUSTODY FORM

Page 1 of 1

Please use our Drinking Water Chain of Custody Form for regulated drinking water samples

REPORT TO:
Client: BluMetric
Address: 102-957 Cambrian Heights Drive, Sudbury, ON P3C 5C5
Contact: Dixie Ortiz
Email: dortiz@blumetric.ca; lmoreau@blumetric.ca
Phone: 705-525-6075 Fax: 705-525-6077

INVOICE TO: (if different from Report)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION:
TM Quote #: 5255
Client P.O. #: 160524
Client Project #: Sandy Bay Water Quality Monitoring

REPORTING/INVOICING FORMAT
☐ Fax ☑ Email ☐ Mail

QC DATA REPORTED
☑ Yes ☐ No

SAMPLE DISPOSAL
☐ Hold ☑ Dispose ☐ Return

TURN AROUND TIME (TAT)*
☐ 1 Business Day ☐ 2 Business Days
☐ 3 Business Days ☑ Standard

SPECIFIC DATE: Tues 16
* Prior arrangements must be made for rush/weekend/holiday work

LABORATORY USE ONLY
WORK ORDER NUMBER: 283013

SAMPLING DATE (mm-dd-yy)	TIME	MATRIX**	SAMPLE DESCRIPTION (This Will Appear On The Report)	NUMBER OF CONTAINERS	DTP/FIA	TP/FIA	Alk, pH, Anions	ICPMST	Reactive Silica – TMS	OCP	NH3/FIA	TKN Digest	Chlorophyll A	TOC, TN	PAH, PCB	EC/TC	FIELD pH (if applicable)	FIELD TEMP (if applicable)	METALS FIELD FILTERED? (Y/N?)	CONTAINERS RECEIVED	TEMP	Btl. Type	Lab ID
08-26-16	11:00	SW	station #1	10	X	X	X	X	X	X	X	X	X	X	X	X	X		N	10	14	4m	307498
08-26-16	12:40	SW	station #2	2	X	X										X				2		1m,1B	307499
08-26-16	13:00	SW	station #3	2	X	X										X				2			307500
08-26-16	12:20	SW	station #4	2	X	X										X				2			307501
08-26-16	12:25	SW	station #4D	2	X	X										X				2			307502
08-26-16	13:30	SW	station #5	2	X	X										X				2			307503

Subcon
Reactive Silica to TMS

CONFIRMATION REPORT SENT

**Matrix: B=Biota, GW=Ground Water, O=Oil, P=Paint, S=Soil, SL=Sludge, SW=Surface Water, W=Water, WW=Wastewater, SD=Sediment

☐ High Concentrations Expected

lot 1610

COMMENTS/FIELD NOTES:

REGULATION
☐ O.Reg. 153: (☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9)
☐ Industrial / Commercial ☐ Residential / Parkland ☐ Agricultural
☐ Coarse Soil ☐ Fine Soil ☐ Surface ☐ Subsurface
☐ O.Reg. 558 ☒ PWQO ☐ MISA ☐ CofA ☐ MMER ☐ EEM ☐ None
Sewer Use: ☐ Sanitary ☐ Storm Municipality:
☐ Other:
AO per Client - 8/30/16 KS

Sampled By: David Peck, David Jonin	Date: Aug 21, 2016	Time: 14:00
Relinquished to Testmark By (Signature):	Date: Aug 21, 2016	Time: 16:45
Received By:	Date:	Time: 16:45
Shipped By: Hand	Shipping Reference: 22707	
Received at Testmark By:	Date: 8/26/16	Time: 16:50

7 Margaret Street, Garson, ON, P3L 1E1 • 705-693-1121 (P) • 705-693-1124 (F) • customer.service@testmark.ca
100 Wilson Ave., Timmins, ON, P4N 2S9 • 705-531-1121 (P) • 705-531-1125 (F) • timmins@testmark.ca
6820 Kitimat Road Unit #1, Mississauga, ON, L5N 5M3 • 905-821-1112 (P) • 905-821-2095 (F) • csr-mississauga@testmark.ca

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V-TM-GEN-2013-3.0

GENERAL CHAIN OF CUSTODY FORM

Page ____ of ____

Please use our Drinking Water Chain of Custody Form for regulated drinking water samples

REPORT TO:

Client: Blumetric
Address: 102-957 Cambrian Heights Drive
Sudbury, ON P3C 5S5
Contact: Dixie Ortiz
Email: dortiz@blumetric.ca; lmoreau@blumetric.ca
Phone: 705-525-6075 Fax: 705-525-6077

INVOICE TO: (if different from Report)

Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION:

TM Quote #: 5278
Client P.O. #: 160524
Client Project #: Sandy Bay Water Quality Monitoring

REPORTING/INVOICING FORMAT

☐ Fax ☑ Email ☐ Mail

QC DATA REPORTED

☑ Yes ☐ No

SAMPLE DISPOSAL

☐ Hold ☑ Dispose ☐ Return

TURN AROUND TIME (TAT)*

☐ 1 Business Day ☐ 2 Business Days
☐ 3 Business Days ☐ Standard

SPECIFIC DATE: Thurs 20

* Prior arrangements must be made for rush/weekend/holiday work

LABORATORY USE ONLY

WORK ORDER NUMBER: 287413

SAMPLING DATE (mm-dd-yy)	TIME	MATRIX**	SAMPLE DESCRIPTION (This Will Appear On The Report)	NUMBER OF CONTAINERS	ANALYSIS REQUESTED: DTP	TP	EC/TC	PCB	PAH	FIELD pH (if applicable)	FIELD TEMP (if applicable)	METALS FIELD FILTERED? (Y/N?)	CONTAINERS RECEIVED	TEMP	Btl. Type	Lab ID
10-12-16	10:00	SW	Station 1	2	X	X	X						2	11	1L,m	820546
10-12-16	10:30	SW	Station 2	2	X	X	X						1			820547
10-12-16	11:00	SW	Station 3	2	X	X	X									820548
10-12-16	11:30	SW	Station 4	2	X	X	X									820549
10-12-16	11:35	SW	Station 4D	2	X	X	X									820550
10-12-16	12:00	SW	Station 5	4	X	X	X	X	X				4		1L,m,250	820551

**Matrix: B=Biota, GW=Ground Water, O=Oil, P=Paint, S=Soil,SL=Sludge, SW=Surface Water, W=Water, WW=Wastewater, SD=Sediment

☐ High Concentrations Expected

COMMENTS/FIELD NOTES:

lot #1547

REGULATION

☐ O.Reg. 153: (July 2011 Standards) Table (1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐)
☐ Industrial / Commercial ☐ Residential / Parkland ☐ Agricultural
☐ Coarse Soil ☐ Fine Soil
☐ O.Reg. 558 ☑ PWQO ☐ MISA ☐ CofA ☐ MMER ☐ EEM
Sewer Use: ☐ Sanitary ☐ Storm Municipality:
☐ Other: as per client 10/13/16 I

Sampled By (Print and Sign)	Date	Time
Dixie Ortiz	Oct 12, 2016	8p
Received By (Print and Sign)	Date	Time

CONFIRMATION REPORT SENT

Relinquished to Testmark By (Signature)	Date	Time
Shipped By: Hand	Shipping Reference	
Received at Testmark By	Date: 10-12-16	Time: 17:00

7 Margaret Street, Garson, ON, P3L 1E1 • 705-693-1121 (P) • 705-693-1124 (F) • customer.service@testmark.ca
100 Wilson Ave., Suite 102, Timmins, ON, P4N 2S9 • 705-531-1121 (P) • 705-531-1125 (F) • timmins@testmark.ca
6820 Kitimat Road Unit #1, Mississauga, ON, L5N 5M3 • 905-821-1112 (P) • 905-821-2095 (F) • csr-mississauga@testmark.ca

Appendix F

Lake Partner Program

Lake Partner Program Information

Contact: Anna DeSellas, MSc
Scientist, Inland Lakes Monitoring
Dorset Environmental Science Centre
Ontario Ministry of the Environment & Climate Change
1026 Bellwood Acres Rd., Dorset, ON, P0A 1E0
Phone: 705.766.2150 Fax: 705.766.2254
email: anna.desellas@ontario.ca

Lake Partner Program
Hotline: 1.800.470.8322 (toll free in Ontario); 705.766.1294 (outside Ontario)
Email: lakepartner@ontario.ca
Web: www.desc.ca

Appendix G

Georgian Bay Biosphere Reserve

Appendix G-Georgian Bay Biosphere Reserve Contact Information

Mr. David Bywater
Environmental Scientist
Georgian Bay Biosphere Reserve
11 James Street
Parry Sound, Ontario.
P2A 1T4
705-774-0978

http://www.gbbr.ca/our-environment/state-of-the-bay-report/

Comparable Phosphorus Data from Georgian Bay Biosphere Reserve Online Database
Great Lakes Nearshore Assessment

OBJECTID	Data_Sour	Location_Description	Year_	Latitude	Longitude	Total_Pho	x	y
169	GLNA	Sandy_Bay_1A	2003	45.80998	-80.6731	4.9	-8980491	5749950
170	GLNA	Sandy_Bay_1A	2003	45.80998	-80.6731	3.15	-8980491	5749950
171	GLNA	Sandy_Bay_1A	2003	45.80998	-80.6731	5	-8980491	5749950
172	GLNA	Sandy_Bay_1B	2003	45.81089	-80.7031	4.05	-8983830	5750095
173	GLNA	Sandy_Bay_1B	2003	45.81089	-80.7031	1.8	-8983830	5750095
174	GLNA	Sandy_Bay_1B	2003	45.81089	-80.7031	4.8	-8983830	5750095

Nutrient Monitoring Website
http://ow.ly/10B5n2

Appendix H

Recreational Water Quality Guidelines and Aesthetics

Recreational Water Quality Guidelines and Aesthetics

Recreational water refers to surface waters that are used primarily for activities in which the user comes into frequent direct contact with the water, either as part of the activity or incidental to the activity. Examples include swimming, windsurfing, waterskiing, white water sports, scuba diving, and dinghy sailing. Secondary recreational uses include boating, canoeing, and fishing, which generally have less frequent body contact with water.

General Requirements

Health and Safety

Water used primarily for recreational purposes should be sufficiently free from microbiological, chemical, and physical hazards, e.g. poor visibility, to ensure that there is negligible risk to the health and safety of the user. Recreational water quality guidelines, summarized in Table 1, were prepared by the Federal–Provincial Advisory Committee on Environmental and Occupational Health and published by Health and Welfare Canada (1992).

These guidelines deal mainly with potential health hazards related primarily to recreational water use, but also relate to aesthetics and nuisance conditions. Health hazards associated with direct recreational contact with water include infections transmitted by pathogenic microorganisms and injuries resulting from impaired visibility in turbid waters. The determination of the risk of infection is based on a number of factors, including results of environmental health assessments, results of epidemiological studies, levels of indicator organisms, and the presence of pathogens. Sampling and enumeration of microbiological indicators and pathogens in recreational waters are also discussed. New guidelines for safe recreational water environments are currently being prepared by the World Health Organization with the assistance of Health Canada.

Aesthetics

The local setting of recreational water bodies is also important, as the surrounding countryside has a strong visual effect on the enjoyment of lakes and rivers, whether the activity is physically active or passive, such as gazing on the scenery.

In northern waters, swimming is not a major recreational activity, and factors other than microbiological are major components when determining the suitability of lakes and rivers and their environments as recreational areas. Visual impact of the whole area is as important as the quality of the water.

Impacts on a water source come from many activities. These include logging, mining, drainage of wetlands, dredging, dam construction, agricultural runoff, industrial and municipal wastes, land erosion, road construction, and land development. These factors all have to be considered in areas of natural beauty that are used for the many recreational activities engaged in by Canadians and visitors to Canada.

References

Health and Welfare Canada. 1992. Guidelines for Canadian recreational water quality. Cat. No. H49-70/1991E. Minister of Supply and Services Canada, Ottawa.

Moody, R.P., and I. Chu. 1995. Dermal exposure to environmental contaminants in the Great Lakes. Environ. Health Perspect. 103(Suppl. 9):103–114.

Recreational Water Quality Guidelines and Aesthetics

Summary — Guidelines for Canadian recreational water quality.

Parameter	Guideline
Microbiological	
Escherichia coli (fecal coliforms)	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 2000 *E. coli* per litre. Resampling should be performed when any sample exceeds 4000 *E. coli* per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Enterococci	The geometric mean of at least five samples taken during a period not to exceed 30 d should not exceed 350 enterococci per litre. Resampling should be performed when any sample exceeds 700 enterococci per litre. See Health and Welfare Canada (1992) for additional information on application of guideline.
Coliphages	Limits on coliphages can not be specified at this time. See Health and Welfare Canada (1992) for additional information.
Waterborne pathogens	The pathogens most frequently responsible for diseases associated with recreational water use are described in Health and Welfare Canada (1992), i.e., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella*, *Shigella*, *Aeromonas*, *Campylobacter jejuni*, *Legionella*, human enteric viruses, *Giardia lamblia*, and *Cryptosporidium*.
Cyanobacteria (blue-green algae)	Limits have not been specified. Health Canada is in the process of developing a numerical guideline for microcystin, a cyanobacterial toxin. Water with blue-green surface scum should be avoided because of reduced clarity and possible presence of toxins.
Chemical characteristics	Limits for chemicals have not been specified because of lack of data. Decisions for use should be based on an environmental health assessment and the aesthetic quality. Dermal exposures to environmental contaminants has recently been reviewed by Moody and Chu (1995).
Temperature	The thermal characteristics of water should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.
Clarity	The water should be sufficiently clear that a Secchi disc is visible at a minimum of 1.2 m.
pH	When the buffering capacity of the water is very low,6.5 to 8.5; range of 5.0 to 9.0 is acceptable.
Turbidity	A limit of 50 Nephelometric Turbidity Units (NTU) is suggested.
Oil and grease	Oil or petrochemicals should not be present in concentrations that • can be detected as a visible film, sheen, or discoloration on the surface; • can be detected by odour; or • can form deposits on shorelines and bottom deposits that are detectable by sight and odour.
Aquatic plants	Bathers should avoid areas with rooted or floating plants; very dense growths could affect other activities such as boating and fishing.
Aesthetics	All water should be free from • materials that will settle to form objectionable deposits; • floating debris, oil, scum, and other matter; • substances producing objectionable colour, odour, taste, or turbidity; and • substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.
Nuisance organisms	Bathing areas should be as free as possible from nuisance organisms that • endanger the health and physical comfort of users or • render the area unusable. Common examples include biting and nonbiting insects and poisonous organisms, for example jelly-fish.

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Reference listing:

Canadian Council of Ministers of the Environment. 1999. Recreational water quality guidelines and aesthetics. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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Appendix I

Polycyclic Aromatic Hydrocarbons Info Sheet

Canadian Water Quality Guidelines for the Protection of Aquatic Life

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds that contain two or more benzene rings in their structure. Present in the environment mainly as a result of incomplete combustion of forest fires, internal combustion engines, wood stoves, and coal coking, etc., PAHs are also constituents of petroleum and its derivatives (Neff 1979). Oil spills and refinery effluents are major sources of PAH contamination of freshwater and marine environments. Domestic sewage, stormwater runoff, landfills, the wood preservative industry (e.g., creosote), and waste disposal sites are further contributors of anthropogenic PAHs to the environment. Neff (1985) reported that PAHs were released by aluminium smelters using Soderberg electrodes. PAHs of natural origin are produced at very low rates (Blumer 1976).

PAHs are ubiquitous in terrestrial, atmospheric, and aquatic environments throughout the world and have been detected in rivers, lakes, groundwaters, sediments, soils, and biota throughout Canada.

PAHs are nonpolar, hydrophobic compounds that do not ionize. Volatilization, photolysis, hydrolysis, microbial degradation, and adsorption and subsequent sedimentation determine the fate of PAHs in the environment (Southworth 1979). Sorption to sediment substrates plays an important role in PAH transport and distribution (Smith et al. 1978; USEPA 1982b; Broman et al. 1991). PAHs tend to adsorb onto solid phases in aquatic environments because of their hydrophobic nature and low water solubilities (Neff 1979; NRCC 1983; Eisler 1987; Slooff et al. 1989). The association of PAHs with the solid phase depends on their molecular weight and octanol–water partitioning coefficient (K_{ow}). Up to 88% of benzo*(a)*pyrene in aquatic systems, for instance, was associated with particulate matter, while 13% of fluorene and 20% of pyrene were associated with particulate (Broman et al. 1991). PAHs may be retained in the water column in the presence of dissolved organics such as humic acids, which increase the solubility of the compound (Slooff et al. 1989; Pinal et al. 1990).

Photodegradation is an important degradation pathway in aquatic systems for high molecular weight PAHs (Suess 1976). Photooxidation can chemically transform PAHs, and the resulting products may be more carcinogenic and toxic than the parent compounds (Suzuki et al. 1982; USEPA 1982b, 1982c; NRCC 1983).

Particle-bound PAHs or PAHs adsorbed to water-suspended materials are more resistant to photo-degradation (McGinnes and Snoeyink 1974; Korfmacher et al. 1980a, 1980b). Other researchers, however, have found that PAHs attached to particulate matter are more susceptible to photolysis than PAHs in solution (Neff 1979; Moore and Ramamoorthy 1984). Zepp and Schlotzhauer (1979) also reported that the partitioning of high molecular weight PAHs to sediment decreases the rate of photooxidation. Smith et al. (1978) reported that the photooxidation half-lives of some PAHs in natural waters are 20–60% longer than those in laboratory solutions.

Volatilization plays an important role in the removal of low molecular weight PAHs from aquatic systems (USEPA 1982a, 1982b, 1982c). Naphthalene has the highest vapour pressure of the PAHs, and volatilization from aquatic environments is probably the most important removal mechanism for this compound (Callahan et al. 1979; Southworth 1979; USEPA 1982a). Based on their Henry's law constants, acenaphthene, anthracene,

Table 1. Water quality guidelines for polycyclic aromatic hydrocarbons for the protection of aquatic life (Environment Canada 1998).

Aquatic life		Guideline value ($\mu g \cdot L^{-1}$)
Freshwater	Acenaphthene	5.8*
	Acridine	4.4*
	Anthracene	0.012*
	Benz*(a)*anthracene	0.018*
	Benzo*(a)*pyrene	0.015*
	Chrysene	NRG†
	Fluoranthene	0.04*
	Fluorene	3.0*
	Naphthalene	1.1*
	Phenanthrene	0.4*
	Pyrene	0.025*
	Quinoline	3.4*
Marine	Naphthalene	1.4*

*Interim guideline.

†No recommended guideline.

fluorene, and phenanthrene have moderate volatility (Coover and Sims 1987). Park et al. (1990), however, suggested that volatilization was insignificant for PAHs with three or more aromatic rings.

PAHs are subject to biodegradation by various microorganisms such as bacteria, fungi, and certain algae that live in soils, in sediment substrate, or are suspended in the water column (Gibson et al. 1975; Gibson 1976).

Microbial degradation of PAHs is one of the main processes responsible for removing these substances from bottom sediments and the water column. Biodegradation of PAHs depends on such factors as the number of aromatic rings and type of ring fusion (Walker et al. 1975; Herbes and Schwall 1978; Lee et al. 1978; USEPA 1982b; Wild et al. 1991). Herbes and Schwall (1978) found that the turnover times (1/rate constant) of PAHs exposed to sediment-associated microorganisms increased 30–100 times per additional aromatic ring. It has also been observed that many two- and three-ringed PAHs, such as naphthalene, phenanthrene, and anthracene, are readily degraded and may be used as primary substrates by PAH-degrading organisms (Herbes and Schwall 1978; Gardner et al. 1979; Sims and Overcash 1983; Uthe 1991). Higher molecular weight compounds, such as pyrene and benzo*(a)*pyrene, degrade more slowly. Some degradation-resistant PAHs are inadequate sources of carbon and are thought to degrade mainly by cometabolism, where one hydrocarbon acts as a substrate for growth while a second, which cannot act as a growth substrate, is degraded by the same process (Neff 1979; NRCC 1983).

In animals, the mixed-function oxygenase (MFO) enzyme systems are responsible for the biotransformation of PAHs. Detoxification of PAHs is not a simple process. Before formation of nontoxic and harmless end products by various enzymatic and nonenzymatic reactions, PAHs are converted to arene oxide intermediates followed by formation of derivatives of trans-dihydrodiols, phenols, and quinones. These intermediate products are known to be toxic, carcinogenic, and/or mutagenic (Moore and Ramamoorthy 1984) and are further broken down to less toxic products by various enzymatic and nonenzymatic reactions (Neff 1979).

Aquatic organisms may remove a significant fraction of PAHs from a body of water. Pelagic organisms may take up PAHs directly from the water column. Benthic organisms may absorb these substances from contact with bottom sediments and the overlying water. Uptake of these compounds, however, tends to occur much more rapidly in the solubilized form. At a high concentration and in a short exposure situation, therefore, pelagic organisms may actually be more at risk than their benthic counterparts.

Aquatic organisms can accumulate PAHs from water, sediment, and food. The literature suggests that PAH uptake by aquatic organisms depends on several factors: (a) physical and chemical properties of the PAH (e.g., molecular weight, octanol–water partition coefficient, etc.); (b) environmental variables (e.g., suspended matter, dissolved organic matter, bioavailability, temperature, presence of other contaminants, biodegradation, etc.); and (c) biological factors (e.g., PAH metabolism and depuration rates, feeding characteristics of organisms, fat content of tissue, life stage, etc.) (McElroy et al. 1989).

The bioconcentration data from the literature exhibit a high degree of variability between species, PAH compounds, as well as within species and over time (Neff 1979; USEPA 1982a, 1982b, 1982c; NRCC 1983). The ability of different organisms to metabolize PAHs appears to play a major role in the potential for bioaccumulation and bioconcentration. Algae, mollusks, and other species, for example, which cannot metabolize PAHs rapidly, exhibit the highest BCFs, while fish and many crustaceans, which readily metabolize PAHs, generally obtain lower whole body residues (Eisler 1987; Neff 1982; Landrum and Scavia 1983).

Water Quality Guideline Derivation

The interim Canadian water quality guidelines for PAHs for the protection of aquatic life were developed based on the CCME protocol (CCME 1991). For more information, see the supporting document (Environment Canada 1998).

Freshwater Life

Acenaphthene

Acute toxicity data were available for five species of freshwater fish, with 96-h LC_{50}s ranging from 580 $\mu g \cdot L^{-1}$ for brown trout *(Salmo trutta)* to 1730 $\mu g \cdot L^{-1}$ for juvenile fathead minnows *(Pimephales promelas)* (Holcombe et al. 1983; Geiger et al. 1985). Cairns and Nebeker (1982) exposed fathead minnow embryos to acenaphthene for 32–35 d and reported LOECs of 495 $\mu g \cdot L^{-1}$ for growth and 682 $\mu g \cdot L^{-1}$ for survival. Lemke (1983) conducted an interlaboratory comparison to evaluate the sensitivity of fathead minnow embryos to acenaphthene. The 28-d

NOECs from seven laboratories ranged from 4 to 420 $\mu g \cdot L^{-1}$.

Acceptable data for invertebrates was limited. The 48-h LC_{50} and NOEC for *Daphnia magna* were 41 000 and 600 $\mu g \cdot L^{-1}$, respectively (LeBlanc 1980). A 96-h LC_{50} of >2040 $\mu g \cdot L^{-1}$ was reported for the snail *Aplexa hypnorum* (Holcombe et al. 1983).

Bastian and Toetz (1982) reported that a 14-d exposure to 2427 $\mu g \cdot L^{-1}$ of acenaphthene increased the biomass of a blue–green algae culture *(Anabaena flos-aquae)* by 26%. A 2-h exposure to acenaphthene levels of 421–4619 $\mu g \cdot L^{-1}$ had no effect on nitrogen fixation by *A. flos-aquae* (Bastian and Toetz 1985).

The interim water quality guideline for acenaphthene for the protection of freshwater life is 5.8 $\mu g \cdot L^{-1}$. It was derived by multiplying the 96-h LC_{50} of 580 $\mu g \cdot L^{-1}$ for brown trout (Holcombe et al. 1983) by a safety factor of 0.01 (CCME 1991). Because the LOEC values were near the LC_{50} values, it was deemed that deriving the guideline from a chronic endpoint would not ensure that the whole range of sensitivities would be covered. The acute 96-h LC_{50} with a higher safety factor was, therefore, chosen in preference to the chronic LOEC for growth (Cairns and Nebeker 1982). Acenaphthene was considered to be a persistent substance, as its half-life in water is 12 d to 14 weeks (SRC 1989).

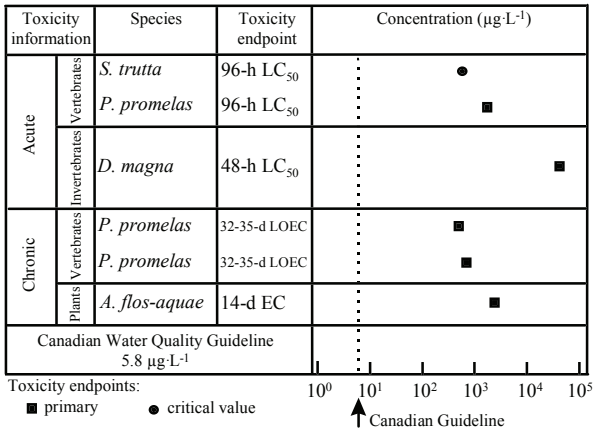

Figure 1. Select freshwater toxicity data for acenaphthene.

Acridine

Chronic toxicity data were available for two freshwater fish species. Freshly fertilized eggs from both rainbow trout *(Oncorhynchus mykiss)* and largemouth bass *(Micropterus salmoides)* were treated with acridine until 4 d after hatching (Black et al. 1983; Millemann et al. 1984). The average hatching times were 23 d for rainbow trout and 3 d for largemouth bass. Black et al. (1983) reported that 4 d after hatching, the 27-d and 7-d LC_{50}s were 320 and 1020 $\mu g \cdot L^{-1}$, respectively. Millemann et al. (1984) used an identical protocol to Black et al. (1983) and reported 27-d (4-d posthatch) and 7-d (4-d posthatch) LC_{50}s of 300 and 910 $\mu g \cdot L^{-1}$ for rainbow trout and largemouth bass, respectively.

Several PAHs are acutely toxic only in the presence of solar UV radiation. Oris and Giesy (1987) reported that exposing fathead minnows simultaneously to 525 $\mu g \cdot L^{-1}$ acridine and UV radiation resulted in 50% mortality in 4.3 h. The 96-h exposure in complete darkness at the above concentration was not toxic.

Acute toxicity data ranged from a 48-h LC_{50} of 1860 $\mu g \cdot L^{-1}$ for *Chironomus tentans* (Millemann et al. 1984) to a 48-h LC_{50} of 2300 $\mu g \cdot L^{-1}$ for *D. magna* (Parkhurst et al. 1981a).

D. magna were exposed to acridine for 28 d in full life cycle toxicity tests (Parkhurst et al. 1981a, 1981b). The total number of young produced per female, the number of broods produced per female, and the number of young per brood were assessed. The NOECs for all three endpoints were 400 $\mu g \cdot L^{-1}$, and the LOECs were 800 $\mu g \cdot L^{-1}$.

Newsted and Giesy (1987) reported an LT_{50} of 53.8 min for *D. magna* simultaneously exposed to 440.1 $\mu g \cdot L^{-1}$ acridine and simulated sunlight.

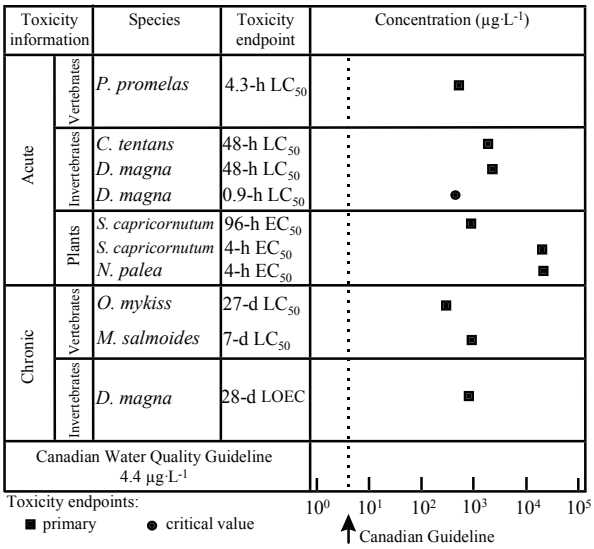

Figure 2. Select freshwater toxicity data for acridine.

Phytotoxicity data are limited. Blaylock et al. (1985) studied the effect of acridine on growth in *Selenastrum capricornutum* and found a 96-h EC_{50} of 900 $\mu g \cdot L^{-1}$. Millemann et al. (1984) reported 4-h EC_{50}s of 20 000 and 20 800 $\mu g \cdot L^{-1}$ for *S. capricornutum* and *Nitzschia palea*, respectively.

The interim water quality guideline for acridine for the protection of freshwater life is 4.4 $\mu g \cdot L^{-1}$. It was derived by multiplying the most sensitive acute concentration of 440.1 $\mu g \cdot L^{-1}$ for *D. magna* (LT_{50} = 0.9 h) by a safety factor of 0.01 (CCME 1991). Although appropriate data were not available from the literature, acridine was considered to be a persistent chemical because it has properties (e.g., K_{oc}, molecular weight, and phototoxicity) similar to other PAHs in its group (PAHs with three benzene rings, e.g., anthracene). The 0.9-h LT_{50} of 440.1 $\mu g \cdot L^{-1}$ for daphnia (Newsted and Giesy 1987) was chosen as the starting point over the 27-d LC_{50} of 300 $\mu g \cdot L^{-1}$ for rainbow trout (Millemann et al. 1984) for two reasons: (1) photoinduced toxicity is relatively more severe than an acute or a chronic toxicity effect in the absence of UV light; and (2) a guideline based on phototoxic effect will be protective of all adverse effects, including photo-induced toxicity. It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to UV radiation in the field.

Anthracene

Anthracene was not acutely toxic to bluegill sunfish *(Lepomis macrochirus)* at saturation concentrations under conditions of artificial light (gold fluorescent light at 500 nm), shade, or darkness (Spacie et al. 1983). However, in the presence of solar UV radiation, anthracene is extremely toxic. The acute toxicity of anthracene to bluegill sunfish depends on the amount of time an animal is exposed to solar UV radiation. Oris and Giesy (1986) reported 96-h LC_{50} values ranging from 4.5 $\mu g \cdot L^{-1}$ for a 24-h light/0-h dark photoperiod to 46 $\mu g \cdot L^{-1}$ for a 6-h light/18-h dark photoperiod.

Invertebrates are also very sensitive to anthracene in the presence of solar radiation. *D. pulex* were exposed to anthracene levels of 1.2, 7.5, and 32.7 $\mu g \cdot L^{-1}$ under laboratory lighting for 24 h (Allred and Giesy 1985). None of these treatments were toxic. When the animals were subsequently exposed to solar radiation, there was 100% immobilization within 2 min at 32.7 $\mu g \cdot L^{-1}$ and within 10 min at 7.5 $\mu g \cdot L^{-1}$. At the lowest treatment level (1.2 $\mu g \cdot L^{-1}$), 50% of the treated daphnids were immobilized within 15 min. The affected organisms did not recover when returned to freshwater and laboratory lighting.

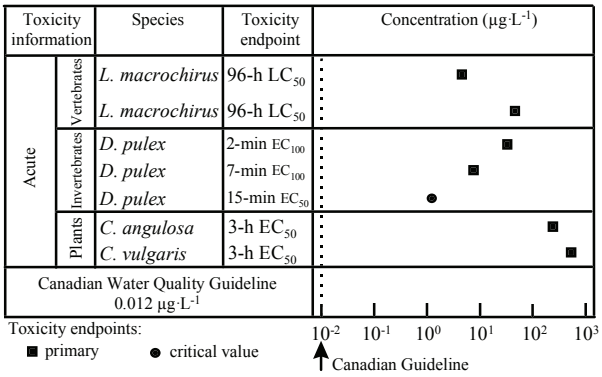

Figure 3. Select freshwater toxicity data for anthracene.

Hutchinson et al. (1980) reported 3-h EC_{50}s of 239 and 535 $\mu g \cdot L^{-1}$, respectively, for the green algae *Chlamydomonas angulosa* and *Chlorella vulgaris*. Gala and Giesy (1993) suggested that the carotenoid pigments provided algae *(S. capricornutum)* with greater resistance to the photoinduced toxicity of anthracene relative to aquatic animals.

The interim water quality guideline for anthracene for the protection of freshwater life is 0.012 $\mu g \cdot L^{-1}$. It was derived by multiplying the acute value (~15 min LT_{50}) of 1.2 $\mu g \cdot L^{-1}$ (Allred and Giesy 1985) for *D. pulex* by a safety factor of 0.01 (CCME 1991). Anthracene was considered to be a persistent substance, as its half-life in water is longer than 8 weeks (SRC 1989). It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to UV radiation in the field.

Benz(a)anthracene

Data for benz*(a)*anthracene toxicity in the freshwater environment are very limited. Brown et al. (1975) reported 87% mortality of bluegill sunfish exposed to 1000 $\mu g \cdot L^{-1}$ of benz*(a)*anthracene for 6 months. The concentrations used by these investigators in their study, however, were much higher than the aqueous solubility of the PAH (11 $\mu g \cdot L^{-1}$). More recently, Oris and Giesy (1987) found that 50% of fathead minnows *(P. promelas)* died in about 65 h when exposed to 1.8 $\mu g \cdot L^{-1}$ benz*(a)*anthracene in UV light (simulated sunlight).

A 48-h LC_{50} of 10 $\mu g \cdot L^{-1}$ was reported for *D. pulex* exposed to benz*(a)*anthracene (Trucco et al. 1983). In another study, Newsted and Giesy (1987) observed 50%

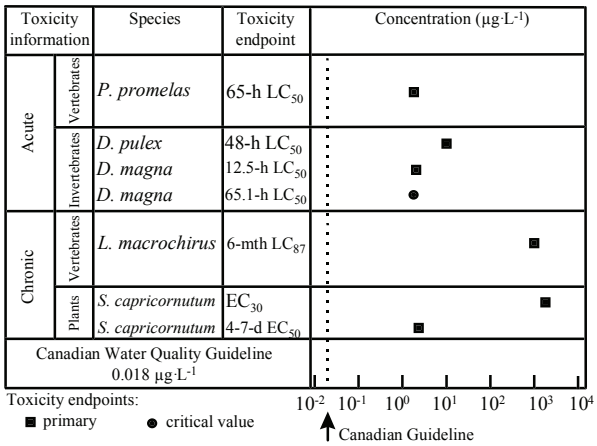

Figure 4. Select freshwater toxicity data for benz*(a)*anthracene.

mortality in *D. magna* exposed to benz*(a)*anthracene concentrations of 2 and 1.8 µg·L^{-1} after 12.51 and 65.1 h of UV exposure (in simulated sunlight), respectively.

A 30% reduction in growth was reported for the green alga *S. capricornutum* following an exposure to 1830 µg·L^{-1} (Schoeny et al. 1988). Cody et al. (1984) observed a 50% decrease in cell growth during a 4- to 7-d exposure to 2.3–22 800 µg·L^{-1} benz*(a)*anthracene.

The interim water quality guideline for benz*(a)*anthracene for the protection of freshwater life is 0.018 µg·L^{-1}. It was derived by multiplying the acute value of 1.8 µg·L^{-1} for *D. magna* (Newsted and Giesy 1987) by a safety factor of 0.01 (CCME 1991). Benz*(a)*anthracene was considered to be a persistent substance, as its half-life in water is longer than 8 weeks (MacKay et al. 1992). It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to UV radiation in the field. The interim Canadian water quality guideline for benz*(a)*anthracene was proposed even though there was insufficient information according to the CCME (1991) protocol (there was a lack of data on coldwater fish such as trout and invertebrates other than daphnia). The reasons in favour of an interim guideline were: (a) fathead minnows, found in a wide range of geographic locations that extend from the southern United States to the Northwest Territories in Canada, can be considered as a coldwater fish; and (b) daphnia are one of the key indicator species that are commonly used to assess toxicity of contaminants.

Benzo(a)pyrene

Chronic effects, including morphological abnormalities and necrosis of brain and spine, have been reported in rainbow trout eggs and alevins exposed to 0.08–0.21 µg·L^{-1} benzo*(a)*pyrene (Hannah et al. 1982; Hose et al. 1984). Oris and Giesy (1987) noted that 50% of the fathead minnows *(P. promelas)* exposed to 5.6 µg·L^{-1} benzo*(a)*pyrene and UV radiation died in 40 h. In the absence of UV radiation, however, a 96-h exposure to benzo*(a)*pyrene at a concentration of 5.6 µg·L^{-1} was not toxic.

Invertebrates were very sensitive to benzo*(a)*pyrene. Trucco et al. (1983) reported a 96-h LC_{50} of 5 µg·L^{-1} for *D. pulex*. Newsted and Giesy (1987) exposed *D. magna* to 1.5 µg·L^{-1} benzo*(a)*pyrene in the presence of solar UV radiation and reported an LT_{50} of only 4.4 h. Kagan and Kagan (1986) reported a 30-min LC_{50} of 8 µg·L^{-1} for mosquitoes *(A. agypti)* exposed to benzo*(a)*pyrene in the presence of UV radiation.

The green alga *S. capricornutum* was exposed to benzo*(a)*pyrene for 4–7 d using different light regimens (Cody et al. 1984). Under cool-white fluorescent light, a 30% inhibition of algal growth occurred at 25.2 µg·L^{-1}; however, under fluorescent black light (high UV radiation), a complete inhibition of growth occurred at 16 µg·L^{-1}.

The interim water quality guideline for benzo*(a)*pyrene for the protection of freshwater life is 0.015 µg·L^{-1}. It was

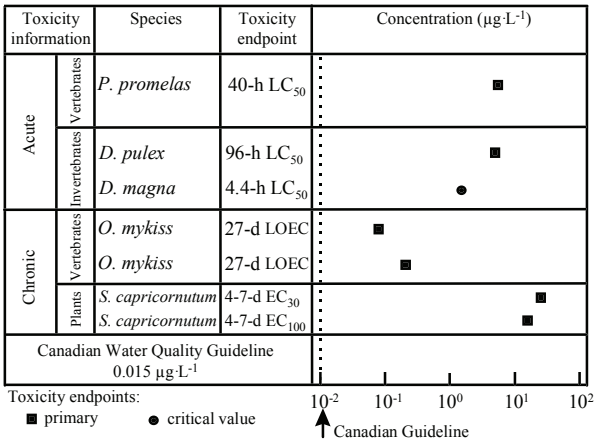

Figure 5. Select freshwater toxicity data for benzo*(a)*pyrene.

derived by multiplying the acute (~4-h LC_{50}) concentration of 1.5 $\mu g \cdot L^{-1}$ for *D. magna* (Newsted and Giesy 1987) by a safety factor of 0.01 (CCME 1991). Benzo*(a)*pyrene was considered to be a persistent substance, as its half-life in water is longer than 8 weeks (SRC 1989). It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to UV radiation in the field. Twenty-seven day LOECs of 0.08 (Hannah et al. 1982) and 0.21 $\mu g \cdot L^{-1}$ (Hose et al. 1984) were also reported for morphological abnormalities in the early life stages of rainbow trout *(O. mykiss)*. The results of Hannah et al. (1982) and Hose et al. (1984), however, were not used in the guideline derivation because they were obtained in the presence of benzo*(a)*pyrene-contaminated sediment/sand in contact with the test water and it was not clear whether sediment toxicity was a factor in the effects.

Chrysene

Data were insufficient to derive a freshwater quality guideline for chrysene. A mortality rate of 50% was observed for *D. magna* exposed to 0.7 $\mu g \cdot L^{-1}$ chrysene and UV light for almost 24 h (the lowest reported effect level) (Newsted and Giesy 1987). Bastian and Toetz (1985) reported a 17% decrease in the rate of nitrogen fixation by blue–green algae (*A. flos-aquae*) exposed to 13.9 $\mu g \cdot L^{-1}$ chrysene. In an earlier experiment, these investigators observed a 35% reduction in the cell growth of the same alga exposed to 1.9 $\mu g \cdot L^{-1}$ chrysene. No other data for chrysene were found in the literature.

Fluoranthene

Kagan et al. (1985) found that 50% of fathead minnows (*P. promelas*) died in 24 h when exposed to 200 $\mu g \cdot L^{-1}$ fluoranthene in UV light for 30 min.

Newsted and Giesy (1987) and Kagan et al. (1985) reported a 50% mortality for *D. magna* exposed for 10.8 h to UV light and a fluoranthene concentration of 9 $\mu g \cdot L^{-1}$. Kagan et al. (1985) reported 1-h LC_{50}s of 4 and 12 $\mu g \cdot L^{-1}$ for *D. magna* and *Aedes aegypti*, respectively, after 1 h irradiation with UV light.

A 38% inhibition in growth of the blue–green alga *A. flos-aqua* was observed after a 14-d exposure to 38 $\mu g \cdot L^{-1}$ fluoranthene (Bastian and Toetz 1982). Complete inhibition of cell growth was observed following exposure to 417 $\mu g \cdot L^{-1}$ fluoranthene. Bastian and Toetz (1985) observed 20–28% inhibition of nitrogen fixation rate after a 2-h exposure of the alga to 434 $\mu g \cdot L^{-1}$ fluoranthene.

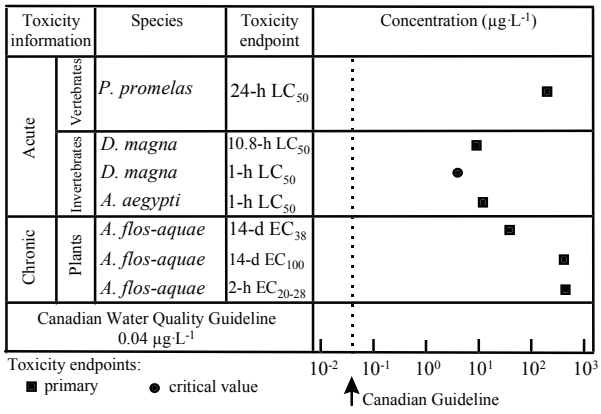

Figure 6. Select freshwater toxicity data for fluoranthene.

The interim water quality guideline for fluoranthene for the protection of freshwater life is 0.04 $\mu g \cdot L^{-1}$. It was derived by multiplying the acute 1-h LC_{50} of 4 $\mu g \cdot L^{-1}$ for *D. magna* exposed to UV light (Kagan et al. 1985) by a safety factor of 0.01 (CCME 1991). Fluoranthene was considered to be a persistent substance, as its half-life in water is longer than 8 weeks (MacKay et al. 1992). It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to ultraviolet radiation in the field. The interim Canadian water quality guideline for fluoranthene was proposed even though the CCME requirement (CCME 1991) minimum data set was not met. (There was lack of data on coldwater fish such as trout.) The reasons in favour of the proposed interim guideline are the same as those suggested for benz*(a)*anthracene.

Fluorene

Finger et al. (1985) reported significant reductions in survival and growth of juvenile bluegill sunfish *(L. macrochirus)* at fluorene concentrations of 500 and 250 $\mu g \cdot L^{-1}$, respectively. Bluegill sunfish exposed to 62 $\mu g \cdot L^{-1}$ struck more frequently at food, but captured fewer prey. Such a reduction in feeding efficiency could translate into decreases in growth and reproductive capacity. These investigators also reported 96-h LC_{50}s of 820 and 910 $\mu g \cdot L^{-1}$, respectively, for rainbow trout *(O. mykiss)* and bluegill sunfish exposed to fluorene. Both species of fish suffered a loss of equilibrium at fluorene levels of 320 $\mu g \cdot L^{-1}$.

Finger et al. (1985) exposed *D. magna* to fluorene levels of 125 $\mu g \cdot L^{-1}$ and found reduced reproduction following 14 d (44% lower fecundity than control). The authors noted that measured fluorene concentrations in the chronic tests were 76% lower than the nominal concentrations. Finger et al. (1985) also reported that the emergence of larval midges *(Chironomus riparius)* was reduced following a 30-d exposure to fluorene at a concentration of 600 $\mu g \cdot L^{-1}$.

There is considerable intraspecific variation in the sensitivities of algae to fluorene. A 20% decrease in nitrogen fixation was reported in the blue–green alga *A. flos-aquae* exposed to 612 $\mu g \cdot L^{-1}$ fluorene for 2 h (Bastian and Toetz, 1985). Finger et al. (1985) reported a 96-h EC_{50} (reduction in photosynthesis) of 3400 $\mu g \cdot L^{-1}$ for the alga *S. capricornutum* and a 21-d EC_{50} (production) of 20 000 $\mu g \cdot L^{-1}$ for the macrophyte *Chara* sp.

The interim water quality guideline for fluorene for the protection of freshwater life is 3.0 $\mu g \cdot L^{-1}$. It was derived by multiplying the 14-d LOEC (a nominal chronic value) of 125 $\mu g \cdot L^{-1}$ reported for *D. magna* (Finger et al. 1985) by a safety factor of 0.1 (CCME 1991). The result, thus obtained, was then multiplied by a correction factor of 0.24 to derive the proposed guideline. This correction was required since the actual (or measured) fluorene concentration during chronic tests with daphnids was, on average, 24% of the reported nominal LOEC of 125 $\mu g \cdot L^{-1}$.

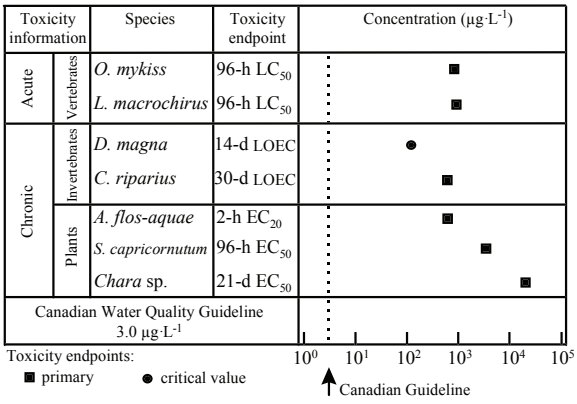

Figure 7. Select freshwater toxicity data for fluorene.

Naphthalene

Black et al. (1983) and Millemann et al. (1984) examined the acute toxicity of naphthalene to early life stages of rainbow trout and largemouth bass *(M. salmoides)*. Freshly fertilized eggs from both species were treated with naphthalene until 4 d after hatching. The average hatching times were 23 d for rainbow trout and 3 d for largemouth bass. Black et al. (1983) reported LC_{50}s at the time of hatching of 120 and >240 $\mu g \cdot L^{-1}$, and 4-d posthatch LC_{50} values of 110 and 510 $\mu g \cdot L^{-1}$, respectively, for rainbow trout and largemouth bass. These results were supported by Millemann et al. (1984) who found 4-d posthatch LC_{50}s of 120 and 680 $\mu g \cdot L^{-1}$, respectively, for the same two species. Black et al. (1983) reported chronic values for rainbow trout *(O. mykiss)* larvae of 8, 15, and 46 $\mu g \cdot L^{-1}$ (~11 $\mu g \cdot L^{-1}$ is the geometric mean of the two lower values). These chronic values represented control-adjusted survival of 97, 91, and 84%, respectively, of the trout 4 d after hatching (at the embryo–larval stages).

Several studies have reported 96-h LC_{50} values for fathead minnows *(P. promelas)* exposed to naphthalene: 7900 $\mu g \cdot L^{-1}$ (DeGraeve et al. 1982), 6080 $\mu g \cdot L^{-1}$ (Holcombe et al. 1984), 1990 $\mu g \cdot L^{-1}$ (Millemann et al. 1984), and 6140 $\mu g \cdot L^{-1}$ (Geiger et al. 1985).

The acute sensitivity of daphnids to naphthalene has been assessed by several studies. For instance, 48-h LC_{50}s of 3400 $\mu g \cdot L^{-1}$ (Geiger and Buikema 1981) and 4663 $\mu g \cdot L^{-1}$ (Smith et al. 1988) were quoted for *D. pulex*. Similarly, 48-h LC_{50}s of 4100 $\mu g \cdot L^{-1}$ (Crider et al. 1982) and 2160 $\mu g \cdot L^{-1}$ (Millemann et al. 1984) were found for *D. magna*. Trucco et al. (1983) reported a 96-h LC_{50} of 1000 $\mu g \cdot L^{-1}$ for *D. pulex*; however, the study was conducted under a combination of fluorescent and natural light; therefore, it is possible that the increased sensitivity was due to photoenhanced effects.

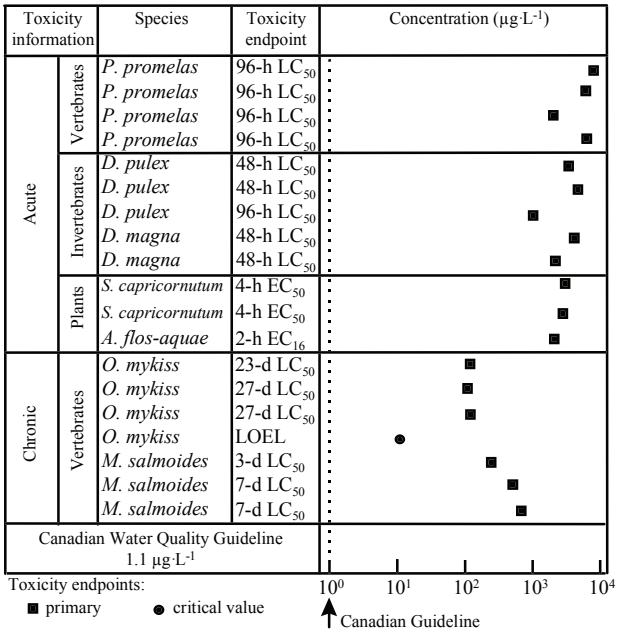

Figure 8. Select freshwater toxicity data for naphthalene.

Millemann et al. (1984) determined 4-h EC_{50}s (photosynthesis) of 2960 and 2820 $\mu g \cdot L^{-1}$, respectively, for the green alga *S. capricornutum* and the diatom *N. palea*. Bastian and Toetz (1985) reported a 16% decrease in nitrogen fixation for the blue–green alga *A. flos-aquae* following a 2-h exposure to 2071 $\mu g \cdot L^{-1}$.

The interim water quality guideline for naphthalene for the protection of freshwater life is 1.1 $\mu g \cdot L^{-1}$. It was derived by multiplying the chronic LOEL of 11 $\mu g \cdot L^{-1}$, which is the geometric mean of the lowest two of three chronic values, namely, 8, 15, and 46 $\mu g \cdot L^{-1}$ corresponding to the 97, 91, and 84% survival success in rainbow trout embryo–larval stages (Black et al. 1983), by a safety factor of 0.1 (CCME 1991).

Phenanthrene

Black et al. (1983) and Millemann et al. (1984) treated freshly fertilized eggs of rainbow trout *(O. mykiss)* and largemouth bass *(M. salmoides)* with phenanthrene until 4 d after hatching. The average hatching times were 23 d for rainbow trout and 3 d for largemouth bass. The early life stages of rainbow trout were more sensitive than that of bass. Black et al. (1983) reported LC_{50}s at the time of hatching of 40 $\mu g \cdot L^{-1}$ for the trout and >70 $\mu g \cdot L^{-1}$ for the bass and 4-d posthatch LC_{50}s of 40 and 180 $\mu g \cdot L^{-1}$, respectively. These authors also reported 93 and 82% control-adjusted survival of the trout (4-d posthatching at the embryo–larval stages) exposed to 4 and 8 $\mu g \cdot L^{-1}$ phenanthrene. Millemann et al. (1984) found 4-d posthatch LC_{50}s of 30 and 250 $\mu g \cdot L^{-1}$, respectively, for the trout and bass. Call et al. (1986) also conducted chronic tests with rainbow trout embryos exposed to phenanthrene. Several endpoints were examined, including hatching efficiency, teratogenic and dead fry at hatch, wet weight, and length, however, the most sensitive endpoint was mortality. The LOEC and NOEC for mortality were 8 and 5 $\mu g \cdot L^{-1}$, respectively, resulting in a SMATC (geometric mean of NOEC and LOEC) of 6 $\mu g \cdot L^{-1}$. The same study found 96-h LC_{50}s of 375 and 234 $\mu g \cdot L^{-1}$ and 96-h EC_{50}s (loss of equilibrium) of 50 and 49 $\mu g \cdot L^{-1}$ for rainbow trout and bluegill sunfish, respectively.

Call et al. (1986) assessed reproductive performance in phenanthrene-exposed *D. magna*. The 21-d LOEC and NOEC values were 163 and 57 $\mu g \cdot L^{-1}$, respectively, resulting in a SMATC of 96 $\mu g \cdot L^{-1}$. The same study examined the toxicity of phenanthrene to several invertebrate species. A 48-h EC_{50} (immobilization) of 117 $\mu g \cdot L^{-1}$ was reported for *D. magna*. These authors also reported 96-h EC_{50}s of 96 $\mu g \cdot L^{-1}$ (shortened tentacles and body column) for hydroids (*Hydra* sp.) and 126 $\mu g \cdot L^{-1}$ (immobilization) for amphipods *(Gammarus pseudolimnaeus)* exposed to phenanthrene. The Call et al. (1986) data suggest that fish are more sensitive to phenanthrene than invertebrates. Several studies have subjected daphnids to acute exposure to phenanthrene. For *D. pulex*, the reported endpoints ranged from a 96-h LC_{50} of 100 $\mu g \cdot L^{-1}$ (Trucco et al. 1983) to a 48-h LC_{50} of 1140 $\mu g \cdot L^{-1}$ (Geiger and Buikema 1981).

Acute phytotoxicity data for phenanthrene are available for blue–green algae *(A. flos-aquae)*, green algae *(C. vulgaris*, *C. angulosa*, and *S. capricornutum)*, duckweed *(Lemna minor)*, and the diatom *N. palea*. *A. flos-aquae* was the most sensitive, with Bastian and Toetz (1985) reporting that nitrogen fixation was decreased by 40% following a 2-h exposure to 134 $\mu g \cdot L^{-1}$ phenanthrene.

The interim water quality guideline for phenanthrene for the protection of freshwater life is 0.4 $\mu g \cdot L^{-1}$. It was derived by multiplying the chronic LOEL of 4 $\mu g \cdot L^{-1}$ for rainbow trout (corresponding to the control-adjusted 93% survival of the trout) (Black et al. 1983) by a safety factor of 0.1 (CCME 1991).

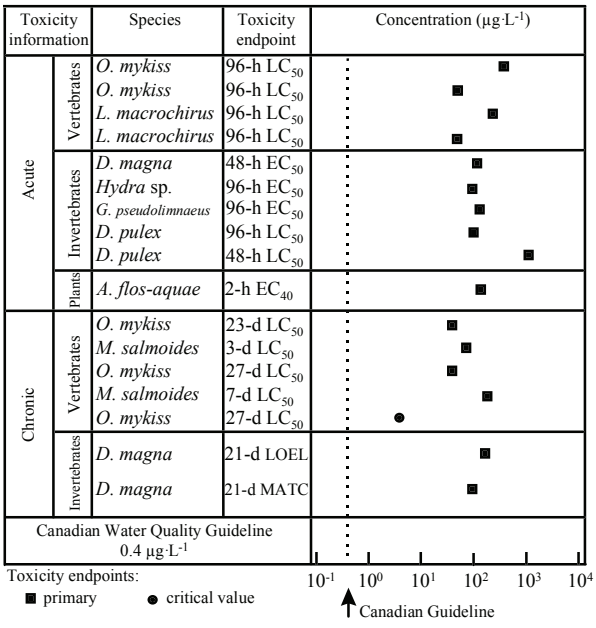

Figure 9. Select freshwater toxicity data for phenanthrene.

Pyrene

Oris and Giesy (1987) exposed juvenile fathead minnows *(P. promelas)* to pyrene in the presence of solar UV radiation and reported an LT_{50} of 3.2 h at 26 $\mu g \cdot L^{-1}$. Kagan et al. (1985) reported a 30-min LC_{50} of 220 $\mu g \cdot L^{-1}$ for fathead minnows exposed to pyrene in UV light (13 W $\cdot m^2$). Kagan et al. (1985) also studied the phototoxicity of pyrene in leopard frog tadpoles *(Rana pipiens)*. The 1-h LC_{50} in the presence of sunlight was 140 $\mu g \cdot L^{-1}$.

The phototoxicity of pyrene to first instar mosquito larvae *(A. aegypti)* was also examined by Kagan and Kagan (1986). Exposure to 30 $\mu g \cdot L^{-1}$ pyrene for 12 h in the absence of a UV light, followed by a further 30 min in UV light, resulted in 100% mortality of mosquitos. No adverse effects of pyrene were observed in the absence of UV radiation for 12.5 h. The LC_{50}s immediately after the irradiation and 24 h later were 12 and 9 $\mu g \cdot L^{-1}$. If the larvae were allowed to develop through to adult emergence, then the LC_{50} was 2.5 $\mu g \cdot L^{-1}$. Kagan et al. (1985) exposed *D. magna* to pyrene for 1 h under laboratory conditions. It was followed by a 30-min exposure of the organisms to UV light (13 $W \cdot m^2$). The investigators reported a 90-min LC_{50} of 20 $\mu g \cdot L^{-1}$ pyrene for *D. magna*. Increasing the initial exposure time (i.e., under laboratory light) to 2 and 12 h resulted in 2.5- and 12.5-h LC_{50}s of 15 and 12 $\mu g \cdot L^{-1}$, respectively. However, doubling the time of UV light exposure from 30 min to 1 h resulted in a 2-h LC_{50} of 4 $\mu g \cdot L^{-1}$, a five-fold increase in sensitivity. Newsted and Giesy (1987) reported that the daphnids treated with the toxicant under laboratory lights for 24 h, followed by a 24-h UV light exposure, displayed a 50% mortality in 208.6 min at a pyrene concentration of 5.7 $\mu g \cdot L^{-1}$.

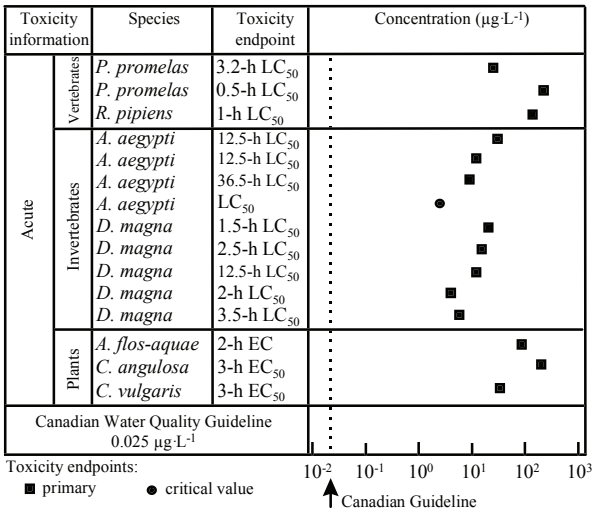

Figure 10. Select freshwater toxicity data for pyrene.

Toxicity data for freshwater algae are limited. Bastian and Toetz (1985) found that nitrogen fixation was elevated in *A. flos-aquae* following a 2-h pyrene treatment of 85 $\mu g \cdot L^{-1}$. Hutchinson et al. (1980) reported that pyrene reduced photosynthetic activity in green algae. For *C. angulosa* and *C. vulgaris*, 3-h EC_{50}s of 202 and 332 $\mu g \cdot L^{-1}$, respectively, were found.

The interim water quality guideline for pyrene for the protection of freshwater life is 0.025 $\mu g \cdot L^{-1}$. It was derived by multiplying the acute value (LC_{50}) of 2.5 $\mu g \cdot L^{-1}$ for mosquito larvae *(A. aegypti)* (Kagan and Kagan 1986) by a safety factor of 0.01 (CCME 1991). Pyrene was considered to be a persistent substance, as its half-life in water is longer than 8 weeks (SRC 1989). It is assumed that the experimental exposure to either simulated or natural sunlight can resemble the potential exposure to ultraviolet radiation in the field.

Quinoline

Black et al. (1983) and Millemann et al. (1984) conducted chronic toxicity tests with freshly fertilized rainbow trout *(O. mykiss)* and largemouth bass *(M. salmoides)* eggs exposed to quinoline until 4 d after hatching. The average hatching times for largemouth bass and rainbow trout were 3 and 23 d, respectively. Millemann et al. (1984) reported 4-d posthatch LC_{50}s of 7420 and 11 500 $\mu g \cdot L^{-1}$, respectively, for the bass and trout. Black et al. (1983) found very similar values with LC_{50}s at the time of hatching of 10 800 and >10 800 $\mu g \cdot L^{-1}$ for the trout and bass and 4-d posthatch LC_{50}s of 11 000 and 7500 $\mu g \cdot L^{-1}$, respectively. In a chronic toxicity test with quinoline, Black et al. (1993) also found that the control-adjusted survival of rainbow trout *(O. mykiss)* (4-d posthatch at the embryo–larval stages) decreased to 95% at 13 $\mu g \cdot L^{-1}$, 89% at 90 $\mu g \cdot L^{-1}$, and 82% at 370 $\mu g \cdot L^{-1}$. The geometric mean of the lowest two chronic values is calculated to be 34 $\mu g \cdot L^{-1}$. Millemann et al. (1984) reported a 96-h LC_{50} for juvenile fathead minnows *(P. promelas)* of 440 $\mu g \cdot L^{-1}$.

Exposing pond snails *(Physa gyrina)* to quinoline for 17–22 d delayed hatching at concentrations of 12 500 $\mu g \cdot L^{-1}$ and reduced embryogenesis at 25 000 $\mu g \cdot L^{-1}$ (Millemann and Ehrenberg 1982). The 48-h LC_{50} of 183 000 $\mu g \cdot L^{-1}$ for *P. gyrina* was considerably higher than the nonlethal end points (Millemann et al. 1984). Millemann et al. (1984) also reported 48-h LC_{50}s of 34 500, 40 900, and

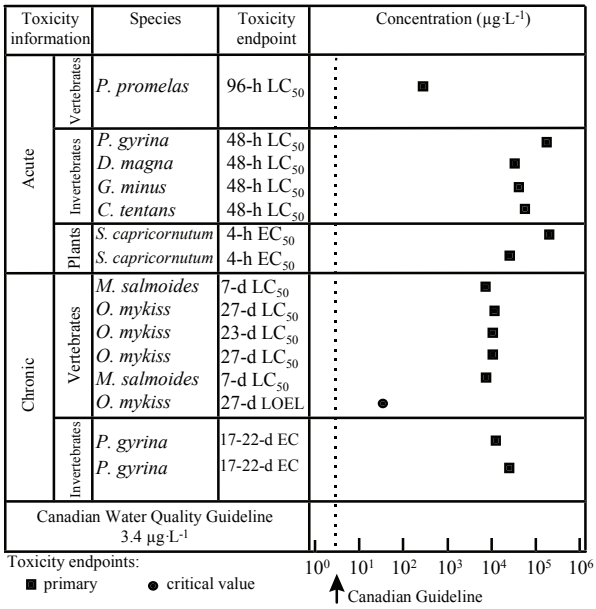

Figure 11. Select freshwater toxicity data for quinoline.

56 800 $\mu g \cdot L^{-1}$ for the water flea *(D. magna)*, scud *(Gammarus minus)*, and midge (*C. tentans*), respectively.

Millemann et al. (1984) reported a 4-h EC_{50} for reduced photosynthetic activity of 202 000 $\mu g \cdot L^{-1}$ in the green alga *S. capricornutum*. Similarly, a 4-h EC_{50}, for reduced photosynthesis in *S. capricornutum* of 25 000 $\mu g \cdot L^{-1}$ was also reported by Giddings et al. (1983).

An interim water quality guideline for quinoline for the protection of freshwater life is 3.4 $\mu g \cdot L^{-1}$. It was derived by multiplying the chronic LOEC of 34 $\mu g \cdot L^{-1}$ for rainbow trout by a safety factor of 0.1 (CCME 1991). Black et al. (1983) observed that the survival of rainbow trout (*O. mykiss*) larvae exposed to quinoline was 95% at 13 $\mu g \cdot L^{-1}$, 89% at 90 $\mu g \cdot L^{-1}$, and 82% at 370 $\mu g \cdot L^{-1}$. The chronic LOEL of 34 $\mu g \cdot L^{-1}$ is the geometric mean of 13 and 90 $\mu g \cdot L^{-1}$. In this case, the geometric mean was chosen as it was assumed to be more environmentally relevant than the lowest effect level (95% survival rate) alone.

Marine Life

Naphthalene

Moles and Rice (1983) reported a 96-h LC_{50} of 1200 $\mu g \cdot L^{-1}$ for juvenile pink salmon *(O. gorbuscha)* exposed to naphthalene. Following 40-d exposures, LOEC and NOEC values (body weight) of 380 and 120 $\mu g \cdot L^{-1}$, respectively, were reported. A 96-h LC_{50} of 1240 $\mu g \cdot L^{-1}$ for pink salmon (Korn et al. 1979) and a 24-h LC_{50} of 2400 $\mu g \cdot L^{-1}$ for the sheepshead minnow *(C. variegatus)* (Anderson et al. 1974) have been reported.

Ott et al. (1978) exposed female copepods *(Eurotemora affinis)* carrying their first egg sacs to 14.2 $\mu g \cdot L^{-1}$ of naphthalene until their deaths (29 d). Lifespan, total eggs per female, mean brood size, and rate of egg production were all significantly decreased by naphthalene treatment. Korn et al. (1979) exposed the marine shrimp *Pandalus goniurus* to naphthalene and reported 96-h LC_{50}s ranging from 971 $\mu g \cdot L^{-1}$ at 12°C to 2160 $\mu g \cdot L^{-1}$ at 4°C. The increase in temperature was thought to elevate the sensitivity of the shrimp by changing the naphthalene uptake and metabolic rate.

Thursby et al. (1985) reported a 50% reduction in growth for the red alga *Champia parvula* over an 11- to 14-d exposure at a concentration of 695 $\mu g \cdot L^{-1}$.

The interim water quality guideline for naphthalene for the protection of marine life is 1.4 $\mu g \cdot L^{-1}$. It was derived by multiplying the lowest chronic value of 14.2 $\mu g \cdot L^{-1}$ for the calanoid copepod (Ott et al. 1978) by a safety factor of 0.1 (CCME 1991).

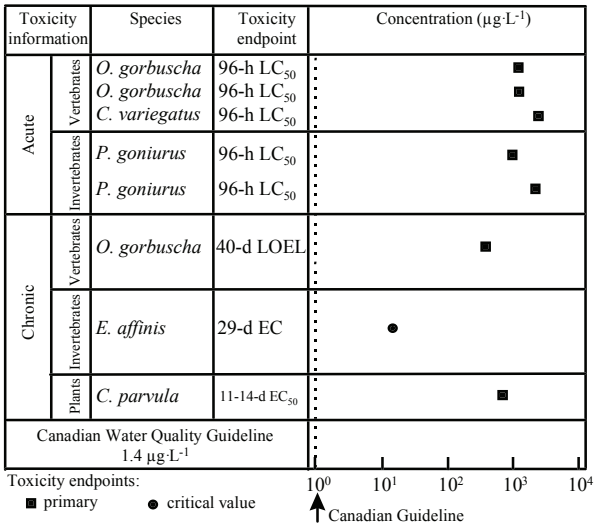

Figure 12. Select marine toxicity data for naphthalene.

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