Salt Spring Island Watershed Protection Authority

St Mary Lake

INTEGRATED WATERSHED MANAGEMENT PLAN - 2015

Photo: Kristine Mayes

Steering Committee

The following members or member agencies comprise the steering committee of the Salt Spring Island Watershed Protection Authority:

George Grams, Chair
Salt Spring Island Local Trustee
Islands Trust Vice Chair

Wayne McIntyre, Vice-Chair
Director, Salt Spring Island Electoral Area
Capital Regional District

Jeff Thompson, Board Member
North Salt Spring Waterworks District

Lorrie Hunt, Chair
Fernwood-Highland Water Commission

Deb Epps (2013 to October 2015)
Provincial Water Quality, Ministry of Environment

Erwin Dyck
Island Health Representative (2013 to June 2015)

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Acknowledgements

SSIWPA would like to thank the generous support of the Real Estate Foundation of British Columbia for funding the Structured Decision-Making process used in the creation of this management plan: an example of local, multi-stakeholder watershed governance.

SSIWPA would also like to thank the Philip and Muriel Berman Foundation for their support of the management planning process and some of the field work at St. Mary Lake in 2014-2015.

Thanks go to the following SSIWPA member organizations for their generous financial support of the 2014-15 St. Mary Lake Monitoring Program (cash and in-kind):

Capital Regional District Environmental Protection: Integrated Watershed Management Program

North Salt Spring Waterworks District

Island Health

Ministry of Environment Water Quality Division

And thanks to the following for participation as SSIWPA member organizations:

Fernwood-Highlands Water Commission
Islands Trust Local Trust Committee Staff
Islands Trust GIS Department

Thanks to the following for independent scientific review:
Lisa Rodgers, University of Victoria (Watershed Runoff Model Results)
Rick Nordin, University of Victoria (Technical Review)

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John Stewart

SSIWPA Public Advisory Committee Members for St. Mary Lake 2014-2015 (Appendix 7)

Compass Resource Management

Citizens who contributed effort and time in communication and interest in the planning process, as well as through formal input in the public consultation period.

[1] Capital Regional District

[2] Ministry of Environment

[3] Vancouver Island Health

[4] North Salt Spring Waterworks District

Executive Summary

This Integrated Watershed Management Plan (IWMP) has been prepared by the Salt Spring Island Watershed Protection Authority (SSIWPA) to provide the Salt Spring Island community with a technically-audited series of appropriate actions to improve watershed health and raw water quality in St Mary Lake (SML).

The Plan is a result of years of involvement and participation of residents, stakeholders, and community organizations, as well as the several agencies that constitute SSIWPA, each of whom has a legislative and regulatory role in protecting the watershed and ensuring the health of the water body. Since 2012, SSIWPA has worked with all stakeholders, reviewed existing research, conducted new research, and has been informed by the limitations of the 2009 St Mary Lake Management Plan. The resulting IWMP reflects the management action decisions at this time, given the information available and taking into account data gaps. A complete list of management actions and implementation measures is available in Table 5.

Throughout the planning process SSIWPA has respected the views of the Technical Advisory Committee (TAC) assembled to provide consensual scientific integrity to both the data gathering process and to how that data is interpreted. For the most part the technical advisory committee attained consensus. However, there are some areas where the committee was split and, for the sake of transparency and clarity, those areas are shown in two columns, giving equal prominence to the differing scientific interpretations that emerged. While some further study may be necessary to reconcile these areas of difference, their nature was not such that the management actions that derive from those interpretations differ. In each case those management actions remain the same. As a consequence of this decision, two differing scientific interpretations of actual internal phosphorus loading and its implications for potential phytoplankton growth co-exist in the report (see Appendix 13: IS-2A and IS-2B).

Since internal loading of phosphorus is the mechanism by which Hypolimnetic Aeration of lakes seeks to reduce nutrient loads, and thereby to reduce available nutrient for algal and cyanobacterial growth, there were also two interpretations in the TAC about the effect of Aeration on nutrient loads and water quality in this lake (Appendix 13: IS-5A and IS-5B). Early on, the Ministry of Environment made it clear to those participating in the planning process that, under the Drinking Water Act. Part 4. Section 23 (1), the addition of chemicals and materials (such as clay) was not permissible in drinking water lakes. As a result, the question of actions to control phosphorus loading internally is a moot point at this time.

The existing aerators are not considered by NSSWD, one of the SSIWPA member agencies and the owner-operator of the aerators, to be candidates for a feasible management action (despite the A and B TAC opinions). According to investigation by NSSWD (Appendix 13 IS-5A), the aerators did not work to prevent algal blooms for 2 reasons:

- Data analysis indicates they probably stirred up sediments;
- The magnitude of internal loading is likely less than previously thought. Blooms are probably runoff/rainfall driven so the aerators are a solution that addresses the wrong problem.

While the content of this IWMP is technical in nature, below are some key highlights that provide a background and rationale for the management actions identified in the plan.

Executive Summary

Take Home Messages:

1. The phosphorus content and amount in St Mary Lake changes over a year and from year-to-year. The 40-year record of lake water phosphorus concentration indicates no long-term trend of increasing phosphorus concentration in the lake;

2. Phosphorus loading from septic systems is minimal and does not warrant consideration of the installation of a central sewage system;

3. As a result of oxygen depletion in bottom waters during summer stratification, a substantial amount of phosphorus (P) is released from sediments to bottom waters. When oxygen is replenished at fall over turn, a majority of the released P is re-combined with iron and re-sedimented;

Interpretation A

The amount of P from sediments that may remain in the lake after overturn (internal loading) may vary from year to year; however, in many years internal loading may be less than the amount of P that enters the lake as runoff from the watershed (external loading).

Interpretation B

Preliminary results suggest that P loading from runoff during late winter may impact early spring algal growth, and more research is needed to determine the pattern.

4. Dredging to remove bottom sediments is not an option. Cost is likely to be extremely high, successful results are uncertain, and the MoE are concerned about impacts;

5. Bird populations add only minimally to phosphorous enrichment;

6. The aerators used in the 1980 ‘s to help oxygenate bottom waters during the summer period of stratification were successful in doing so and also lowered phosphorus (P)-release from sediments by preventing bottom water anoxia. As a result, in 2009 much larger aerators were installed in an attempt to improve water quality. The aerators were turned off mid- summer 2013 and have not been used since;

Interpretation A

Not only less successful in maintaining oxygen in bottom waters, the aerators also appeared to increase P loading (internal recycling) and to prolong algal blooms including toxic blooms in 2011-2013.

Interpretation B

TP at turnover is ≈300-500 Kg in five years of effective aeration (1988, 1989, 1990, 2009, 2010); TP at turnover is ≈580 - 970 Kg in thirteen years of no aeration (or when aerators were overwhelmed); Regardless of aeration TP measured in March was consistently 33-35% lower than the amount in the mixed lake right after autumn turnover.

7. Phosphorous entering the lake through stormwater runoff is subject to ongoing field measurements, but might be greater than previously estimated. Therefore, mitigating phosphorus enrichment from the watershed is proposed in this Plan;

8. Fish species present in the lake, types of plankton, and seasonal temperature and sunlight changes impact algal blooms. Non-native fish species, such as yellow perch introduced in 2005 are not to be released, stocked or knowingly introduced into Salt Spring Island surface waterways (http://www.gofishbc.com/fish-facts/invasive-plants-animals/aquatic-invaders.aspx);

9. Altering the lake ecosystem by adding or removing species in order to reduce numbers of perch is unlikely to be effective and may have unintended negative consequences on the system;

10. While SSIWPA did not study the potential impacts of raising the weir to 41.0 m, based on the current understanding, it is unlikely that the proposed increase in weir height by 30 cm will have any significant effect (either positive or negative) on the phosphorus balance (inputs and outputs) for the lake;

11. Current nature and extent of regular recreational activities in and around the lake are considered to be of relatively low impact on phosphorus in the lake, compared to other sources.

Executive Summary

Planning Process Summary

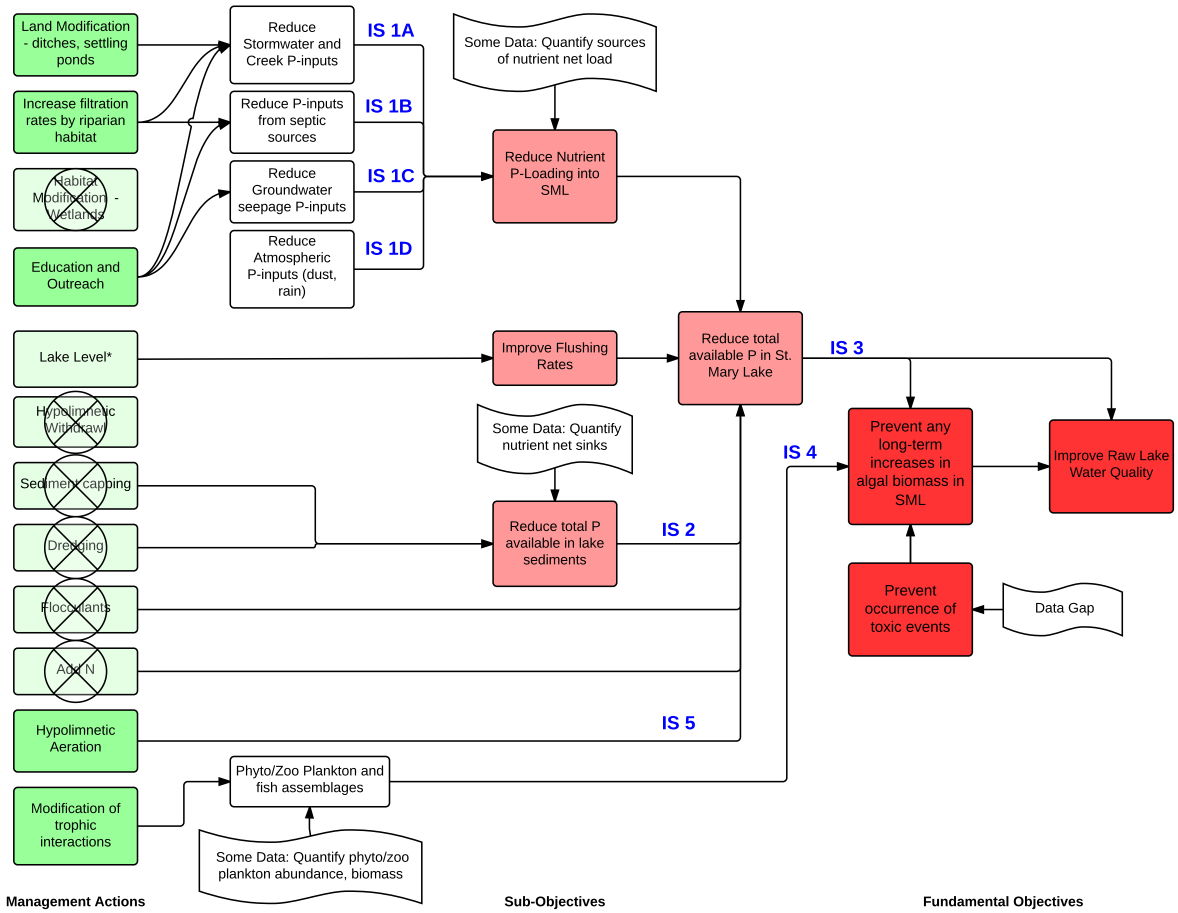
A Structured Decision Making (SDM) planning process, designed and facilitated by Compass Resource Management, used workshops and integration meetings between workshops, to generate objectives and a series of recommended management actions (Tables 4, 5, and 6). Primary issues and concerns about the lake were generated by all three SSIWPA committees, as well as members of the public in an Open House in November 2014. Based on input from the community and direction from the Steering Committee, the Technical Advisory Committee (TAC) identified the main objective to improve lake water quality using the most current scientific evidence and technical assessment of previous research results.

The TAC assessed technical actions that might address the main objective, and recommended that the other two committees review those actions that were considered to be both technically sound and affordable for reducing phosphorus in the lake, and therefore most effective in reducing the frequency and intensity of algal blooms (Figure 1). Throughout this SDM process, all objectives and actions were reviewed by the Steering Committee and the Public Advisory Committee (PAC) through the lenses of social science, environmental values and cultural feasibility (including economic impacts). Other evaluation tools included cost and feasibility of each management action with respect to provincial guidelines for approved substances in drinking water lakes.

Watersheds are dynamic in nature (Figure 8). As such, management plans to safeguard them should be adaptable and the actions should be responsive to changes in ecological systems, changes in scientific and cultural knowledge, as well as current economic realities. The IWMP relies on regular, rigorous evaluation of actions taken, within the context of the specific system. The Ministry of Forests, Lands & Natural Resource Operations defines adaptive management as:

"*A systematic, rigorous approach for deliberately learning from management actions with the intent to improve subsequent management policy or practice.*"

As a collaborative, multi-agency organization, SSIWPA will continue to respect best management practices, including ongoing evaluation and review of the plan to ensure the effectiveness of regulations, legislation, strategies and actions in meeting its primary objective of improving raw lake water quality.



This influence diagram summarizes the main impact pathways related to raw water quality and the occurrence and distribution of algal and cyanobacteria blooms in SML. The Technical Advisory committee to SSIWPA developed this pathway as a means to guide the development of management planning objectives and actions for this IWMP. For descriptions of the impact pathways (numbered IS-1A, etc.) please refer to Appendix 13.

Figure 1. Phosphorus Influence Diagram for St. Mary Lake

Introduction

Background and Rationale for St. Mary Lake Watershed Management

The history of main anthropomorphic events at St. Mary Lake is depicted in Figure 2. In recent years, St. Mary Lake (SML) has experienced periods of extensive and at times toxic algal and cyanobacterial blooms, which have been linked to the phosphorus concentrations in the lake (Figure 2). Algal biomass affects drinking water quality, fisheries productivity, recreational use of the lake, and other uses. Toxins produced by these blooms can lead to 'Do not consume' advisories, lake closures, and biophysical impacts to the lake environment. Together these impacts affect residents, businesses, and institutions that rely on the water for domestic purposes, as well as recreational opportunities such as fishing, swimming and boating.

The previous St. Mary Watershed Management Plan (St. Mary Lake Steering Committee, 2009), outlined objectives to restore and protect surface water quality within the watershed. While some of those objectives were implemented, lack of coordination between and among the government agencies and SML local residents and non-governmental organizations was identified as a serious issue. Watershed residents and local business owners expressed increasing concerns about how the lake is managed (Water Council Report December, 2012)(Appendix 1). In response, the Salt Spring Island Local Trust Committee (LTC) with the help of then-CAO of Islands Trust, Linda Adams, studied various feasible structures for a multi-agency coordinating body for watershed management. In 2013, Islands Trust and the LTC established the Salt Spring Island Watershed Protection Authority (SSIWPA) to coordinate watershed governance and action on Salt Spring Island.

In response to the severe cyanobacterial bloom of 2011-2013 in St. Mary Lake, SSIWPA established the primary need to update the 2009 St. Mary Lake Management Plan. SSIWPA embarked on a research monitoring program, as part of the process to use the most up-to-date evidence upon which to build the 2015 SML Integrated Watershed Management Plan (i.e. this Plan). Compass Resource Management was hired in September, 2014 to design and facilitate the planning process.

	Event	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	Water quality study Nordin *et al.*	•																																
2	First aerators operational					•	•	•	•	•	•	•	•																					
3	Study of aerator effects on fish habitat										•																							
4	Lake hydrology results																•																	
5	Sediment Core Sampling																				•													
6	Weir installed 40.7m																									•	•	•	•	•	•	•	•	•
7	Second set of aerators operational																											•	•	•	•	•		
8	St. Mary Lake Management Plan #1																											•						
9	Cyanotoxin-producing blooms*																							•	•					•	•	•		
10	Study of impacts of lake levels on vegetation																													•				
11	Water Council Community Meeting about SML																														•			
12	SSIWPA formed																															•		
13	Hydrology Report Kerr Wood Leidal																																	•
14	Integrated Planning Process completed																																	•

*Cyanotoxins may have been present prior to 2005, however detection technology was not then available to water suppliers.

Figure 2. History of the Lake

Introduction

Purpose and Scope

The purpose of the 2015 St. Mary Lake Integrated Watershed Management Plan is to:

- improve understanding of accurate ecological structures and functions in the watershed;
- describe the state of the science on issues impacting source water quality;
- describe the range of solutions to those issues;
- describe an implementation and monitoring strategy in an adaptive management framework, and cooperative governance model;
- describe the multi-stakeholder planning process undertaken to determine the objectives and most economically-, legislatively- and logistically-suitable actions;
- inspire broad public support and engagement.

The IWMP is an iterative management tool, and an example of Collaborative Watershed Governance, the general premise of which has been evidenced as a means for culturally-relevant and scientifically-rigorous resource management results (Appendix 3 Collaborative Watershed Governance).

In the collaborative process, the SSIWPA member agencies and representatives reviewed and assessed previously-published scientific studies of the watershed, with a focus on water quality, hydrology and limnology. SSIWPA formed two advisory bodies: Technical (TAC) and Public (PAC). TAC conducted a year of research (Research and Monitoring by SSIWPA 2014-2015), half way through which a Structured Decision-Making process was launched, resulting in the deliverable of this Plan. The Plan is limited to those actions that are within the scope of the six agencies that comprise SSIWPA. (Please see more detail in the History of SSIWPA, Appendix 4.)

The Plan does not specifically address issues of demand management for the community water supply, although awareness of the impacts of climate change and drought conditions have been considered at each step in creation of this Plan (please see Sutherland and Yao, 2015 for up-to-date hydrological information about this watershed). At the time of writing, one of SSIWPA member agencies, NSSWD, was in process of application to MFLNRO to raise the weir height at St. Mary Lake outlet to Duck Creek from 40.7 m to 41.0 m above sea level.

Policy Context: Legislative Protection of St. Mary Watershed

St. Mary Lake is the largest water body on Salt Spring Island, and North Salt Spring Waterworks District supplies many residences on the north end of the island and parts of the village of Ganges with water from St. Mary Lake. However St. Mary represents only the third largest watershed on Salt Spring Island. The renewable supply relies on rainfall that is captured by the watershed, and St Mary has a relatively small watershed. Supply is also related to both lakewater residence time (Table 1), and groundwater recharge rates. In that respect, Cusheon and Ford Lakes have larger amounts of water flowing into them, i.e. greater discharge volumes, even though they are smaller lakes.

Provincial and local government regulations define permitted land uses in island watersheds. Provincial regulations include the Agricultural Land Commission Act and the Farm Practices Protection (Right to Farm) Act. Both Acts are superior to local government Acts on land use. Relevant local government Bylaws include the Salt Spring Island Official Community Plan (OCP)(Bylaw 434), the Salt Spring Island Land Use Bylaw 355, and the Riparian Area Regulations (Bylaw 480) designed to protect fish habitat. (Appendix 5. Governing Laws, Bylaws and Regulations Resource Directory).

Federal legislation that is implicated in this Plan includes Transport Canada "Vessel Operation Restriction Regulations". On Page 2, Section 2 (3) of these regulations, "power-driven vessels cannot be operated on waters listed in Schedule 3" (which includes St Mary Lake – page 81 lake number 91). The following are known to be exempt from this restriction regulation: an employee or agent of a regional district acting within the scope of their duties (section 3(2)(b) on pages 3-4), first responders from the following government supported agencies, acting within the scope of their duties: Royal Canadian Marine Search and Rescue, BC Ambulance or Fire Protection District and Royal Canadian Mounted Police (RCMP). Salt Spring Island Rowing Club boat personnel are also exempt: SSI Rowing Club is a member of the national organization, Rowing Canada Aviron.

Clubs in this national organization are permitted by Transport Canada, and required by law, to use a gasoline-powered safety boat at authorized club practices on Canadian lakes. Float plane pilots are not exempt from this restriction; float planes are considered a "vessel" under the Transport Canada Regulations as soon as both pontoons have landed fully on a water body.

Introduction

Any development that takes place on Salt Spring Island must do so in a manner that respects the sustainable limits of its natural resources, in accordance with the 'preserve and protect' mandate of the Islands Trust. The Plan offers empirical guidance for improvements to local government policy, and as an adaptive management strategy, it also offers a model for an upcoming comprehensive integrated sustainable community-wide process on Salt Spring Island.

Painting by Don Hodgins

Stakeholders with Interests in the SML Watershed

Government Agencies and Water Service Areas
British Columbia Ministry of Environment
British Columbia Ministry of Forests Lands and Natural Resource Operations
British Columbia Ministry of Community Culture and Sport
British Columbia Ministry of Health
Capital Regional District
Fernwood-Highland Water District (serviced by CRD)
Islands Trust
Island Health
North Salt Spring Waterworks District

Conservation Interests and Non-Governmental Organizations

Salt Spring Island Conservancy promotes the protection of the sources of potable water on Salt Spring Island for the benefit of the general public through the preservation and restoration of watershed lands, by supporting scientific research into water resources and by providing public information on how to protect Salt Spring's potable water resources.

Salt Spring Island Stream and Salmon Enhancement Society has an interest in the protection of fish-bearing streams, riparian areas, wetlands and the removal of invasive species in riparian areas.

SSISSES has already conducted a salmonid enhancement project in Duck Creek, as well as wetland restoration surveys of other watercourses in SML watershed (Reimer, 2003).

Salt Spring Island Water Preservation Society is a non-profit organization founded in 1982 to protect Salt Spring Islands' drinking water sources. SSIWPS owns and manages a 110 hectare watershed preserve on the western slopes above St. Mary Lake, and thus is likely one of the largest land owners within the SML watershed.

Salt Spring Island Water Council is a forum for sharing information on the quantity and quality of Salt Spring's surface and groundwater resources, including research and education about potable water quality and supply issues and related programs.

The SSI Fire/Rescue Protection District has an interest in fire management and response, and public safety on Salt Spring Island. SSI Fire/rescue relies on St. Mary Lake water for filling emergency response vehicles with water necessary to fight fires, as well as for emergency response training of personnel.

Agricultural Interests

Salt Spring Island Farmer's Institute promotes the theory and practice of agriculture including education and circulation of information.

Salt Spring Island Farmlands Trust to promote agriculture by acquiring and leasing land for farming, and to educate farmers and the public about the benefits and practices of locally-produced agriculture.

Island Natural Growers, the local chapter of Canadian Organic Growers.

Salt Spring Island Agricultural Alliance is a collaborative group of agricultural member organizations: Island Natural Growers, Farmer's Institute, Community Market Society, Chamber of Commerce, and Transition Salt Spring.

Aboriginal or First Nations Interests

St Mary Lake Watershed is within the traditional territory of members of the Hul'qumi'num Treaty Group including: Cowichan Tribes and the Chemainus, Halalt, Lake Cowichan, Lyackson and Penelakut First Nations. The Plan encourages the expansion of relationships between SSIWPA member agencies, and these First Nations to ensure that management activities in Salt Spring Island watersheds considers Aboriginal Rights and Title, values and cultural heritage. First Nations continue to practise their aboriginal rights with SML watershed area, which include fishing, gathering and other cultural and spiritual activities. All known and unknown archaeological resources on private and public lands in the SML watershed are protected under the Heritage Conservation Act.

Recreation Interests

The Salt Spring Island Trail and Nature Club has an interest in providing trails for walkers and hikers on Salt Spring Island, including the maintenance of existing trails in the Channel Ridge Trails Recreation Area - CRD Parks. Channel Ridge Trails are located partially within the St. Mary watershed. Watershed preservation trails are portions of longer trails, as indicated on the map in Appendix 2, that are located on the land owned by Water Preservation Society, under covenant. Please respect the restrictions on recreational uses that are applied to the Watershed Preservation trail portions, as indicated.

The Salt Spring Island Rowing Club has an interest in safe and continued boating activities on the lake, within the watershed.

The Salt Spring Island Trail Riders and the Back Country Horsemen of BC – Salt Spring Chapter have an interest in horseback trail riding in Channel Ridge trail sections where horses are permitted. Portions of Channel Ridge trails are located within the St. Mary watershed.

Definitions and Terminology

Adaptive management is a system of management of a resource base that is grounded in robust decision-making in the face of uncertainty, based on a ”whole watershed” picture that includes ecological parameters, local values, legislative possibilities and public education. It is iterative and based on Planning-->Action/Implementation>Monitoring and Assessment—>Adjustment —>Planning, repeat…

Revision of this Plan will determine lessons learned, changing circumstances and/or attainment of objectives.

BMP – Best Management Practice

CAO – Chief Administrative Officer

CRM – Compass Resource Management

CWB – Cowichan Watershed Board

DP – Development Permit

DP – Dissolved Phosphorus

dam – decametres

dam3 - Cubic decametres is ten metres cubed, a three dimensional unit of measurement of water volume

FAQ – Frequently Asked Question

Fe – iron

IS – Impact Statement

IMR – Impact Mini-Reports

Influence diagram – conceptual tool to illustrate impact pathways between environmental components; does not represent exact information

IWMP – Integrated Watershed Management Plan

MFLNRO – British Columbia Ministry of Forests Lands and Natural Resource Operations

MOE – Ministry of Environment

P- phosphorus

P-external – the phosphorus entering the lake from creeks and ditches as stormwater, from groundwater or atmospheric deposition

P-Internal – the amount of total phosphorus released from sediments into the hypolimnion during the period of anoxia

P-load – the amount (mass) of phosphorus available for uptake by organisms

PAC – Public Advisory Committee (St. Mary Lake, SSIWPA)

QEP – Qualified Environmental Professional

SC – Steering Committee

SDM – structured decision making

SML – St Mary Lake

SRP – Soluble Reactive Phosphate

SSIWPA – Salt Spring Island Watershed Protection Authority

TAC – Technical Advisory Committee (SSIWPA)

TP – Total Phosphorus

WS – workshop

Watershed Characteristics

Description

St. Mary Lake is situated in the Northwest of Salt Spring Island, British Columbia. It is one of the largest drinking water sources on Salt Spring Island, and serves more than 1500 properties (approx. 1080 of which are served by NSSWD), making it one of the largest community water districts in the Province. It is also used for recreation, including fishing. Its surface rests at approximately 40.7 metres above mean sea level. The watershed boundary, and watercourses flowing into the watershed are shown in Figure 1. Some hydrological metrics are found in Table 1.

Table 1. Watershed Metrics

Item	*Description*
Surface area of lake	182 hectares
Watershed Drainage Basin Area Including Lake Excluding Lake	 647 hectares 465 hectares
Maximum Depth	16.7 metres
Mean Depth	8.8 metres
Littoral Zone Area (>6m depth)	30% of lake surface area
Volume	15,954 cubic metres
Yearly Inflow	3,270,000 cubic metres
Time to Replace 95% of water molecules	15 years
Time to Fill if Empty	4.9 years

* (source: St. Mary Lake Management Plan, 2009 and updates by Sutherland and Yao, 2015)

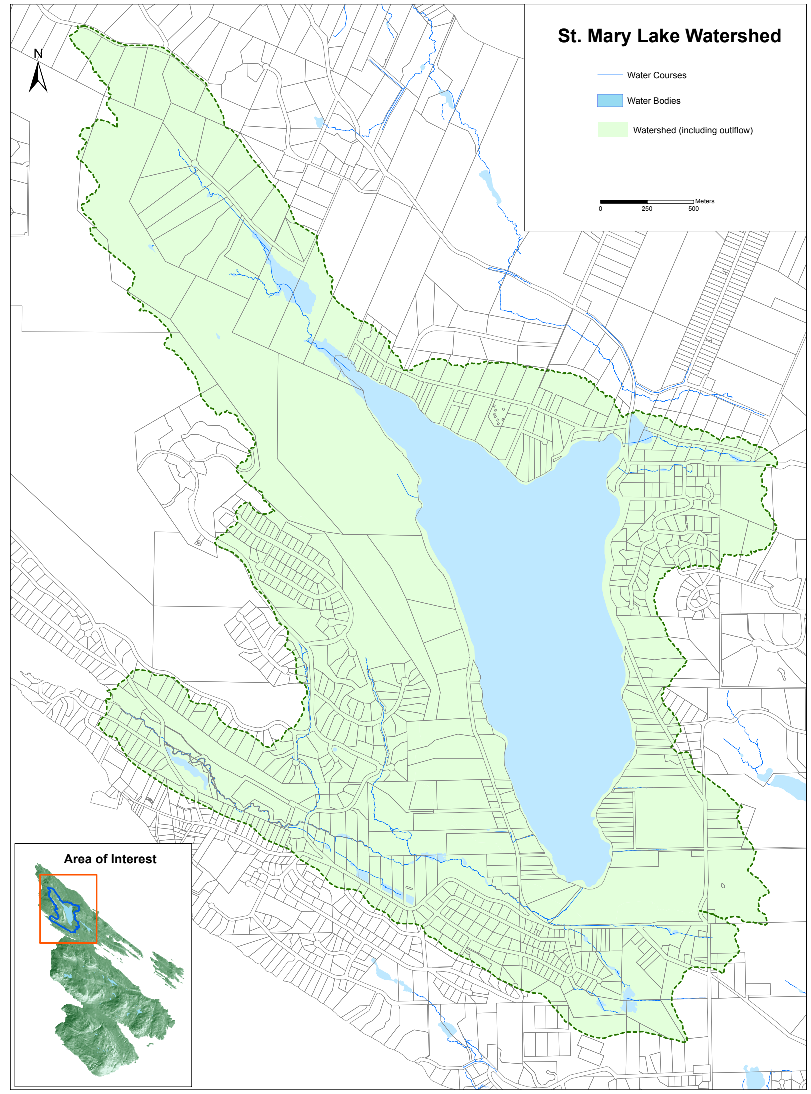


Figure 3. St. Mary Lake Watershed

Watershed Characteristics

As shown in the bathymetric map (Figure 4), St. Mary Lake has two deep areas side by side at the 16-metre contours near the north-easterly corner of the lake. A little further to the northeast is a shallow area which contains an island. The southerly end of the lake gradually shallows. The outlet, Duck Creek, is shown at the southerly tip of the lake. The small inlet creeks on the northerly end are not shown in Figure 4. St. Mary Lake is one of the nine largest lakes on Salt Spring Island. It ranks first in volume (Figure 5). However, in terms of the size of its drainage basin and its yearly inflow of water, St. Mary Lake is only the third largest, after Cusheon and Ford lakes. Like all the lakes on Salt Spring, St. Mary Lake receives most of its inflow during the wet season (November to May) and little or none during the dry season (June through October). See Water Supply and Demand Management.

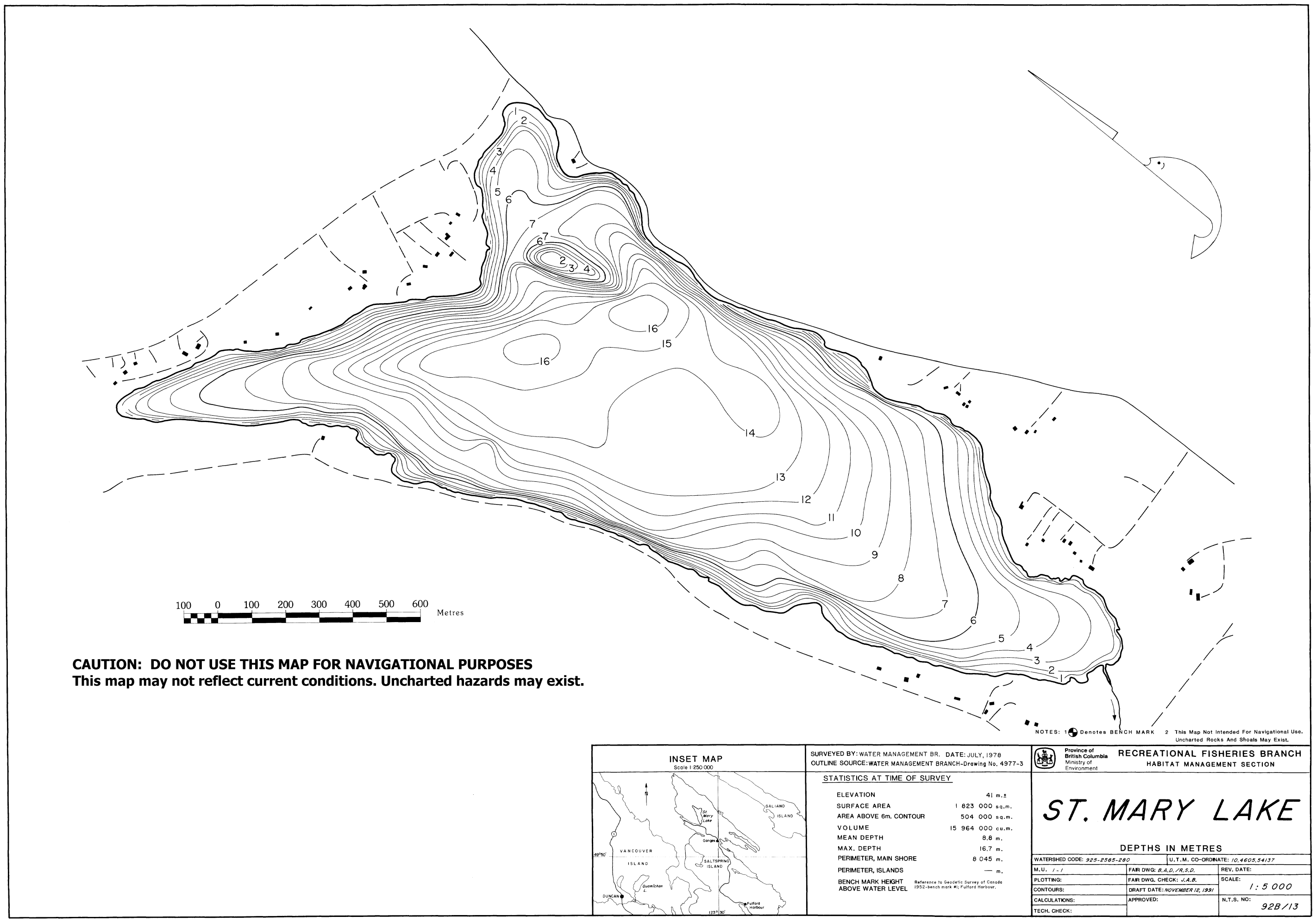


Figure 4. Bathymetric Map of St. Mary Lake

Watershed Characteristics

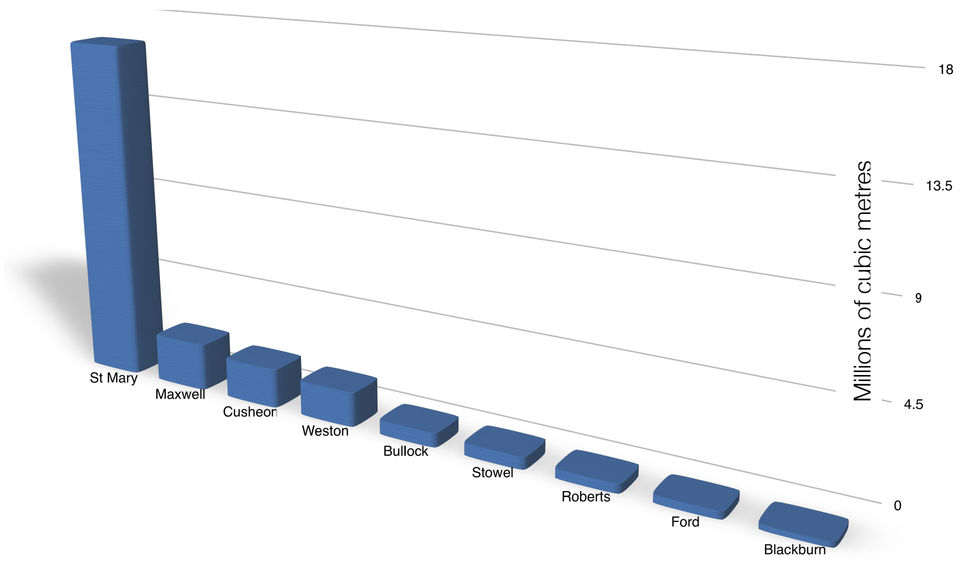


Figure 5. Standing water volumes in nine Saltspring lakes

The main human use of St. Mary Lake water is for domestic consumption. The lake is also used for swimming, fishing and recreational boating. Gasoline-motorized vessels are not permitted on St. Mary Lake, except where approved by Transport Canada. See Policy Context section for regulations about Transport Canada-approved gasoline-motorized vessel use on this lake. The lake is an aesthetic asset for shoreline property owners and residents, islanders-at-large, and for tourism.

Land Use and Zoning

There are 10 different land use / zoning classifications within the St. Mary watershed:

1. Agriculture 1 (A1)
2. Agriculture 2 (A2)
3. Commercial Accommodation 3 (CA3)
4. Comprehensive Development (CD1)
5. Parks and Reserves 6 (PR6)
6. Residential 6 (zone variant a) (R6[a])
7. Rural (R)
8. Rural Watershed (RW1)
9. Shoreline 6 (S6)
10. Shoreline 8 (S8).

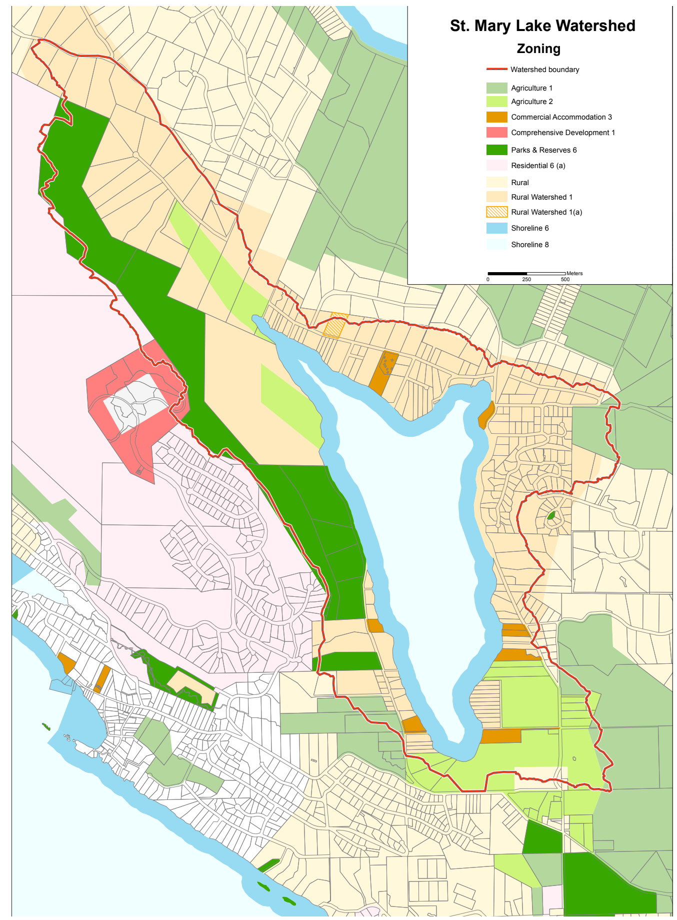


Figure 6. St. Mary Lake Watershed Zoning Map

Watershed Characteristics

Most of the agricultural land in the watershed is zoned A2. A1 and A2 land are both permitted to have farm buildings and structures and one additional dwelling unit but camping and seasonal cottages are allowed only in A1 and require written permission from the B.C. Agricultural Land Commission. Permitted activities include the processing and sale of farm products and operation of a home-based business. RW1 allows single family dwellings, agriculture, and home-based businesses, with a minimum lot area of 4 hectares. CA3 allows cabins and campgrounds. R6(a) allows for one dwelling unit per lot; unlike R6 it does not allow 2-family dwellings. PR6 permits passive outdoor recreation. S8 is the most restrictive shoreline zoning category, with the only permitted use being navigational. S6 is restricted to navigational uses, and private floats, docks, and buoys. The most important areas for the protection of water quality are those closest to the lake. The areas immediately adjacent to St. Mary Lake are zoned A2, RW1, PR6 and CA3, with the shoreline zoned S6. Most of the properties in the watershed are zoned RW1. The predominant land use/land cover types in the watershed include “Young Forest”, “Rural Residential” and to a minor extent, “Agricultural” (See Figure 2-2 in Sutherland and Yao, 2015).

Riparian Zones: Protection and Regulations (Bylaw 480)

On Salt Spring, protection of water quality is achieved via environmental management and flood protection setbacks established in the Land Use Bylaw and through development guidelines established in Development Permit Area 4 (DPA4), and Development Permit Area 7 (DPA7), both found in the Official Community Plan, Volume 2.

Regulated setbacks for specific uses from the natural boundary of water bodies range from 7.5 m for animal feeding troughs to 30 m for confined livestock areas and 60 m for sewage disposal fields. DPA4 establishes development guidelines for areas within 10 m of St. Mary Lake (61 m for installation of a septic field). No removal of vegetation, alteration of drainage courses, or subdivision may occur without a permit demonstrating guidelines being met. Guidelines are consistent with the provincial land development guidelines for the protection of aquatic habitat.

DPA7 establishes development guidelines for areas within: 30 m of St. Mary Lake, 30 m of neighbouring wetlands, 15 m of streams flowing into St. Mary Lake, and 5 m of drainage ditches leading to the lake. No commercial, residential, or industrial development may occur without a permit. Applicants are required to provide a report by a qualified environmental professional (QEP) prior to a permit being issued. The QEP may recommend restoration or enhancement activities, dedication of watercourses, or protection works to be constructed which preserve, protect, restore or enhance fish habitat or riparian areas. The QEP may require monitoring and a follow up report on compliance with conditions imposed in the permit. Permit exemptions include emergency procedures to take down dangerous trees, gardening and land maintenance within an existing landscaped area, restoration activities approved by a QEP under seal, and farm operations as defined in the Farm Practices Act.

Topography, Soils, Property Uses and Drainage

To the West and East are moderate to extreme slopes headed away from the lake, while the northern and southern shores slope up only gently to moderately away from the lake. Marine deposits over unweathered till are evident on the north and south shores of the lake. To the west and northwest of the lake there is second growth forest in the ‘Parks and Reserves 6’ (PR6) zoning designation (Figure 6). The Salt Spring Water Preservation Society owns 110 hectares in this portion of the watershed, covenants for which are held with SSI Conservancy and the Land Conservancy of BC; public access in this portion is restricted to trails (Appendix 2). An approximate total of 70% of the watershed has been modified by human use (according to data from Islands Trust). ‘Rural Watershed 1’ and ‘Agriculture 2’ are the other dominant land use types on the NW height of land, and in the lowland drained by Epron Creek into the lake. The ‘Shoreline’ zoning designation lines the waterfront, with the exception of two zones for ‘Commercial Accommodation 3’ (Figure 6).

Agriculture is small scale in this watershed (approximately 9% of the modified category is attributable to agricultural land uses), and includes hay and livestock production (sheep, poultry, cattle/horses to lesser extent), horticulture, market gardens and orchards, as well as some silviculture and an equestrian centre. There was a Wildlife Natural Care Centre housing seals, birds and otters previously located in the watershed on Lang’s Road that has just recently moved to a new location outside of the watershed. At time of writing, the Islands Trust was considering further legislative controls (Bylaw 484).

There are 82 shoreline lots, including approximately 6 resorts. There is one main public access on the East side, to the north of centre, that is managed by CRD Parks and Recreation Department, and some minor public access points along Dodds Rd. with no beach area, just a path from the road to the lake. During mid-May to end of September the main public beach is frequented daily by a large number of islanders and visitors. Pets are restricted from the public beach access during June 1 – September 30, and there is a pet waste receptacle and signage. There is also a portable toilet for human waste.

The soils of the steepest heights of land in the watershed are mainly Saturna, Bellhouse, Haslam and Galiano. They are all loamy or sandy soils, less than 100 cm deep. The lowland near the lake is mainly Mexicana soil, which is gravelly sandy loam less than 100 cm deep over compact till.

Watershed Characteristics

Epron Creek to the North/NW drains into St. Mary Lake during the wetter months, typically November through April. Provincial mapping shows all watercourses in the NE along Ensilwood Rd. to be draining to a wetland, which drains to St. Mary Lake. Creeks draining the height of land along Ensilwood, and LePage roads flow into a wetland on the E side of North End Road, which drains into SML seasonally. Sutherland and Yao (2015) confirmed that the upland area along Whims Road drains to McFadden creek which flows NW and into the ocean at North Beach Road; it does not enter the wetland on the E side of North End Road, which drains into SML. At times, beavers have blocked the culvert under North End Rd., causing drainage from the NE wetland to flow over the road toward the lake.

St. Mary Lake drains to the Southwest via Duck Creek. Water flow is maintained to Duck Creek year-round for its fish habitat by a weir that was constructed in 2006. The flow to Duck Creek is maintained by NSSWD as required by authorization from Fisheries and Oceans Canada.

Geology

St. Mary Lake watershed soils are underlain with sedimentary rock (Van Vliet et al., 1987), composed mainly of sandstone of the Upper Cretaceous Age in the Nanaimo group, as well as siltstone, shale and conglomerate sedimentary rock types (Greenwood and Mihalynuk, 2009 “BC Geological Survey Map”). There is a seismic fault extending to the Southeast from the lake. The soils at the shoreline of the lake can further be roughly classified into Sandy Gravelly loam (in the SW corner), and either Loamy Sand or Shaly Sandy Loam (East side and NE), and Shaly Loam to Shaly Silty Loam (W side) (Figure 2-3 in Sutherland and Yao, 2015).

Current and Future Development

Most of the lots in the St Mary Lake watershed are already developed. There are over 200 residential structures on properties fully within the St. Mary Lake watershed, and about 32 more on properties partially within the watershed. Table 3 delineates the subdivision potential within the watershed; it is fairly limited, with the possibility of another 17 lots being created with an additional 17 dwelling units and 5 cottages. It should be noted that subdivision external to the watershed also has potential to impact demand on water for St. Mary Lake, since this is the source of drinking water for more residential and business connections outside of the watershed, than within it.

Potential for future development in Channel Ridge area (which lies on the western boundary of the watershed and beyond) is unknown at the time of writing, and the status of drinking water allocation to the potential Channel Ridge development from St. Mary Lake is also unknown at the time of writing.

Table 2. Subdivision Potential in the St. Mary Lake Watershed

Zone Code	*Existing Lots*	*Subdivision Potential*
A1	6	2
A2	14	1
CA3	18	0
PR6	8	0
R	10	5*
R6(a)	4	0
RW1	243	9
Totals	**303**	**17**

(Source: Islands Trust)
*Refer footnote[1]

[1] Subdivision includes 5 dwellings and 5 cottages in these lots zoned R which are currently undeveloped.

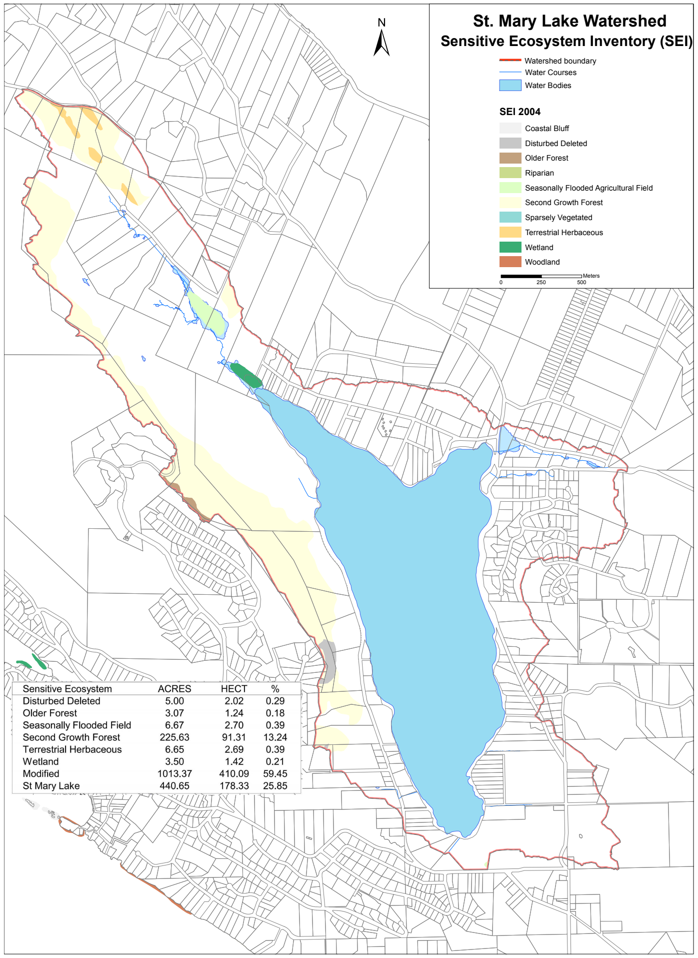
Plants and Animal System Components

The St. Mary Lake watershed is in the coastal Douglas fir biogeoclimatic zone. The characteristic tree is Douglas fir (*Pseudotsuga menziesii*). The drier rocky areas support arbutus (*Arbutus menziesii*) and Garry oak (*Quercus garryanna*). In the low wet areas there are western red cedar (*Thuja plicata*), Grand fir (*Abies grandis*) and western hemlock (*Tsuga heterophylla*) (Van Vliet et al., 1987). Deciduous trees include red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), various willow species (*Salix spp*.) and black cottonwood (*Populus balsamifera*). The shrubs along the lakeshore include many native species such as salmonberry (*Rubus spectabilis*), mock orange (*Philadelphus lewisii)*, indian plum (*Oemleria cerasiformis)*, black hawthorn (*Crataegusdouglasii*), wild roses (*Rosa spp.*) and red-Osier Dogwood (*Cornus stolonifera*). In the protected watershed area there are patches of the native fairy slipper orchid (*Calypso bulbosa*) (Reimer, 2003).

Shorelines are habitat for a complex vegetative structure that provides nesting, food and cover for a range of terrestrial and aquatic animals, including birds, insects, reptiles, amphibians and fish. An inventory of sensitive ecosystems is a starting point for conservation management actions, which have potential to impact nutrient loading, and thus, water quality in SML. In Figure 7, note the wetlands, disturbed areas, and riparian habitats where species diversity inventories would be a useful next step.

Painting by Don Hodgins

Watershed Characteristics



Sensitive Ecosystem	ACRES	HECT	%
Disturbed Deleted	5.00	2.02	0.29
Older Forest	3.07	1.24	0.18
Seasonally Flooded Field	6.67	2.70	0.39
Second Growth Forest	225.63	91.31	13.24
Terrestrial Herbaceous	6.65	2.69	0.39
Wetland	3.50	1.42	0.21
Modified	1013.37	410.09	59.45
St Mary Lake	440.65	178.33	25.85

Figure 7. St Mary Lake Sensitive Ecosystem Inventory

Predominant plant species along shoreline areas in the riparian zone, and into the littoral aquatic zones are resilient and tend to sustain prolonged muddy, saturated soils, as well as drier soils. They include: sedges (*Scirpus spp.*), rushes (*Juncus spp*.), grasses (*Poa spp*.), willow (*Salix spp*.) and hardhack (*Spirea douglasii*) (Atwood, 2011). Some of the less human-influenced regions of the littoral shoreline feature cattails (*Typha latifolia*), especially at the outlet of Epron Creek, which is a dense riparian zone. Yellow flag iris (*Iris pseudacorus*) is an invasive species, and can be found in some shoreline habitats of the northeast corner of the lake (Cowan, personal communication to SSIWPA June 19, 2015).

Many insects, which are food for fish and birds, begin their life cycle in an aquatic habitat. Approximately 25 bird species frequent the lake, wetland and stream habitats, as well as the riparian areas: it is a haven for at least 15 different types of migratory waterbirds, such as Canada geese, double-breasted cormorants, a variety of ducks, especially ring-necked, common mergansers, common goldeneye and buffleheads, among others (Sprague, 2015). The wetland edges of the lake are home to a small number of breeding ducks for part of the year, as well as a variety of semi-aquatic birds, other wildlife, and insects. Birds such as great blue herons, red-winged blackbirds, belted kingfishers and bald eagles are also present at various times of the year.

St. Mary Lake supports fish populations of cutthroat trout (stocked), rainbow trout (native and stocked), three-spined stickleback (native), smallmouth bass (illegally introduced), yellow perch (illegally introduced), and occasionally, coho salmon fry. Stocked trout originate from the provincial government's hatchery in Duncan on Vancouver Island.

Understanding spawning and feeding habits of fish species is essential in order to protect their habitat. Smallmouth bass are predatory, eating invertebrates and fish when they are adults. Bass move into deeper, cooler water in the summer but they do not require cold water to the same degree as trout and salmon. Yellow perch larvae and young-of-the-year fish tend to consume zooplankton, and are known to cause shifts in zooplankton community structure and size distribution (Fisheries and Oceans Canada, 2009), which in turn can impact biomass and abundance of phytoplankton species known to cause algal blooms. Yellow perch egg masses contain an average of 23,000 eggs, which are rarely consumed by other fishes (Newsome and Tompkins 1985 in Fisheries and Oceans Canada, 2009).

Large zooplankton consume algae (including cyanobacteria and other types of phytoplankton that are known to produce "algal blooms"). During spring and summer, large zooplankton are observed in SML, and may assist to keep algal blooms to a minimum during summers. During winter, when nutrient loading and algal biomass reach relatively high levels in a typical year, zooplankton tend to enter resting stages and many may already be consumed by perch, so they are not available to consume algae.

More information about fish diet and habitats, plankton species and abundance, and fish-plankton interactions can be found in the report to SSIWPA (Squires, 2015).

Water Quality - Status

SML was classified as a relatively productive lake and labelled mesotrophic (150-year fossil record inferred 13-16 ug/L total phosphorus estimates, Cumming et al., 2006).

Interpretation A	Interpretation B
Based on the algal biomass levels observed in 2014-15 during the summer, the trophic status of SML surface waters is in the oligotrophic range. In contrast, during the winter the trophic status is in the mesotrophic range. During the winter, when the lake is fully mixing, runoff is activated in Dec.-Jan. After plentiful rainfall, and in turn nutrient levels, phytoplankton/algal biomass sharply increases (Squires, 2015)(Figure 8). Also, in winter, many zooplankton may enter dormancy, which reduces zooplankton grazing on phytoplankton (algae and cyanobacteria), and contributes to increases in winter algal blooms (Squires, 2015).	Based on a TP average of ~ 30 ppb, the lake is classified as eutrophic (anything above 20 ppb has historically been classified as eutrophic in Canada (IJC 1980, Ontario MOE 1984).

Stratification results in two layers of lake water: the 'epilimnion' (top layer) and the 'hypolimnion' (bottom layer), which are separated by a zone of water called the 'thermocline'. During stratification warmer, less dense water floats on top of cooler, denser bottom water. Over the annual cycle, the phytoplankton assemblage undergoes a series of blooms, and die offs when algal cells settle out of the water column, thereby transferring phosphorus from surface waters to bottom waters. During the period of stratification, in the hypolimnion, algal decomposition uses up all of the oxygen in hypolimnion, affecting both water chemistry and aquatic life in bottom waters. During this low-oxygen period of time, some of the molecular phosphorus (P), that is inactive and bound to sediment particles, gets released to surrounding hypolimnetic waters. At the time of lake mixing (October-November), the dissolved P in the hypolimnetic waters joins dissolved P in the upper layer of the lake. During and following lake mixing, dissolved P decreases because of re-binding to iron and subsequent sedimentation, outflow from the lake via Duck Creek, and drinking water withdrawals. Increases in dissolved phosphorus tend to lead to increases in algal growth and algal biomass. In the past, it was thought that the P released from sediments was the dominant source of annual P loading to SML. However, the 2014-15 In-lake study revealed that the iron to phosphorus ratio in anoxic waters is more than sufficient to re-sequester the P that was released from sediments during and after overturn, when bottom waters are replenished with oxygen.

During the relatively clear water phase of SML in summers, shallow sediments foster plentiful growth of rooted aquatic plants and benthic algae on sediments and plant surfaces in shallow-water zones. Benthic algae and higher plant production in shallow waters provide habitat for the organisms that fish consume. Examination of fish stomach contents confirms this (Squires, 2015).

The balance between P brought into the lake by stormwater and precipitation, and the amount generated internally as dissolved P that was released from sediments will vary naturally from year to year. In large measure, this is driven by inter-annual differences in rainfall, both amount and time of occurrence, and the dynamics of overturn. Consequently, water quality of the lake and the response of algal growth also varies from year to year. The precise influence of stormwater runoff on algal growth is not yet clear. Since the time to replace the lake volume is approximately 3 to 5 years (Table 1), this is also a source of variation in the amount of total phosphorus measured in the lake, taken in the same season, from one year to the next. The slow replacement of lake-water means the lake may be sensitive to new nutrients coming in, which, in turn, means that it is important to maintain natural or undisturbed areas in the watershed. These act as filters to help offset the effects of human-introduced nutrients and soil and water runoff from the land. Even under pristine conditions, St. Mary Lake's nutrient sensitivity is greater than that of other island lakes. Of interest, relatively high total P concentrations occurred in SML in the spring of 1980, 2005, 2011, and 2012.

Possible explanations for higher than usual spring phosphorus levels in SML include the following (explanations are not mutually exclusive):

- Higher than usual watershed runoff due to intense storms following high rainfall in preceding weeks; this hypothesis finds anecdotal support in the coincidence in SML of high phosphorus in spring 1980 and spring 2005 and significant landslides in North Vancouver in winter 1979/80 and 2004/05 triggered by high antecedent rainfall followed by high rainfall intensity (Porter et al., 2007);
- Higher than usual internal loading related to turn-over dynamics and/or weather; and,
- Unintended consequences of artificial aeration of the lake between 2009 and summer 2013; for explanation of how aeration could explain high phosphorus in 2011 and 2012 see the In-Lake Study Synopsis under Research and Monitoring by SSIWPA 2014-2015 in this IWMP.

Proposed Two-Phase Model of the St. Mary Lake Ecosystem showing a Summer Clear Water Phase alternating with a Winter Turbid Water Phase, and the contrasting physical, chemical, and biological conditions that characterize each Phase. O2 = oxygen, N=nitrogen, P=phosphorus, Atm=atmosphere. Sediment-P IN is followed by Sediment-P OUT due to chemical changes associated with shift from low O2 to high O2 conditions in bottom waters. Atmosphere N-IN and N-OUT correspond with different lake processes, with N-IN representing N-fixation by cyanobacteria.

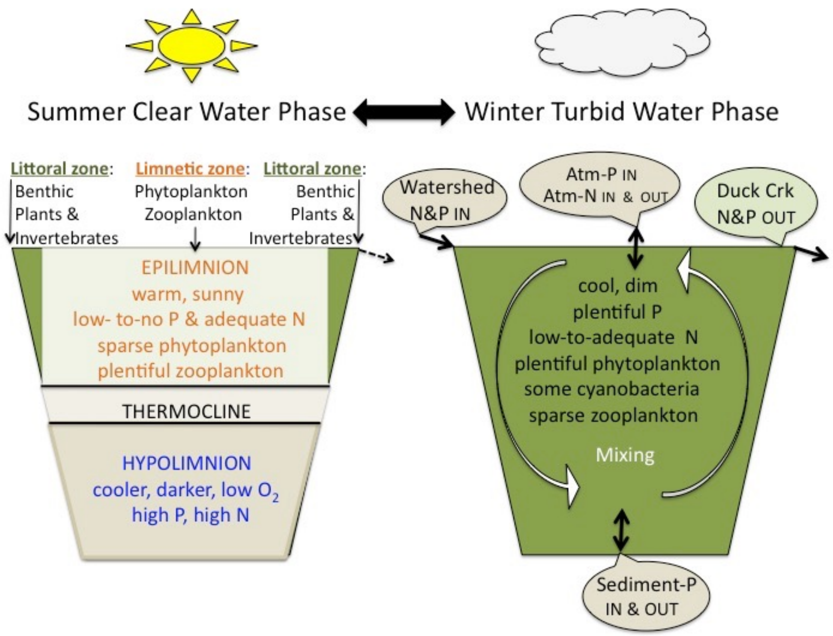


Figure 8. St Mary Lake Ecosystem Phase Model

The 2014-15 lake study shows St. Mary Lake has a Clear Water Phase during the summer when nutrient inputs fall to near-zero, and a Turbid Water Phase during the winter following fall turn-over (lake mixing) and onset of winter rains and streamflow and storm water runoff. During the summer Clear Water Phase when lake water level decreases, the shallow water littoral zone, which is comprised of rooted aquatic plants, attached algae, and metaphyton (attached algae that overgrows attached surfaces), is highly productive while phytoplankton growth in the offshore limnetic zone is relatively low. During the winter Turbid Water Phase when lake water level increases, plant growth in the littoral zone decreases and phytoplankton growth throughout the lake increases.

Water Quality Monitoring

NSSWD is not required to conduct water quality monitoring in SML but has done so in the past due to awareness of the importance of source protection and monitoring to drinking water quality. NSSWD currently monitors a variety of water quality parameters in SML at different frequencies; however, monitoring programs are subject to change due to operational needs. Parameters that are typically monitored include dissolved oxygen, temperature, nutrients (various forms of nitrogen and phosphorus), clarity (secchi depth and turbidity), algal abundance and identification, cyanotoxins, bacteria, hardness, metals, alkalinity, and pH.

After publication of the final report on the planning process (Angus and Harstone, 2015), SSIWPA TAC recommended that the following items be added to the long term monitoring criteria for SML:

- Nitrogen (TN, Nitrate, and Ammonia)
- Phytoplankton and zooplankton abundance and biomass
- Chlorophyll

Since 2009, the Capital Regional District (CRD) Water Quality Program regularly monitors St Mary Lake water quality at the intake (8 m depth) for the Highland-Fernwood Drinking Water System using a combination of CRD Water Quality Laboratory and external contract labs. The algal populations at the intake are also regularly monitored by the CRD in-house aquatic ecologist. In addition to the monitoring program occasional one-off projects have been carried out, e.g., depth profiling for iron, manganese, pH, dissolved oxygen, and nutrients.

Where available, MOE data for SML were included in the historical data set (typically up to and including 2007). Water quality monitoring in SML for the SSIWPA 2014-15 field study was conducted primarily by NSSWD staff and data analysis was done by Dr. Maggie Squires, Limnologist.

Phosphorus (TP and SRP) is the key (limiting) nutrient, which controls algal growth. However, phosphorus alone cannot determine algal production levels, since nitrogen, sunlight and temperature are also of great importance. Phosphorus enters the lake from creeks and other land runoff, with small amounts from rain and dustfall, groundwater, and excrement from wintering ducks and other waterbirds. Residential septic fields do not appear to contribute phosphorus to this lake.

The combined factors of available nutrients, and favourable conditions of light and weather result in irregular algal growth cycles. Such cycles contain blooms and die-offs, where decaying algae are known to ‘sink’ to the sediments where bacteria will return the cells to their raw nutrient forms. Blooms are of various species of algae and cyanobacteria, sometimes heavy enough to discourage recreational activities. Occasionally the algal colonies are dominated by species of cyanobacteria (“blue-green algae”). Certain species of cyanobacteria may (not always!) produce toxins that are very dangerous to the human nervous system and liver. There is no scientific mechanism to predict whether a potentially toxin producing cyanobacterial species will actually produce cyanotoxins at any given time; however, NSSWD and CRD have developed operational protocols that use turbidity and cyanobacterial species composition and abundance as triggers to initiate toxin monitoring.

Special monitoring and treatment for cyanotoxin levels, which is conducted by the large water license-holders on St. Mary Lake, is required so that toxins do not reach the public’s water supply. Fortunately, cyanotoxins in this particular lake were treatable using chlorine oxidation during the 2011-2013 cyanobacterial bloom. However, not all cyanotoxins can be safely managed in that way (Health Canada, 2002).

Watershed Characteristics

Water Supply and Demand Management

The lake is used for treated water supply. It supplies three water supply districts, including one that serves much of the North part of the island. Two different, unique intakes for water treatment exist: North Salt Spring Waterworks District owns and operates the west shore facility, and CRD owns and operates the northeast facility, which serves Fernwood-Highland Water District (two districts combined into one, holding 5 combined licences – see Table 3).

A recent hydrology study for St. Mary Lake was completed for NSSWD by engineers Kerr Wood Leidal Ltd (Sutherland and Yao, 2015). Readers are asked to refer to this thorough document for up-to-date information about water supply and demand management at St. Mary Lake. Among other recommendations, the authors of the hydrology report emphasized the need for cooperative management of the water supply under drought conditions by way of an adaptive management planning process including NSSWD, and all stakeholders in the watershed.

SSIWPA acknowledges the close relationship between demand management, supply, and water quality. However, for the purpose of the planning process SSIWPA undertook for this IWMP, water quality metrics were the focus. SSIWPA member agencies individually, and SSIWPA itself as a collaborative local water management effort, are undertaking Demand Management planning and actions to complement the results presented in this IWMP. Please see Appendix 6 – IWMP Planning Process.

There are 9 licences for municipal waterworks withdrawals from St. Mary Lake (4 held by NSSWD and 5 by Fernwood-Highland (CRD)). These comprise 89.9% of total licenced annual withdrawal volume (Table 4). There are 30 domestic licences (combined, 1.8% of total annual allowable withdrawals). Agriculture withdrawals come from 12 licences (6.4% of total annual). There are 6 industrial licences comprising 1.9% of total withdrawal volume. The Fire Protection district licence is for short term demand for 4.8 m3/minute (2.83 cubic feet /s or 80 L/s). NSSWD is required by the Ministry of Forests, Lands, and Natural Resource Operations to store water for withdrawal between 40.0 m and 41.0 m elevation (GSC datum). NSSWD is also required by the federal Department of Fisheries and Oceans to supply a minimum flow of 8.9 L/s to Duck Creek (278.5 dam3/year).

Table 3. Summary of St Mary Lake Water Withdrawal Licenses

Water District	***Annual Volume (dam3)****
North Salt Spring Waterworks District	1,202.47
Fernwood-Highland Water District (CRD)	229.81
Total Annual Withdrawal from all Waterworks Districts Combined	1,432.28

*See footnote [1]

[1] Cubic decametres is ten metres cubed, a three dimensional unit of measurement of water volume

Objectives

These objectives (Table 4) were related to the overall goal for the Management Plan, which is: improving water quality in SML and reducing the prevalence of algal and cyanobacteria blooms. Each of the management actions in Table 5 are designed to address one or more of the planning objectives in Table 4.

Table 4. Planning Objectives

Category	Objective	Sub-objective
Environment	Preserve and protect ecological functions of SML Watershed that impact raw water quality	Preserve and protect native species
		Preserve and protect aquatic habitat
		Preserve and protect terrestrial habitat
		Enhance and restore riparian areas
		Improve stormwater quality
Health	Improve health related water quality	Minimize exposure to cyanotoxins
Tourism and Recreation	Maintain and enhance water-based recreation opportunities in SML	Minimize exposure to pathogens
		Safe swimming conditions
		Improve lake aesthetics related to algal blooms
		Fishing opportunities
		Maintain access for TC approved vessels
Cost	Provide cost effective and equitable solutions to water quality issues for landowners, rate payers,waterworks districts, and government.	Optimize capital costs
		Optimize maintenance costs
		Optimize costs of monitoring and research

Table 4 (ctd.)

Means Objective		
Source Water	Reduce algal and cyanobacteria bloom frequency and intensity	Reduce P loading into SML
		Reduce total available P in SML waters
		Reduce total available P in lake sediments
		Reduce P loading from external sources
Process/Strategic Objectives		
Social	Maintain and enhance community involvement and stewardship opportunities in implementing the SML IWMP	Improve interagency communication and cooperation
		Achieve SSIWPA mandate
		Facilitate community input into management plan
		Promote community input through engagement, citizen science, enforcement and implementation

During the first of the three workshops in the planning process, the Steering Committee used conceptual diagrams developed by the TAC in order to explore the relationship between the preliminary planning objectives, lake water quality, and all of the possible management actions that can be effectively applied.

For each planning objective, Steering Committee agreed that improving water quality would be the best way to address stakeholder's interests for the lake. Management actions to improve water quality were developed at subsequent meetings of the SSIWPA working groups, in between workshops I and II.

The water quality metric of Phosphorus (including both Total Phosphorus (TP), and Soluble Reactive Phosphate (SRP), which represents the fraction of TP that is available to organisms for growth) was used as a performance measure for water quality in SML. To ensure an efficient use of funds by SSIWPA and their partner agencies, cost was included as a second performance measure by which the IWMP management actions were assessed.

The planning process was undertaken concurrently with the second half of the year of Research and Monitoring by SSIWPA. As results from the field studies emerged, they were incorporated into the planning process. To help in the dissemination of the field study results, the TAC developed a phosphorus influence diagram for SML (Figure 1) and used it to develop a number of impact hypotheses (IH) (Appendices 14) that summarized, in a condensed format, the field study results.

Drinking Water Treatment

NSSWD supplies water to the village of Ganges and much of the north end of SSI. NSSWD draws water from two sources: St. Mary Lake and Maxwell Lake. St. Mary Lake provides approximately 60 percent of the water delivered by NSSWD. Current water treatment at the St. Mary Lake facility consists of only pre-chlorination, pressure sand filtration and post-chlorination and does not meet Island Health requirements for surface water treatment. Specifically, it does not remove sufficient organic matter including algal cells to prevent disinfection by-products from forming when chlorine is added for disinfection. Construction of a new Dissolved Air Floatation (DAF) treatment facility will begin in late 2015. The treatment process includes the following steps:

1. Coagulation – a chemical coagulant is added to the raw water while it is rapidly mixed.
2. Flocculation – the water is mixed slowly and the coagulant helps dissolved and suspend materials to bind together in small particles known as "floc".
3. DAF – the water passes into a tank where a stream of air-saturated water is pumped from the bottom up and the rising air bubbles lift the floc to the surface where it forms a layer of 'float' and is skimmed off.
4. Filtration – the water is filtered by passing through layers of sand and anthracite.
5. Primary Disinfection – the treated water is exposed to UV radiation.
6. Secondary Disinfection – the treated water is chlorinated.

This treatment process will enable NSSWD to reliably meet demand as well as the requirements for surface water treatment, the BC Drinking Water Protection Regulation and the Guidelines for Canadian Drinking Water Quality. It will also produce potable water even during toxic cyanobacterial blooms, provide protection from Giardia and Cryptosporidium and pathogenic bacteria and significantly reduce the concentrations of disinfection by-products such as trihalomethanes (THMs) and haloacetic acids (HAAs). In the new NSSWD DAF plant, filter backwash water will be recycled to the beginning of the process after settling instead of draining back to the lake. The Fernwood-Highland DAF treatment process already prevents the backwash from filter cleaning from entering SML.

The Highland-Fernwood water treatment plant uses a very similar DAF process on a smaller scale.

Research and Monitoring by SSIWPA 2014-2015

SSIWPA TAC carried out a three-part research program in St. Mary Lake and its watershed within the period July 2014 – July 2015. The research had the following objectives:

1. To verify whether septic effluent seeps into the lake by measurement of the P content in
2. Groundwater wells installed between septic fields and the lake at three sites (Figure 9);
3. To derive estimates of the load of P entering the lake from watershed runoff (creek and ditch) (Figure 10. Stormwater runoff monitoring sites);
4. To measure the distribution of nutrients in the lake, and their seasonal variations, with better spatial and temporal resolutions than were available in existing data.

The full research proposal can be downloaded from the SSIWPA website (titled TAC Field Study Proposal St Mary Lake 2014 – Public Summary).

Research Results:

The results of the SSIWPA TAC 2014-2015 monitoring program were considered by all who participated in the planning process. Full research reports have yet to be published, as the research came to conclusion at the same time as Plan publication. They are expected to be published by the end of 2015. A summary of results for 1) Septic, were presented July 6, 2015 at a public meeting, and a summary for results for 2) In-Lake Studies, were presented October 7, 2015 at a public meeting. A summary of results related to 3) “Nutrients in SML” were presented at a Public

Presentation (October 7, 2015). A synopsis of each 1), and 2) follow here:

Synopsis 1) Update on the assessment of phosphorus inputs to St. Mary Lake from septic systems.

Prepared by Donald O. Hodgins, Ph.D., Project Manager, SSIWPA 2014/15 Monitoring Program.

In 1983 the BC Ministry of Environment (MoE) released a report[1] identifying the major sources of phosphorus to St. Mary Lake. The two major sources were found to be internal loading from sediments, accounting for about 67% of the total, and infiltration from septic fields, amounting to another 28%. Other sources were much smaller. These same estimates were brought forward as the basis of the St. Mary Lake management plan released in 2009. For over 30 years, discussions of reducing the septic contribution by means of a sewer system of some kind have taken place based on these numbers.

The septic estimate of about 300 kg each year provided in the MoE report was derived from engineering calculations typical of the time. Assumptions were made about the number of occupants of residences and resorts, the per capita phosphorus contribution and transmission rates based on soil and set-back parameters. Importantly, however, no site-specific data were collected for St. Mary Lake.

The objective of the present study was to update the estimate of phosphorus seeping into the lake from septic systems, taking changes in phosphate content of household products into account (a major factor) and verifying phosphorous uptake by local soils and modern septic drain fields. This second step was based on direct field measurements.

These measurements were made over the winter of 2014-2015 by installing 15 groundwater monitoring wells at three different residential properties fronting onto the lake. Additional sampling sites were installed in the lake itself, and in the shallow surface zone close to the drain fields. The sampling locations were confirmed to lie in the pathway of the septic effluent using chemical tracers, including phosphorus. Samples were collected monthly from November through to the end of May. It was noted, that at all sites, no groundwater was present in the sand layer above the glacial till when the monitoring wells were

1 Nordin, R.N., C.J.P. McKean and J.H. Wiens, 1983. St. Mary Lake Water Quality: 1979-1981

drilled in August. This agrees with the description in the Van Vliet et al[1]., that groundwater is seasonal, and means that during late summer there is, by definition, no means for phosphorus to reach the lake.

For Langs Road east, and at Tripp Road, groundwater became re-established in November and rose rapidly to occupy about two-thirds of the sand layer. By late January, the water table had receded to roughly one-half of the sand layer thickness where it remained until July. Phosphorus measurements consistently showed that groundwater concentrations ranged from about 2% to 4% of concentrations in the effluent entering the drain fields. Concentrations decreased with distance out from the drain fields and no evidence of septic phosphorus was detected in lake-side samplers. These results are in good agreement with the recent, comprehensive body of research carried out in Ontario[2].

At the third site, along Langs Road west, no groundwater was present for the entire sampling period. This means that rainfall, and flow from higher land, is completely removed by run-off, by direct evaporation and taken up by trees and released through evapotranspiration. There is no flow from septic drain fields toward the lake and no pathway for phosphorus to reach the lake. This condition is likely the case for all properties along the western portion of Langs Road in view of the forest cover and set-back distances from the lake.

In conclusion, on-site sewage treatment systems are working efficiently, with phosphorus retention factors immediately under the drain fields exceeding 95% for the slightly acidic soils around St. Mary Lake. The evidence also shows that no phosphorus attributable to septic systems is reaching the shoreline waters of the lake, indicating that even if phosphorus plumes form in the groundwater below drain fields, all of it is adsorbed to soil particles before reaching the lake.

A revised estimate for the total load of phosphorus to the lake is less than 5 kg each year, considering the efficient retention and low or nil transmission factor for local soil conditions. This estimate, based on 151 possible contributing properties, also takes the reduction in phosphates in household products into account, as well as the actual seasonal water use for lake-side residents.

Because a load of about 5 kg, or less, is negligible in terms of the phosphorus content of the lake and other external sources, wastewater collection and treatment facilities are not necessary, and would provide no benefit for water quality in St. Mary Lake.

Figure 9. Septic Monitoring Sites 2014-2015

1 Van Vliet, L.J.P., A.J. Green and E.A. Kenney, 1987. Soils of the Gulf Islands of British Columbia, Vol. 1, Soils of Saltspring Island. Report No. 43, British Columbia Soil Survey, Research Branch, Agriculture Canada.

2 Robertson, W.D., S.L. Schiff, C.J. Ptacek (1998). Review of phosphate mobility and persistence in ten septic system plumes. Groundwater, 36: 1000"-1010"

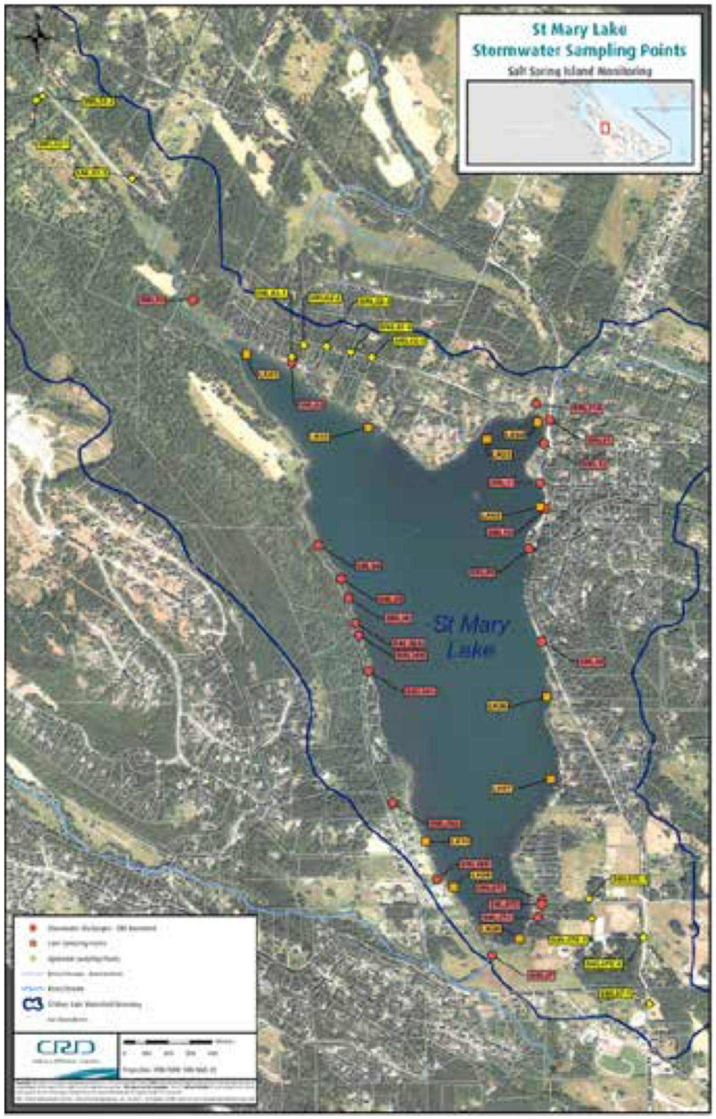


Figure 10. Storm Water Monitoring Sites

Synopsis 2) 2014-15 In-lake Studies at St. Mary Lake and Implications for Interpretation of the Long-term Phosphorus Record

Prepared by: Maggie Squires, Ph.D., Limnologist, Lead Scientist, SSIWPA 2014-15 Monitoring Program.

What was done

The 2014-15 In-lake Study was designed to compare the relative magnitude of nutrient loading from the watershed (external) versus nutrient loading from lake sediments (internal). To assess the relative impact on lake nutrient and algal biomass levels of external versus internal loading, the amount of phosphorous (P), nitrogen (N), and iron (Fe) (dissolved and total) in surface and bottom waters, and the amount of algal biomass in surface waters was measured every two weeks across the four seasons, as follows: 1) during the period of summer stratification; 2) before, during, and after fall overturn; 3) during the period of winter rain; and, 4) during spring pre-stratification period.

Results and what was learned

Among seasons, dissolved phosphorus (DP) and algal biomass were at minimum levels during the summer, both increased modestly at fall overturn, and both increased sharply with the onset of winter rains (Squires, 2015).

The pattern of change in water column nutrient levels before, during, and after overturn suggests very modest internal P loading controlled by iron (Fe). (I.e. Release of P from Fe complexes during anoxia is followed by re-complexation of P with Fe during overturn, when bottom waters are re-oxygenated).

After start up of the winter rainy season and initiation of runoff is a period of relatively high P level in the lake (unpublished data). In addition, the sharp rise in lake water P in early 2015 was not accompanied by a similar rise N level and, as a result, the biomass of N-fixing cyanobacteria increased.

The results suggest the following: 1) during the summer period of stratification, draw-down of available P, P-limitation of algal growth, and nutrient and algal biomass levels corresponding with oligotrophy; 2) during the rainy season, increase in P and algal biomass levels, plentiful P, N (and light)- limitation, and P and algal biomass levels corresponding with mesotrophy (i.e. moderate nutrient enrichment); and, 3) overall, external P loading related to runoff from the watershed greater than internal loading related to P-recycling from lake sediments.

Implications for Interpretation of the Long-term Phosphorus Record

The results of the 2014-15 study challenge several common perceptions about St. Mary Lake, as follows:

1) SML is eutrophic and getting worse; 2) Cyanobacteria are bad because they produce toxins; 3) Internal loading is much larger than external loading.

Although St. Mary has occasionally experienced increases in P levels, i.e. 1979-80, 2005-06, and 2012-13, the long-term P record (1979-2015, some data gaps) does not suggest overall increase over time in P levels.

While it is true that some cyanobacteria can and do produce toxins, the cyanobacteria in St. Mary Lake also fix atmospheric nitrogen when N availability is low relative to P availability. In short, blooms of N-fixing cyanobacteria may occur more frequently than blooms of toxic cyanobacteria. Potential for harm to humans and wildlife warrants testing for toxins whenever cyanobacteria with potential to produce toxins are detected.

The results of the 2014-15 In-lake Study challenge a long-held ‘belief’ that internal P loading is much greater than external loading in St. Mary Lake. In short, due to strong control by iron of net release from sediments, external P inputs from the watershed appear to be greater than internal P inputs. This result raises questions related to the use of artificial aeration as remediation strategy to improve water quality (i.e. lower algal biomass) by decreasing internal P loading. Specifically, if internal P loading is not large and dominant due to full-circle release at anoxia and re-sequester at overturn, then little or no change in overall lake P loading and, in turn water quality would be expected as a result of aeration of bottom waters to prevent anoxia and associated P-release from sediments. Moreover, several lines of evidence (precipitation, observations of extreme runoff, landslide occurrence) can link years with peak P levels (1979-1980 & 2005-06) with years of extreme runoff.

Last, peak P levels in 2012-13 can be explained by sediment disturbance by the aerators. Evidence of sediment disturbance includes decrease in water clarity during 2009-2013, hydrogen sulphide gas emissions in the vicinity of the aerators in 2012-2013, and increase in bottom water oxygen demand. The 2012-13 peak P level can be explained by sharp reduction in the availability of iron for re-binding with P released from sediments as a result of short-term iron-removal via complexing with sulphide.

Conclusions

The results of the 2014-15 In-lake Study suggest the following: 1) St. Mary is mesotrophic; 2) N-fixation by Cyanobacteria can be beneficial; and 3) external P loading is greater than internal P loading. The results have important implications for selection of remediation strategies for lowering P inputs to the lake.

Selected Reading List

On the Role of Iron and Sulphide in controlling the P-binding capacity of sediment:

Gunnars, A. et al., 2002. Formation of Fe(III) and oxyhydroxide in freshwater and brackish sea water, with incorporation of phosphate and calcium. Geochim Cosmochim Acta 66: 745-758.

Caraco, N.F., J. J. Cole, and G.E. Likens. 1989. Evidence for sulphate-controlled phosphorus release from sediments of aquatic systems. Nature 341:316-318.

Hoffman, A.R. et al., 2013. Influence of phosphorus scavenging by iron in contrasting dimictic lakes. Can J Fish Aquat Sci 70:941-952.

Impact Mini-Reports: Key Findings

The TAC completed an “Impact Mini-Report” for each of the impact statements that were presented in the influence diagram (Figure 1) where each potential management action pathway that could assist or detract from the attainment of the desired objectives in this plan is portrayed. Each Impact Mini-Report contains the following information:

i. Impact Statement
ii. Description
iii. External influences
iv. Assessment
v. Results (Conclusions, if warranted)
vi. Consequences of being wrong
vii. Uncertainties and data gaps
viii. References.

The complete set of Impact Mini-Reports are found in Appendix 13. They are useful living documents that will change as data gaps are filled and research and monitoring and implementation steps are completed.

Over time the Phosphorus (P) budget in SML tends toward dynamic equilibrium (P net in = P net out) with inter-annual variation determined by the relative contribution of P-external and P-internal loading;

- Septic fields are not considered a significant source of P loading as monitored levels were in line or only slightly above P background levels;
- P-external loading (runoff from the watershed) may be larger than previously calculated under the previous SML management plan, with current runoff P estimates of 50-150 kg annually;
- Internal P loading is less than previously calculated in Nordin *et. al*., (1983). More reliable data on external P loading (runoff) is required (see Table 5) before the relative impact of external P loading compared with internal P loading can be determined. See Appendix 13 number 5 options A and B;
- The role of phytoplankton, zooplankton, and fish population dynamics in overall P-balance is not well defined for SML.

Management Actions

Management actions were categorized by:

- **Physical Works** – such as dredging, hypolimnetic aeration, or sewerage;
- **Chemical Treatments** – such as addition of iron, flocculants, or algicides;
- **Biological Approaches** – such as habitat modifications, trophic cascades, and riparian planting;
- **Land Use / Public Polic**y – such as modification of bylaws, improved enforcement of bylaws, and development of environmental farm plans;
- **Public Outreach and Education**

Through the course of the three SDM workshops and integration phases, the preliminary list of actions was whittled down to 13 recommended management actions, and another 4 possible actions contingent on: necessity after further investigation, collaborations with other groups, and/or funding. Those actions that were discarded due to technical feasibility or probable technical inefficacy are listed in Appendix 9.

Some of the recommended actions are aimed at assisting with island-wide opportunities for improvements to stormwater nutrient management from agricultural sources. While not all of them are specific to the SML watershed, they are included in this Plan, as their achievement was deemed to provide another opportunity for reducing P loading from the watershed to SML (and other island lakes, potentially). All action cost numbers in the following table are estimates, and not broken down into cash and in-kind expenses. Cost estimate for a given action is inclusive of SSIWPA coordination expenses.

Table 5. Details about Management Actions

	Management Action
Research Question	What is the measured P loading in stormwater runoff from the watershed into the lake?
Related Objective	Reduce P loading from external sources.
Suggested Study Methods	a) Inventory water quality and nutrient loading to the lake from runoff creeks, ditches and culverts (several, chosen based on size and/or frequency of flow); Measure concentrations of P and N as: SRP, TP and NO and flow rates; b) Selection to include diversity of landscape types; c) Installation of water level data loggers; and, d) Data collection timing and frequency. Selection for sample sites will refer to both CRD stormwater site sampling data (2012), and data collected by Don Hodgins, January – April 2015.
Duration	November 2015 - April 2016
Cost	$5,000 to $10,000 (already allocated) CRD financial support as carryover from SSIWPA 2014-15 Research Program at SML.
Lead Agency	SSIWPA, CRD

* See Footnote[1]

1 Cost to add a fourth site is prohibitive given the lower priority ranking of this study: cost would be 18K-20K just to drill new site wells.

Table 5(ii). Verification of Septic Nutrient Input Study

2	Management Action
Research Question	What confidence does TAC have that 2014-15 results have captured the septic outflow data accurately?
Related Objective	Reduce P loading from external sources
Suggested Study Methods	a) Continue the 2014-15 monthly septic well sampling, at all three sites* if owners agree; b) Confirm whether septic effluent actually reaches the lake with dye tracer study: rhodamine or fluorazine dye added to D-box or Field prior to sampling wells down-field.
Duration	November 2015 - April 2016
Cost	Up to $10,000
Lead Agency	SSIWPA, CRD

* Footnote [1]

Table 5(iii). SML Water Quality Monitoring

3	Management Action
Research Question	How much of the phosphorus released from sediments during anoxia is actually loaded into the lake in a form usable by algae and cyanobacteria?
Related Objectives	Reduce total available P in SML waters; Reduce P loading into SML.
Suggested Study Methods	a) Continue monthly water quality monitoring program (NSSWD); b) Add monthly measure of iron (Fe), chlorophyll (Chl), nitrate ($N0_3$) (SSIWPA); c) Measure weekly amounts of three above parameters, as well as phosphorus (TP, SRP) during the turnover period (SSIWPA).
Duration	Weekly starting October 15th, 2015 until end December, 2015 (before, during, and after fall turnover). January – March 2016 the same extra parameters will be measured monthly.
Cost	$25,000
Lead Agency	SSIWPA

[1] Cost to add a fourth site is prohibitive given the lower priority ranking of this study: cost would be 18K-20K just to drill new site wells.

Table 5(iv). Water Quality Best Management Practices

4	Management Action
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	a) post a list of water quality BMPs and information sources for landowners to the SSIWPA website. b) summarize how landowners and other islanders can help reduce point sources of P from their land, industry or homes.
Duration	Fall 2015
Cost	$300
Lead Agency	SSIWPA

Table 5(v). Survey of Improvement Actives by SML Landowners

5	Management Action
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	a) SSIWPA will canvas the SML community for examples of water quality or quantity improving activities that have been undertaken by local property owners; b) With permissions this information will be published to the SSIWPA website; c) If applicable, some participants may be invited to host experiential tours as part of the Watershed Stewardship Workshops.
Duration	Fall 2015
Cost	$1,000
Lead Agency	SSIWPA

Table 5(vi). Watershed Stewardship Workshops

6	Management Action
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	a) SSIWPA will look to host quarterly workshops that promote watershed stewardship on the island. This may include: b) **Expert Presentations** – SSIWPA will look to support local and regional experts speaker/ workshop series on topics like: a. Limnology/hydrology/water quality and resiliency speaker series; b. Design and build bioswales; c. Stormwater management landscape design; d. Riparian stewardship c) **Experiential tours** – visit properties that have implemented water quality or water conservation best practices. E.g. rain-water capture, Ecologically Appropriate Shoreline Tour. d) Fall 2015 trip hosted by Cowichan Lake and River Stewardship Society Riparian Revegetation Project
Duration	Fall 2015
Cost	$10,000
Lead Agency	SSIWPA

* See Footnote[1]

[1] SSIWPA may assist with establishment of a community-based SML Watershed Stewardship Group, to help imple-ment stewardship and community engagement in this Plan

Table 5(vii). Environmental Farm Plan

7	***Management Action***
Related Objectives	Help to understand better how to reduce runoff sources of P loading, any agricultural hotspots (island-wide); Reduce total available P in SML waters if applicable to SML farmers in Group.
Methods	Lead agencies to host workshop, island-wide invitations **Presenter:** David Tattam (ARDCorp EFP Planning Advisor) Subsequent workshops for eligible group(s)
Duration	Winter 2015 - 2016
Cost	$1,000 (and cost-shared with ARDCorp if results in follow up).
Lead Agency	SSIWPA and SSI Agricultural Alliance.

Table 5(viii). Water Quality Signage

8	***Management Action***
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	a) water quality information signage at SML beach (perhaps other locations): the nutrient cycles in the lake, highlight the results of TAC work, and may include a section on SML water quality myth busting; b) brochures will be made and disseminated island-wide in public watershed; c) engagement campaign; d) signage to include BMP for reducing P inputs from human activities and direct people to SSIWPA website; e) impacts that pets can have on the SML lake quality may also be considered in signage.
Duration	Winter 2015 - 2016
Cost	$4,000
Lead Agency	SSIWPA (or contractor QP).

Table 5(ix). Island-wide Fair

9	Management Action
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	• continue and possibly increase its support, in-kind or financial, of the annual community Water Fair; • coordinator will work with other water conservation groups and the islands water districts to organize and run the one-day Fair held in March.
Duration	1 year
Cost	$9,000 *
Lead Agency	SSIWPA (Water Council, others).

Table 5(x). Youth Watershed Stewardship Activities

10	Management Action
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation*. Preserve and protect ecological functions of SML Watershed.
Methods	Support and coordination of Kids for Creeks program island wide, and specific partnership with Fernwood School for SML watershed learning programming; Curriculum is not the goal for SSIWPA in this action. Coordinating curriculum with those already engaged with youth watershed stewardship programming is the goal.
Duration	2015 (and ongoing)
Cost	$2,000 *
Lead Agency	SSIWPA (partners with individuals and groups).

Table 5(xi). Residential Septic Maintenance Education in SML

11	Management Action
Research Question	Reduce P loading from external sources
Related Objectives	Preserve and protect ecological functions of SML Watershed
Methods	• SSIWPA will work with the CRD to provide information to SML watershed homeowners (and new buyers) that summarizes proper septic system use and maintenance. • Realtors may also be asked to include this information in their correspondence with buyers • CRD Septic system education information including bylaws https://www.crd.bc.ca/service/sewers-wastewater-septic/septic-systems may be offered on Salt Spring I.
Duration	Winter 2015 (and ongoing)
Cost	$2,000
Lead Agency	SSIWPA and CRD.

Table 5(xii). Biodiversity Inventory in Sensitive Habitats

12	*Management Action*
Research Question	What are the aquatic, wetland and terrestrial species (plants, animals, insects) in the SML watershed?
Related Objectives	Preserve and protect ecological functions of SML Watershed
Methods	a) building on Atwood, 2011; b) identify zones of sensitivity that may be targeted for conservation or restoration (e.g. rehabilitation, remediation or revegetation); c) predicted impacts of lake level changes on vegetation; d) GIS Maps of the SML watershed are available, and could use updating (Islands Trust, CRD); e) inventory also to determine features that could be added to these maps for educational purposes: species-at-risk, invasive species sightings, creek mouths, wildlife corridors, adjacent wetlands, biologically productive areas, fish and wildlife habitat, human shoreline alterations: • could be combined with the Stormwater MA#1 to identify erosion hotspots. • examples for methods: Canadian Aquatic Biomonitoring Network (CABIN), Environment Canada; SHIM* http://www.livinglakes.ca/science/sensitive-habitat-inventory-mapping/
Duration	Not assessed
Cost	Not assessed
Lead Agency	SSIWPA, SSI Conservancy, Home Owners, Stewardship group.

Table 5(xiii). Watershed Stewardship Grant Writing Assistance

13	*Management Action*
Related Objectives	Promote community input through engagement, citizen science, enforcement and implementation**. Preserve and protect ecological functions of SML Watershed.
Methods	SSIWPA will work with interested parties to apply for grants that support the SSIWPA mandate and the objectives of this Integrated Watershed Management Plan.
Duration	Ongoing
Cost	As approved in annual SSIWPA workplan for coordination.
Lead Agency	SSIWPA

* See Footnote[1]
** See Footnote[2]

1 SHIM – Sensitive Habitat Inventory Mapping

2 SSIWPA may assist with establishment of a community-based SML Watershed Stewardship Group, to help implement stewardship and community engagement in this Plan

Table 5(xiv). Sediment Pore Water Profiling

14	*Sediment Pore Water Profiling*
Research Question	What is the importance of iron in controlling the P concentrations (due to internal and external P loads) in SML?
Related Objectives	• Reduce total available P in SML waters • to confirm that iron is sequestering P in sediment
Study Methods	a) deploy a pair of porewater samplers (borrow or contract); b) sample monthly during 1 year quantify iron, phosphorus, manganese, and sulphur chemistry of lake sediment; c) iron could affect the amount of P that remains in the lake water after external and internal P inputs.
Duration	1 year
Cost	$2500, using borrowed equipment and volunteer labour. $10,000, if contracted.
Lead Agency	SSIWPA (or contractor QEP).

Table 5(xv). Stormwater Management (Prior to Phase 2) Design

15	*Stormwater Management (Prior to Phase 2) Design*
Related Objectives	Reduce P loading from external sources
Study Methods	a) TBD
Duration	TBD after summer 2016, based on results of item 1
Cost	$15,000 - $30,000 (not yet allocated) This action only necessary pending results of item 1 in this table.
Lead Agency	SSIWPA, CRD.

Table 5(xvi). Subsidized Permaculture Water Management Program

16	*Subsidized Permaculture Water Management Program (Keyline Design)*
Research Question	How might keyline design minimize nutrient runoff and leaching from cultivated zones or animal husbandry zones in specific agricultural systems (island wide) How might keyline design assist with groundwater recharge?
Related Objectives	Help to understand better how to reduce runoff sources of P loading, any agricultural hotspots (island-wide). Reduce total available P in SML waters if applicable to SML farmers in Group.
Methods	• workshops with SML farmers (if there is interest) • expect medium to high effectiveness for Stormwater P-loading reduction, if runoff hotspots coincide with possible impacts due to farming practices. • effectiveness for water conservation management on farms, and groundwater recharge is likely high
Duration	TBD
Cost	$5,000* Funding assistance possibility: Growing Forward 2 or other agri-environmental funding programs.
Lead Agency	SSIWPA and SSIA.

Table 5(xvii). Water Profiling Toolkits

17	*Water Planning Toolkits*
Objectives	• to increase awareness of climate impacts (e.g. drought and rainfall intensity shifts) on farm water management*, (not specific to SML) • to develop practical tools producers can use to effectively manage water on the farm*, and • to increase producers' resiliency against increasingly variable and extreme weather. Reference: http://www.bcagclimateaction.ca/wp/wp-content/media/Cowichan-Integrated-Water-Summary.pdf
Methods	Liaise with Cowichan Farm Water Toolkit, and Cowichan Farm Water Management program experts and producers
Duration	TBD
Cost	Not assessed*
Lead Agency	SSIA (with SSIWPA).

* The cost and extent of these management actions depend on grant funding assistance to SSIWPA or one of its member agencies, and at the time of writing, had not been confirmed.

Stormwater Management Phases: Details of Actions 1 and 15

Point sources for any stormwater runoff from the watershed to the lake are not well understood, at present. The 2014-2015 SSIWPA-TAC field research identified storm water runoff (Appendix 13, IS-1A) as a potentially significant source of P-loading into SML. Paved roads, buildings, and other impervious areas create an immediate and complete runoff of rainwater particularly during storm events. Nutrients and other pollutants are carried into SML through seasonal creeks, stormwater drains, and more generally through diffuse run-off.

P-loading through these pathways can be reduced through the reduction of impervious areas and the application of SWM techniques such as settling ponds, bio-swales, and improving riparian vegetation cover among other actions.

A two-phase management action of conducting future research is intended to determine the feasibility of mechanisms and specific locations where slowing the storm water runoff and improving ground water recharge may successfully reduce P loading to the lake, from runoff. If phase 1 yields results that warrant phase 2 to be undertaken, the results of phase 2 will be assessed for cost effectiveness per unit phosphorus reduction anticipated before any stormwater management actions are completed.

If feasible in phase 2, existing CRD stormwater management programs can be applied to suitable areas of the watershed to target and reduce P loading from point sources, starting with a design assessment of hotspots or target areas.

Implementation and Review of Plan

Implementation is due to begin Fall 2015 for most of the management actions in this Plan (Table 6). Some actions are underway, and others will begin in 2016 pending agreements with other groups outside of SSIWPA. Regular evaluation of the objectives, actions and their deliverables will be conducted by SSIWPA, with assistance from advisory working groups, on an annual basis as part of the SSIWPA workplan. At any time, SSIWPA may determine that a shift or change in the watershed warrants review of the Plan or its components.

Table 6. Management Actions and Implementation Measures

	Action	Dates	Lead Agencies	Measure of Success
1	Stormwater Quality Monitoring Phase 1: Inventory	October 2015 - April 2016	SSIWPA CRD	P load in stormwater from major sources; identification of hotspots that exceed avg load.
2	Verification of Septic Nutrients - SSIWPA TAC research study	November 2015 - Spring 2016	SSIWPA CRD	Verify evidence that septic load to groundwater entering lake from 3 representative septic fields is nil. Confirm that P does not reach the lake using dye tracer.
3	Water Quality Monitoring	October 2015 - April 2016	SSIWPA	Improve understanding of the amount of P loaded into the lake at overturn and of the re-complexation and sedimentation of P with Fe after overturn.
4	Water Quality Best Management Practices (BMPs)	Fall 2015 (deferred)	SSIWPA	Web page created and reviewed.
5	Survey of Quality / Quantity Improvement Activities by St. Mary Lake Residents & Property Owners	Fall - Winter 2015 - 2016	SSIWPA	Public results of community action survey; Web page created and reviewed.
6	Watershed Stewardship Workshops [Shoreline stewardship, water quality and resiliency, others]	Fall - Winter 2015 - 2016	SSIWPA CRD Islands Trust	Feedback by community received for at least 2 workshops or field trips before Fall 2016.SML stewardship actions that relate to workshop(s) are evident.
7	Environmental Farm Plan (EFP) - Group Plan Island-wide workshop	Spring 2016	SSIWPA SSIA ARDCorp	A group of farmers in a watershed undertakes application for EFP to receive funding assistance from the program; BMPs related to runoff implemented within 3-5 years of application.
8	Install Water Quality Information Signage	Fall 2015 - Winter 2016	SSIWPA	Signage installed at SML public beach. Signage Winter 2016 at access points; brochures disseminated.
9	Island-wide Water Fair (annual)	Spring 2016	SSIWPA, WPS WC, local sponsors	>200 participants in second annual Water Fair.

	Action	Dates	Lead Agencies	Measure of Success
10	Youth Watershed Stewardship Education [partner with existing programs]	2015-16 (ongoing)	SSIWPA WPS WC	Watershed expertise and coordination added to youth programs about watershed stewardship; more than 1000 youth/children reached.
11	Residential Septic Maintenance Education in SML [with existing materials]	Winter 2015 start	SSIWPA CRD	Baseline survey to establish septic pump out frequency in 2015 (follow-up in 3 years)
12	Biodiversity Inventory at SML	2016 - 17	SSIWPA CRD other local organizations	Create GIS habitat maps (focus on rare, endangered, invasive, including fish); management planning for invasives; measure community volunteers and engagement.
13	Watershed Stewardship Grant Writing Assistance	Fall 2015 ongoing	SSIWPA (in kind)	Grants received for water stewardship programs by SSI groups.
The following actions or research will only be implemented pending necessity, funding and/or partnering with agencies outside of SSIWPA				
14	SML Sediment Pore Water Profiling	1 year	SSIWPA (unconfirmed)	Confirmation that iron is major mechanism to sequester P in sediment; quantification of P sequestered within sediment over time.
15	Stormwater Quality Monitoring Phase 2: Design	2017 or later	CRD (unconfirmed)	Design of stormwater capital works; agreements for implementation of designs with landowners in place.
16	Subsidized Permaculture Water Management Program (Island-wide)	2016 or later contingent on SSIAA involvement	Unconfirmed	Landowners with potential for nutrient-rich runoff in watersheds implement keyline design on their properties
17	Farm Water Planning Toolkits – (SML Pilot)	2016 or later contingent on SSIAA involvement	Unconfirmed	Farm Water Management Program Pilot implemented (SML watershed properties only)

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APPENDIX 1. Summary of Water Council Interviews (2012) with St. Mary Lake Residents, conducted by K. Trajan

Outreach by Salt Spring I. Water Council to St. Mary Lake Lakeside Properties

Informal results of a canvassing after release of a brochure about water quality management.

Out of 65 lakeside properties:

- 54 residential
- 7+ appear undeveloped and/or uninhabited
- 6 cabin resorts
- 3 farm-residences
- 1 equestrian centre
- 1 RV park

We performed 20 interviews:

- 4 resort owners/managers
- 2 farm owners/managers
- 1 equestrian centre
- 15 residents (2 are also farm owners)

47 properties received brochures

Interview summary covered the following topics:

- Water Supply and Use
- Impacts of the Blooms
- Septic Systems, Phosphate Products, Land Use
- Information needed about the Lake
- Causes of Blooms
- Desired Actions
- Public Meeting

Information expressed by property owners that is needed about the lake:

- Where can we get up to date info on the toxin levels in the lake?
- Is it safe to drink the water and eat the fish now?
- What are the immediate and long-term health risks of ingesting the toxins?
- What kind of water treatment works against cyanobacteria?
- Who is the governing body of the lake?
- We have been getting our information from the CRD and VIHA websites and the Driftwood.
- An archive of data on the NSSWD website would be helpful.
- This brochure is very good.

Desired actions:

- Put in a sewer system so it is fixed once and for all - but probably more expensive than small scale individual systems.
- Residents will agree to monitoring of their septic systems if it means improving the quality of the lake.
- Bring in some experts and stop experimenting.
- The bass attracts fishers to our lake – get rid of those perch.
- Monitor septic pumping .
- We may have to restrict water-taking from the lake.
- We must harvest the algae. (Use a biogas digestor?)
- Don’t play Russian Roulette with the lake by using chemicals.

APPENDIX 2. Channel Ridge Trail Map

APPENDIX 3. Collaborative Watershed Governance in BC

The issue of watershed governance has been the subject of considerable discussion in BC and across Canada, given there are often many different jurisdictions and a range of users that affect watershed health. POLIS Institute at the University of Victoria, B.C. is a research Think-Tank that straddles the worlds of academic research and policy, and grassroots action centered on watershed research, management and governance issues (http://poliswaterproject.org/). POLIS has assisted SSIWPA in its formation and pilot work with collaborative watershed governance in the St. Mary Lake Watershed.

Among many recent publications, Good Governance for Water Conservation: A Primer provides an introduction to some of the challenges communities face in regards to watershed governance. It indicates that while improved governance is central to the success of watershed conservation, governance issues are often overlooked in favour of technical solutions. The authors quote research from the UBC Program on Water Governance that indicates the three most important issues to address are 1) lack of accountability, 2) neglect of fairness and equity issues and 3)lack of co-ordination among different levels of government. (Furlong et al., 2008).

The provincial government has passed a new Water Sustainability Act, which, in part, aims to better address the topic of watershed governance in British Columbia. The associated regulations have not yet been completed for this new Act. The need for improved collaboration and coordination between diverse agencies is further evidenced by the draft Collaborative Watershed Governance Accord, in development by the Union of BC Municipalities.

In BC, a number of models for collaborative watershed management have been developed or are being evaluated. Some examples are:

a. **Okanagan Basin Water Board**

The Okanagan Basin Water Board is established by provincial legislation and has taxation powers to support its actions. It was originally created in the 1970s in response to eutrophication of lakes in the Okanagan Basin had resulted in algal blooms, poor water quality, declining property values and loss of tourism revenues. Today, its activities are overseen by a board comprised of political representatives from the three regional districts in the Okanagan. It has a small staff with expertise and duties related to water quality protection, community stewardship and communications as well as a field crew that are primarily focused on management of Eurasian milfoil. It also provides grants for the improvement of sewage disposal systems.

b. **Shuswap Lake Integrated Planning Process (SLIPP)**

SLIPP is a partnership of agencies including federal, provincial, regional and local governments, First Nations, and the Interior Health Authority that work towards the health and prosperity of the Shuswap Lake region. It was set up as a 3-year pilotprogram and is funded through contributions (financial and in-kind) from each of the partner agencies. Its organization includes a steering committee of elected representatives, technical teams of agency staff, and public advisory committees. Financial management and administration is provided through the Fraser Basin Council.

c. **Cowichan Watershed Board (CWB)**

The Cowichan Watershed Board's mandate is 'to provide leadership for sustainable water management to protect and enhance environmental quality and the quality of life in the Cowichan watershed and adjoining areas'. The Board is comprised of members of the Cowichan Valley Regional District, first nations and representatives of federal and provincial agencies. It receives advice from a Technical Advisory Committee and is funded by financial and in-kind contributions of the partners. A paid coordinator is funded by the partners. Because the Board has no legal structure, it cannot attract grant funds and may consider constituting itself as a society for this purpose. An important collaborating body to CWB is the Cowichan Lake and River Stewardship Society, with which the CWB collaborates on projects (http://www.cowichan-lake-stewards.ca/).

d. **Regional District of Nanaimo Drinking Water and Watershed Protection**

The Regional District of Nanaimo set up a Drinking Water and Watershed program as a regional service to 'learn more about water in the Region, use this information to make better land use decisions, and help communities protect the environment'. The regional board has established a Technical Advisory Committee (TAC) that consists of staff from partner agencies. The TAC advises the regional board's Sustainability Committee. The district has one full time staff person working to implement programs and an annual budget raised through a parcel tax.

e. **Integrated Watershed Management Program**

The Capital Regional District's stormwater, Harbour and Watersheds Program 'works with local governments and the community to maintain healthy watersheds and protect the near-shore receiving environment. The Program takes a collaborative approach by involving the community, environmental and professional organizations and all levels of government. Working in partnership, it monitors stormwater quality, develops regulatory tools such as model stormwater bylaws and codes of practice, restores key areas within the harbours and watersheds, educates the public, and promotes voluntary Best Management Practices'.

Salt Spring Island taxpayers contribute to this program, where its operations include supporting SSIWPA and other related functions related to Stormwater runoff. The service provides funding for CRD staff, sampling expenses and consultants directed by CRD staff to undertake related work. The service reports to the SSI Director and there is currently no formal body such as a commission or advisory committee associated with the service.

APPENDIX 4. History of SSIWPA

Salt Spring Island Watershed Protection Authority (SSIWPA) arose out of a recognition that interagency cooperation was essential to constructing and implementing a management plan for watersheds that were subject to regulatory and statutory oversight by several provincial and local government agencies. The concept of an interagency oversight authority was devised by Islands Trust staff, discussed and agreed with the several stakeholder agencies to measure the level of interest, then approved by the Salt Spring Island LTC prior to being submitted for Trust Council's approval in 2013. For the first time in the Islands Trust's history, Council delegated powers to a local trust committee that enabled it to function as management coordinators for the several stakeholder agencies. Islands Trust Council granted permission to SSI LTC to raise a local tax requisition to fund the work.

Prior to SSIWPA, the work of watershed oversight was largely conducted by private societies and environmental interest groups. Management plans were undertaken, yet because of the absence of levers to implement actions, their recommendations were not thoroughly effectuated. However, SSIWPA was continues to benefit from the substantial body of evidence, as well as monitoring and outreach work undertaken by those societies and groups.

Over the first year, SSIWPA refined its structure: Steering Committee and two advisory bodies, a Technical Advisory (TAC) and a Public Advisory (PAC) (specific to the watershed). The Steering Committee is a roundtable of elected officials and representatives from local, regional and provincial government agencies responsible for water quality, drinking water safety and watershed health. Local First Nations groups have been invited and are welcome to join the SSIWPA SC.

The mandate of the TAC includes peer review of existing scientific and technical information, identification of knowledge gaps and preparation of technical recommendations for watershed remediation.

The PAC includes representation of the various public stakeholder groups affected by and implicated in the particular watershed in question. The PAC mandate emphasizes action as a conduit for the identification and consideration of community values, and the provision of input on social, cultural, economic and environmental relevance of watershed issues and the priorities that drive those values.

SSIWPA's work has been initially focused on the largest surface water body on Salt Spring Island that is a source of potable water - St Mary Lake. Once the management plan for SML is completed and implemented, other watersheds will be targeted, beginning with Cusheon Lake watershed.

Because of on-going concerns about water quality and quantity, management of the St. Mary Lake watershed has been of community concern for many years. Settlement of private lands in the watershed predates the introduction of community planning (established in the 1970's), and includes residential, agricultural and recreational land uses. The watershed is now characterized by a diverse group of users with a variety of interests. Since the 1990's, land use regulations have also addressed some of the activities along the lake margin that could degrade water quality.

The North Salt Spring Waterworks District and Capital Regional District (operator of Fernwood-Highland Water Commission) have undertaken projects to address water quality challenges, such as artificial aeration of the lower level of the lake during May-October in several years.

Volunteer groups, such as the Salt Spring Water Preservation Society, the Salt Spring Island Water Council Society and the St. Mary Lake Steering Committee (a previous stewardship group, unrelated to the current SSIWPA Steering Committee), have worked to restore and protect the water quality of St. Mary Lake. The St Mary Lake Steering Committee released the St. Mary Lake Watershed Management Plan (2009) to recommend primary objectives and a range of actions. The objectives put forward in that Plan were the result of work by many groups and individuals; some objectives were implemented through the actions set out (such as the continued operation of hypolimnetic aerators by NSSWD). A primary recommendation in the 2009 SML Management Plan was that a coordinated, whole watershed approach was necessary. The objectives listed in the previous SML Management Plan (2009) appear in Table 7.

Prior to the formation of SSIWPA, there had been no coordinated governmental approach to watershed management at St. Mary or other drinking water lakes, although different agencies and groups at the local, regional, provincial and federal level have intersecting responsibilities and have taken, and continue to fund and take individual actions. Coordinated watershed management relies on informal and formal agreements, an equitable and consensual multi-stakeholder decision table, and an on-going recognition of watershed management objectives, which SSIWPA is now poised to provide.

Table 7. SML Management Plan Objectives, 2009

Item	Objective
1	Define SML watershed; map waterways, land uses, riparian areas
2	Monitor all P inputs and sources, scientific data analysis
3	Reduce P loading through aeration
4	Reduce P loading through domestic sewage inputs
5	Reduce P loading through surface runoff in built up areas
6	Reduce P loading from runoff in other areas
7	Continue to assess P reduction target
8	Encourage stewardship and provincial protection

APPENDIX 5. Governing Laws, Bylaws and Regulations

Islands Trust

- Bylaw 434. Salt Spring Island Official Community Plan (2008). Objectives that relate to watershed management and land use planning: http://www.islandstrust.bc.ca/ltc/ss/pdf/ssbylbaseocp434vol1.pdf

Especially,

- Watershed and Islet Residential Designation Section B.8.1. (e.g. B.8.1.1.2. To avoid an increase in development or activity within watershed catchments.)
- Objective C.3.2.1.3 "…to ensure that zoning changes do not result in such a level of development in North Salt Spring Waterworks District, such that water would not be available for firefighting, hospital and school expansion, and affordable housing."

Appendices

- Obj. c.3.2.1.5 applies to regulation of the demand of "island water sources" (not only St Mary Lake) to ensure that agricultural activities can still obtain water.
- Map 1 in OCP Schedule A, available at: http://www.islandstrust.bc.ca/islands/local-trust-areas/salt-spring/bylaws/salt-spring-island-official-community-plan-bylaw-no-434.aspx
- Map 21, Bylaw 434. Development Permit Area 4 Lakes, Streams and Wetlands http://www.islandstrust.bc.ca/ltc/ss/pdf/ssbylbaseocp0434map21.pdf And Map 28. DPA 7 Riparian Areas. http://www.islandstrust.bc.ca/media/328027/ocp_28.pdf

Riparian Areas Regulation

RAR Bylaw 480. http://www.islandstrust.bc.ca/media/312024/ss-bl-480-adopted.pdf

Madrone Environmental Services Ltd. (2012) The Salt Spring Island Riparian Areas Regulations Peer Review – St Mary Lake and Cusheon Lake Watersheds (Prepared for Stefan Cermak, Islands Trust by Madrone Environmental Services Ltd.): http://www.islandstrust.bc.ca/media/241698/Peer_Review_Fina_Report_for_St_Mary_Lake_and_Cusheon_Lake_RAR_Assessment_Peer_Review_Salt_Spring_Island.pdf

Islands Trust Community Stewardship Awards Policy

Islands Trust Policy Manual. Chapter 2. Subsection 1. Subsection xi. Community Stewardship Awards Program. http://www.islandstrust.bc.ca/media/284719/21xicommunitystewardshipawardsprogram.pdf

- "to recognize and encourage the actions of individuals and organizations that support the mandate of the Islands Trust." This program is delivered every two years, on odd-numbered years.

Capital Regional District

Storm water Runoff Control

Bylaw 2454 Salt Spring Island Stormwater Quality Management Extended Service Establishment No. 1, 1996:

https://www.crd.bc.ca/about/document-library/Documents/bylaws/liquidwasteseptagesewersourcecontrolandstormwater

Fees and Charges

Salt Spring Water Service Area Fees and Charges Bylaw 3864. No 1. 2012:

https://www.crd.bc.ca/about/document-library/Documents/bylaws?liquidwasteseptagesewersourcecontrolandstormwater

Septic Systems and Management

Management of Onsite Sewage Systems in the CRD. Bylaw 3478. 2007: https://www.crd.bc.ca/about/document-library/Documents/bylaws/liquidwasteseptagesewersourcecontrolandstormwater

And Bylaw 3479:

https://www.crd.bc.ca/docs/default-source/septic-pdf/onsite-sewage-systems-bylaw-crd-bylaw-no-3479.pdf?sfvrsn=6

Septic Bylaw Information Page with FAQ:

https://www.crd.bc.ca/service/sewers-wastewater-septic/septic-systems/certifying-septic-maintenance

Homeowner's Septic Information Webpage:

https://www.crd.bc.ca/service/sewers-wastewater-septic/septic-systems

CRD weblink: www.crd.bc.ca/septic

CRD septic information line at 250-360-3187

CRD septic email inquiries septic@crd.bc.ca.

More Septic Resources:

http://www.crd.bc.ca/service/sewers-wastewater-septic/septic-systems/septic-system-resources

FAQs about Septic: https://www.crd.bc.ca/docs/default-source/septic-pdf/septicsavvyonsitefaqtype1.pdf?sfvrsn=2

How to find your septic tank: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/septic_tank.pdf

What Health Regulations apply to Septic Systems? http://www2.gov.bc.ca/gov/topic.page?id=1B1F09DF74D24580BD6CC28AF4F30074

Who can service Septic Systems? http://www2.gov.bc.ca/gov/topic.page?id=25E8D42DFB1B42658FA91E40253E5CA7#authorized-persons

Septic Savvy Kit: http://www.crd.bc.ca/docs/default-source/septic-pdf/septic-savvy-household-information-kit-.pdf?sfvrsn=0

CRD Videos:

Appendices

How Septic Systems Work:

https://www.youtube.com/watch?v=1D6edKPsniM

What can go wrong with your septic system?

https://www.youtube.com/watch?v=sFcVH4H6Ge4

Operating and Maintaining a Septic System

https://www.youtube.com/watch?v=7egqnL0PiPs

Provincial Ministry of Environment

Bill 18 Water Sustainability Act (2014):

The Act

http://leg.bc.ca/40th2nd/3rd_read/gov18-3.htm

Regulations for Groundwater Protection have been set out by the provincial government here:

http://engage.gov.bc.ca/watersustainabilityact/regulations/

At the time of writing, the province had yet to begin regulations for the following (which will have impacts on the current IWMP for St. Mary Lake):

Water objectives

Water sustainability plans

Licence reviews

Designated agricultural water

BC Surface Water Treatment Objectives

Info: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/how-drinking-water-is-protected-in-bc

Regulations: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/200_2003

BC Approved Water Quality Guidelines – Summary Report (May 2015).

These regulations apply to drinking water lakes on Salt Spring Island, such as St. Mary Lake.

http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/waterqualityguidesobjs/approved-wat-qual-guides/wqg_summary_2015.pdf

BC Riparian Areas Regulation

These regulations apply to all lakes and surface water bodies on Salt Spring Island

http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/fish/riparian-areas-regulation

Revegetation Guidelines

http://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/riparian-areas-regulations/rar_reveg_guidebk_sept6_2012_final.pdf

Fish Protection Act

http://www.env.gov.bc.ca/habitat/fish_protection_act/act/documents/act-theact.html

Provincial Ministry of Agriculture, and Lands

Farm Practices Protection – Right to Farm Act

Right to Farm

http://www.bclaws.ca/Recon/document/ID/freeside/00_96131_01

Agricultural Research Development Corporation of BC

Environmental Farm Plan

EFP

https://www.bcac.bc.ca/ardcorp/program/environmental-farm-plan-program

Drainage (Runoff) Management Guide

Guide

http://www.al.gov.bc.ca/resmgmt/EnviroFarmPlanning/EFP_Drainage_Mgmt_Guide/Drainage_Mgmt_Guide_toc.htm

Nutrient Management Guide

NM Guide

http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/EFP_Nutrient_Guide/Nutrient_Guide_toc.htm

Irrigation Management Guide

Irrigation Guide

https://www.bcac.bc.ca/sites/bcac.localhost/files/Ardcorp_Program_Documents/EFP/Irrigation%20Managment%20Guide.pdf

Provincial Ministry of Health
B.C. Drinking Water Protection Act
Drinking Water Protection

http://www.bclaws.ca/Recon/document/ID/freeside/00_01009_01

Health Canada
Canadian Drinking Water Guidelines
http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/guide/index-eng.php

and Summary Table (2014)

http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index-eng.php

Fisheries and Oceans Canada
DFO. Pacific Region Operational Statement. Version 3.0. Measures to Protect Fish Habitat

When Building Your Dock and Boathouse. Retrieved from http://www.klsb.org/wp-content/uploads/2012/11/Appendix-B_1.pdf

APPENDIX 6. Planning Process

Structured Decision-Making

Structured Decision Making, or SDM, is an organized framework for making defensible choices in situations where there are multiple interests, high stakes, and uncertainty. It is designed to provide stakeholders and decision makers with insight about the decision by clarifying objectives, identifying creative alternatives, evaluating how well different objectives are satisfied by different alternatives, exploring how risky some alternatives are relative to others, and exposing the fundamental trade-offs or choices that need to be made. It is particularly useful for groups working together on complicated planning and decision-making projects. For more information on SDM consult the SDM website at www.structureddecisionmaking.org/.

The Planning Approach

These are the main steps that were followed in the process of developing the Management Plan.

- Understanding interests and developing the planning objectives;
- Characterizing the relationship between objectives, water quality, and management actions;
- Developing and characterizing management actions;
- Screening and prioritizing management actions; and,
- Identifying and prioritizing data gaps and needed studies.

The planning steps and activities were carried out over three SDM workshops, that were facilitated by Compass and supported by a number of integration activities by the SC, TAC, and PAC in between the workshops. In addition, a project initiation meeting was held in the fall of 2014 to develop and confirm a terms of reference (or Decision Charter) for the planning process. The Decision Charter described the planning context, scope, roles and responsibilities, and work plan. For a more detailed description of the planning steps refer to Decision Charter (Angus and Harstone, 2014; www.ssiwatersheds.ca/ssiwpa-reports/). The Final SML SDM Report, and each workshop report, can be found on the SSIWPA website.

The Objectives and Management Actions in this Management Plan were developed through input from the Public Advisory committee (PAC), the Technical Advisory Committee (TAC) and through input and guidance from the SSIWPA Steering Committee (SC).

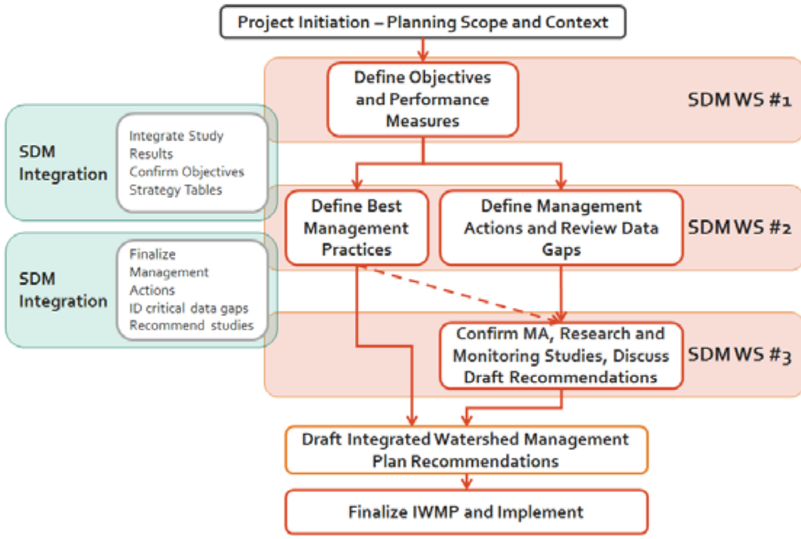

Figure 11. Schematic of the Planning Process

A Project Team composed of SSIWPA Coordinator Cowan, SSIWPA Chairperson Grams, Islands Trust Planner Cermak, and consultants from Compass Resource Management met as required to compile information, prepare for the SDM WS, and coordinate the SDM integration tasks including this final report.

SSIWPA provides a forum through which the several agencies who share responsibility for management of the SML watershed can coordinate their management actions. In that context SSIWPA drafted this Management Plan, considering the various interests and objectives identified by the PAC and the technical recommendations of the TAC, as identified throughout the rigorous SDM process. As well, the various regulations, policies, licenses, and monitoring requirements of the partner agencies are considered. The outcome of the various planning activities will be the development of the final SML IWMP that will be implemented by SSIWPA with its partner agencies.

Appendices

Understanding interests and developing the planning objectives

The SML planning objectives represent the social, economic, and environmental values that stakeholders hold for the SML watershed.

The preliminary planning objectives were derived from the list of the stakeholders' 'Issues and Concerns' (Appendix 9). They were refined throughout the planning process through input from the SC, PAC and TAC. They were reviewed and discussed during every SDM workshop, and finalized at the end of the Process.

Characterization and Screening of Management Actions

Through the IWMP process, management actions were developed to improve the water quality of SML. A preliminary list of management actions was compiled by the TAC and PAC. The list of management actions was screened for technical and environmental feasibility and applicability to the objectives by the TAC with input from Ministry of Environment representatives. This preliminary screening used the following assessment criteria:

- Effectiveness – under most conditions the management action is likely to help reduce the amount of Phosphorus available in the lake water or sediments.
- Technical viability – under most conditions the management action is technically sound, feasible, and manageable on an ongoing basis (if need be) and/or has proven successful in other jurisdictions.
- Governance – the management action is applicable under existing laws and policies or could be implemented under new bylaws or amendments to bylaws.

The TAC preliminary screening assessment resulted in the removal of many of the proposed management actions including all physical works (except aerators) and all chemical treatments. A list of the management actions that were screened out at this stage appears in Appendix 10. The actions that remained largely dealt with addressing phosphorus inputs from stormwater sources (including runoff from properties in the watershed by way of ditch, creek or stream drainage, as well as non-point source overland runoff), improving development permit area bylaws, and improving education of residents on best management practices (BMP) to reduce phosphorus loading.

Following the preliminary screening of management actions by the TAC, a two round assessment process was adopted. Figure 12 summarizes the management action assessment process.

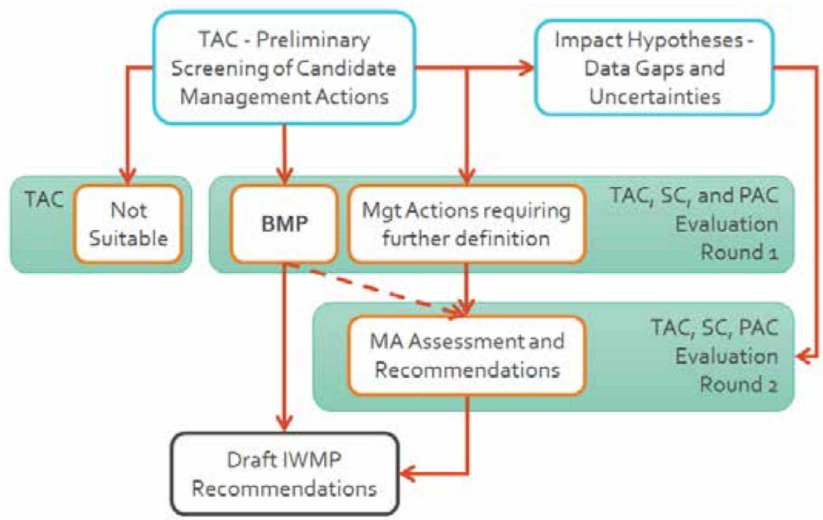

Figure 12. Management Action Assessment Process

In round one (SDM Workshop II), the Steering Committee agreed that the remaining management actions should be restructured to focus on public outreach and education by further developing a Watershed Stewardship Education Management Action Package, and Agriculture Education Management Action Package.

As well, the SC suggested in SDM Workshop II that the TAC with assistance from the CRD should develop a SWM scoping study for inclusion into the Plan.

Round 2 of the management action assessment task occurred during the second SDM integration phase (the time period between Workshops II and III). Through integration activities such as further TAC interviews by the project team, and the regular PAC and TAC committee meetings, the candidate management actions were refined.

During the SDM Workshop III (final one), the Steering Committee confirmed the final list of management actions. The SC recommended additional information be included in the Plan for the application of the DPA; modified then confirmed the Storm Water Management Scoping and Design study details; restructured the various components of the watershed stewardship education and the agriculture education management actions; and, agreed that for all education management actions SSIWPA would act as collaborator and assistant for funding and implementation, but that it would rely on the participation of interested local organizations in carrying out the educational activities.

Identification of Data Gaps and Future Needed Studies

A list of potential research and monitoring studies was developed by the TAC. Appendix 12 contains a summary table of Data Gaps that were identified by the TAC.

The TAC assessed the probability that study results would affect future watershed management actions, as follows:

- High: this study has a high probability of impacting future water management actions that will reduce phosphorus loading (or in some way affect the phosphorus budget in a way that aims to reduce frequency and intensity of algal blooms)
- Medium: this study has some likelihood of impacting future water management actions that will reduce phosphorus loading (or in some way affect the phosphorus budget in a way that aims to reduce frequency and intensity of algal blooms)
- Low: this study is not likely to serve as a basis for future water management actions that will reduce phosphorus loading to the lake.

During the SDM workshop III (the final one), the SC assessed each of the future research study proposals. SC took into account a wider range of considerations than did the TAC, including: the quality of information, the cost of undertaking the study, the agency responsible, and the overall timing of the study in relation to SSIWPA's other priorities. The SC assigned a priority to each the studies defined by the TAC using the following scale:

- High: this study must be undertaken in order to make responsible future water management decisions.
- Medium: this study is recommended as it will likely affect future water management decisions.
- Low: this study is not likely to serve as a basis to make future water management decisions.

Public Input and Stakeholder Engagement in the Planning Process

Concern over the level of public input into the 2008 SML management plan was one of the key reasons SSIWPA chose to undertake an integrated watershed management planning process on SML. Public input into this Draft Management Plan occurred through:

- The SSIWPA PAC: included a broadly representative sample of Salt Spring Island residents who rely on the St. Mary Lake Watershed for drinking water, recreational and economic purposes. (Appendix 7)
- Regular PAC meetings: provided a forum for the PAC members to contribute input from the public at large and to conduct the planning tasks assigned by the SC.
- SSIWPA Open House November 2014: provided an opportunity for members of the public to contribute their interests to the planning process. These discussions were recorded (Appendix 9) and contributed to the development of the planning objectives in the multi-stakeholder process.
- SDM Workshops: PAC members and members of the public at large were encouraged to attend the SDM WS as observers. Given time in the meeting agenda, the floor was regularly opened to questions and comments from the public. Public put was recorded and included into the process record.
- SDM Process Reports: detailed process reports included a summary of the feedback received at the various committee meetings and open houses and most importantly how those comments and interests they represented were addressed through the planning process.

SSIWPA coordinated a public consultation process in July to August 14th, 2015, in order to receive broad public input into the recommendations in this Plan. The public consultation process will allow feedback through mail, email, phone calls to the SSIWPA coordinator, and in person during an evening public open house and several daytime information sessions, to review the Draft Plan.

Assimilation of public input into the plan will be completed by early September 2015 (Appendix 14). Plan implementation is scheduled for October 2015.

Aboriginal Values and Input to the Planning Process

Outreach by SSIWPA Coordinator is ongoing.

APPENDIX 7. Public Advisory (PAC) Group Membership

Name	Affiliation
Anna Haltrecht (Ian VanWyck – alternate)	Watershed resident and lakefront property owner
Catherine McEwen	Water and ecological education, Member-At-Large
Herb Otto	Watershed resident, CRD Trail Advisory Committee, Trail and Nature Club Member
Hugh Greenwood - alternate	Water Council
John Borst	Water Council
Judy Smith (and alternate SD64)	Rowing Club
Kelly Hyslop	Lady Minto Hospital Foundation
Ken Byron	Watershed resident and lakefront property owner, agriculture
Margaret Thomson (alternate)	SSI Agricultural Alliance
Maxine Leichter	SSI Water Preservation Society
Murray Nurse	Chamber of Commerce
Randy Cunningham	Watershed resident and lakefront property owner, resort owner
Rob Pingle	School District 64
Robert Huber	Watershed resident
Susan Grace	SSI Agricultural Alliance
Usha Rautenbach (alternate)	SSI Water Preservation Society

APPENDIX 8. Stakeholder Interests & Preliminary Planning Objectives (before screening)

The following steps generated the list of preliminary interests and objectives:

1. Scoping interviews with SC and TAC members;
2. The project kick-off meeting with SC, TAC, and PAC members;
3. Drafting the Decision Charter with SC, TAC, and PAC input;
4. Feedback received from the SC, TAC, and PAC committee meetings; and,
5. SDM tasks assigned to the committees in preparation for Planning Workshop #1.

Source	Interest	Treatment
SSIWPA Open House	Contaminants (ie. Chemicals from roads,overland runoff, pharmaceuticals/others) - Knowledge sufficient about those other than P? Inclusion of how to reduce in the IWMP	**Means objective** – The TAC is focusing on P budgets in their research. This item flagged for follow up with TAC.
Open House Table Notes	Cost needs to fit community economic reality	**Fundamental objective** – costs are considered throughout the SDM steps
PAC 31 January	Cost of remediation or actions is a real issue for lakeshore accommodation operations	**Fundamental objective** – costs are considered throughout the SDM steps
Open House Table Notes	Timing of plan implementation and practicality	**Strategic objective** – addressed under planning approach
Open House Table Notes	Aquatic wildlife health	**Fundamental objective**
Open House Table Notes	Need to set standard for evaluation of 'improvement' during implementation	**Strategic objective**
PAC 4 November	Different types of publication and participation needed for success	**Means objective** – see planning approach
Open House Table Notes	Governance - are all who have authority and interest actually invited and involved?	**Process objective** - see planning process and structure of committees
Open House Table Notes	Water quantity is not address in IWMP but equally important	**Considered out of scope for IWMP**
PAC 31 January	Is 'Quantity" too broad an issue for SSIWPA to handle, under the current structure? The addition of quantity to SSIWPA's mandate needs appropriate sourcing or outsourcing.	**Considered out of scope for IWMP**
Steering Committee 16 January 2015	Invasive species - fish and plants should be considered (others?)	**Means objective** – included as sub-objective to aquatic ecosystem health
Steering Committee 16 January 2015	A review of grant and financial assistance resources	**Means objective** – in the assessment of alternatives funding opportunities will be reviewed.

Source	*Interest*	*Treatment*
PAC 31 January	TAC advice to IWMP should receive priority over non-scientific advisory input.	**Process objective** – SDM uses a values focused approach; places hard to quantify values on equal footing with more conventional measures.
PAC 31 January	Effective interagency communication – Especially for evaluation of implementation steps.	**Process objective** – Interagency communication occurs through the SC and given additional consideration under the SDM steps
PAC 31 January	Communication with lakeside users for potable source. Those who are not on "municipal water".	**Fundamental objective** – costs are considered throughout the SDM steps
PAC 31 January	Water District Rate Structures - Variation in rates for treated water from each of the two water districts that draw from SML should be harmonized to encourage conservation. CRD has higher infrastructure cost, but much lower rates at each step of graduated scale.	**Considered out of scope** – objective of IWMP is to improve source water quality
PAC 31 January	SSIWPA Resources should prioritize Public Awareness and Education more than they are.*	**Means objective** – public education addressed under preliminary management actions.
PAC 31 January	A Sustained Public Awareness Campaign is essential for success of IWMP.	**Means objective** – public education addressed under preliminary management actions.
PAC 31 January	A positive approach when conducting public awareness - Especially about water supply/quantity, demand, and what constitutes "conservative use."**	**Means objective** – public education addressed under preliminary management actions.
PAC 31 January	Certain "local values" appear to be directly incompatible - concern about "how" and who will be prioritizing the values that are deemed most important.**	Strategic objective – process is designed to maximize public consent under available budget
PAC 31 January	TAC options will need to be presented to the public. Concern TAC present options with pros and cons both to the Steering Committee and the public.	Strategic objective – process is designed to maximize public consent under available budget
PAC 31 January	Fish Stocking - is stocking essential for fishing to continue at the lake? Ecosystem study warranted.	Means objective – impact of fish stocking requires further study

APPENDIX 9. List of Management Actions Removed During Preliminary Screening

Proposed Management Action	***No or Low Technical Viability***	***Not Effective to Significantly Reduce Phosphorus***
Hypolimnetic withdrawal * **	√	√
Dredging	√	uncertain
Removal of macrophytes (aquatic plants)	unknown	√
Sewers		√
Periphyton substrate (for growth, then removal of plankton, thus also removal of nutrients in these organisms)	√	√
Lake level		Outside scope of TAC to advise
Dilution flushing	√	√
Diversion	√	√
Destratification	√	√
Chemical addition: Nitrogen	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Iron	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Flocculants	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Sediment capping	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Phosphorus	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Bacteria	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Algicides	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Aluminium salts	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment
Chemical addition: Calcium	Not allowed by Ministry of Environment	Not allowed by Ministry of Environment

* ** See Footnotes 1 and 2 on following page

[1]Hypolimnetic withdrawal to Duck Creek:

Efficacy at significant removal of P that would otherwise be internal loading during the non-stratified period:

Although P is released from the sediment during stratification (anoxia), the concentration gradient remains quite steep from the bottom to the thermocline. There was no evidence of diffusion of P across the thermocline. Therefore, nearly all the P released during anoxia stays in the hypolimnion until turnover. At turnover, some P that is mixed from hypolimnion through the full lake re-binds with iron and settles out as a particulate. Previous estimates of the amount of P that could be removed through hypolimnetic withdrawal were calculated as:

(total P in fall after turnover) - (total P in spring), which has now been found to overestimate the amount of P actually being “loaded” into the lake (Squires, 2015). As such, hypolimnetic withdrawal during stratified months is not likely to be an efficacious method to reduce late winter and springtime levels of available phosphorus in the epilimnion.

Technical viability:

The cost far outweighs the benefit. The south end of SML is shallow and a pipe would need to stretch far into the lake to access the high P water of the hypolimnion. Not only would the capital cost of such works be very high, there is not sufficient water in SML to enable ‘dumping’ of water for those purposes. The water exported would need to be more than is available, in order to reduce the overall P load in the lake by a significant amount so as to impact algal production. NSSWD has conditions on its water license that guide how it manages the lake level and meeting those conditions would not permit release of that volume of water to Duck Creek during the period of stratification (when the P is high at the bottom), because it is when water supply is dependent on rainfall and vulnerable to drought. In the winter, when the water is available, the lake is unstratified and there is no high P bottom water to export.

[21]Hypolimnetic withdrawal for water treatment intakes:

Efficacy:

(see above under Hypolimnetic withdrawal to Duck Creek – explanation applies here also)

Technical Viability:

NSSWD has two intakes currently. One is already in the hypolimnion part of the year. The new plant will have one intake that is adjustable in order to access the best water to maintain treatment efficiency and treated water quality. That intake will be in the hypolimnion but it will not be near the bottom where P concentrations are highest because the same anoxic conditions that cause release of P from the sediments also cause release of manganese and iron and formation of ammonia and hydrogen sulfide gases. Each of these interferes with treatment operations and finished water quality and ammonia can also interfere with chlorine disinfection. The nearer to the bottom, the worse those problems are so there is no possibility of making the intake lower. Furthermore, the new plant will produce a waste product (float), which is costly to de-water and dispose of and the annual operational costs will increase if the water is of lower quality. So, the new plant cannot be designed to withdraw maximum phosphorus from the hypolimnion for two reasons: it would jeopardize the quality of the treated water and it would increase costs to NSSWD ratepayers.[2]

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[1] An example of effective public education was cited: Signage that “Water is a precious resource” and “Remember to turn off the tap when brushing your teeth” have been very effective in Europe for reducing consumption of potable sources. It was suggested that more of the Coordination funding should be allocated to public awareness and education campaigns on SSI.

[2] It was noted in the PAC meeting Jan 31 2015 that the schools are already carrying on an extensive water conservation awareness education program.

APPENDIX 10. List of Future Research Studies
(that were removed after June 19, 2015 Steering Committee review of the Compass Resource Management Planning Report)

Biomanipulation Study	
Research Question	Can the current stocking program be modified to include more beneficial species such as piscivores to help reduce the level of algal biomass in SML?
Related Management Decision	To determine if changes to existing stocking programs should be discussed with MoE. Should they stock more suitable piscivores fish species?
Suggested Study Methods	Step 1: Maggie Squires studied the 2014-15 phyto- and zoo-plankton abundance data along with the 2012 fish assemblage data from MOE. See Biomanipulation Report by M. Squires, 2015. Step 2: No longer needed, based on results of Step 1.
Duration	Complete
Approx Costs	n/a
TAC Rating	Low n/a
SC Rating	No longer recommended
Waterfowl Effects on Water Quality	
Research Question	At what waterfowl density does fecal and nutrient contamination of lake water potentially occur?
Related Management Decision	Results would inform decisions about a waterfowl management program. E.g. egg addling, and other bird deterrents.
Suggested Study Methods	Mass balance study of estimated contributions of P from waterfowl feces. Was completed June 2015.
Duration	Results in June 19 agenda package. See below.**
Approx Costs	Negligible. In-kind.
TAC Rating	No further study or action recommended (Sprague, 2015)
SC Rating	No further study or action recommended (Sprague, 2015)

Aerator Engineering Study	
Research Question	Why did current aerators appear to function appropriately in only some of the years of use and to fail in other years? (See Impact Hypothesis Sheet #5)
Related Management Decision	To understand conditions for appropriate use of aerators, if any, in this watershed or others on Salt Spring I.
Status	At the time of publication, Steering Committee removed this item from the current IWMP because aeration was not determined (based on available data) to have significant benefits (ie assurance that it would reduce algae/cyanobacterial production) to offset negative consequences in SML.

Waterfowl Effects on Lake Quality Study Results*:

The total phosphorus input estimate for all species of birds visiting St. Mary Lake and over-wintering is 13kg/yr. This is a relatively small amount, and compares to the estimated 10kg/yr. that seeps into the bottom of the lake through groundwater flow into the lake. There are two interpretations of the potential impacts of the bird P inputs: 1) it is "new P" because it was previously locked up in other elements of the ecosystem, and is now available to stimulate algal growth, and 2) it is not a new addition to the lake, because it was already there in the form of plants and animals which would eventually decay and release their P content to the water anyway. (Sprague, 2015 and the SSIWPA June 19 2015 Agenda Package).

APPENDIX 11. Impact Statement Summary Table

The table right summarizes the research impact statements that were studied by the TAC during SSIWPA's SML Monitoring Program 2014-15.

ID#	Impact Statement (IS)
1A	Creek inflow and storm-water runoff from land contribute P to SML and might increase available P in the lake with consequent increase in frequency and distribution of algal/cyanobacterial blooms.
1 B and C	External sources of P from lakeside septic fields is increasing the total available P in SML and may increase the frequency and distribution of algal / cyanobacterial blooms. (This applies to groundwater movement into the lake, as well)
1D	Atmospheric desposition contributes significant amounts of phosphorus to St. Mary Lake surface waters through rain and dust fallout.
2	*Option 2A:* P-internal loading may occur in St. Mary Lake and its magnitude may be similar or lower than P-external loading. *Option 2B:* P released by bottom sediments (during fall overturn, and remaining as residual in the upper lake water after re-sedimentation has occurred) may increase the frequency and distribution of algal / cyanobacterial blooms.
3	Inter-annual variation in the amount of phosphorus (P) corresponds with inter-annual variation in the level of algal biomass in SML.
4	Trophic interactions (food web dynamics) affect the frequency and severity of algal and cyanobacterial blooms.
5a	(Two options using the same hypothesis were explored): Hypolimnetic aeration **IS NOT** an effective tool to reduce phosphorus (P) loading (i.e. P-internal total loading) in SML or to reduce the occurrence of cyanotoxins.
or 5b	Hypolimnetic aeration **IS** an effective tool to reduce the total available P in SML and contributes to a reduction in the frequency and distribution of algal / cyanobacterial blooms:

APPENDIX 12. Data Gaps and Uncertainties Summary Table

The table below summarizes the uncertainties identified in the Impact Mini-Reports and any outstanding data gaps that were identified either in the Impact Mini-Reports or during the course of the IWMP planning process as of the time of writing. These uncertainties and data gaps lead to the development of the Future Research and Monitoring Table by the TAC.

IH ID#	Description of Data Gap or Uncertainty

1A	Different land cover and uses in SML watershed render the use of Cusheon watershed coefficients questionable. • Calibrate coefficients to watershed
2	Assess sedimentation after overturn and sediment pore water P concentrations in order to confirm conclusions of the 2014-15 monitoring program research results and the magnitude of internal P loading.
4	Confirm change over time in the fishery that is evident in 2009 and 2012 data. • Assess total fish abundance and biomass • Refine phytoplankton data (depth-stratified sampling and diurnal zooplankton and spatial variation near and offshore). Additional research on food web dynamics was discussed throughout the SDM process. After the final workshop on May 25, 2015, research on the interactions between zoo plankton, fish, and fish stocking was conducted by a previous TAC member in June, 2015 with the data available. On that basis, biomanipulation for St. Mary Lake was not recommended (Squires, 2015). Also, see Impact Mini-Report #4.
5	Since hypolimnetic aeration is intended to reduce internal P loading, reducing uncertainty about the magnitude of internal P loading (in #2 above) will also provide clarity on the efficacy of hypolimnetic aeration.
All	Additional research on algal blooms may assist IWMP implementation and adaptive management – what factors contribute to the formation of cyanotoxins?

APPENDIX 13. Impact Mini-Reports

One mini-report is presented below, for each of the impact statements in the summary table above in Appendix 12.

Impact Mini-Report - 1A. External Sources of Total Phosphorous from Creek Inflow and Storm Water

by Donald O. Hodgins

Impact Statement

Creek inflow and storm-water runoff from land contribute P to SML and might increase available P in the lake with consequent increase in frequency and distribution of algal/cyanobacterial blooms.

Description

Storm water runoff, from both roadside ditches and Epron Creek which enters St. Mary Lake at its northwest corner, contribute P to the lake.

External Influences

Possible external influences are land use within each drainage basin, land cover, slope and soil composition. Agricultural practices are considered an important factor that may contribute higher P loads than other land uses.

Assessment

An estimate for the P load associated with runoff was obtained by combining storm water inflows with in-creek measurements of P concentration, made during the period 2008-2015. The inflows were calculated using a water balance model for the lake, based on measured water levels and withdrawals. Details of the water balance model are provided in Hodgins (2015). Simulations for several years provided a range of P-loads. Variations are related primarily to precipitation.

A second independent estimate was made by transferring an export coefficient derived from a study of the Cusheon Lake watershed (Sprague 2007) to the St. Mary Lake watershed. The Cusheon value of 0.089 kg of P per hectare of watershed was based on four independent estimates, which were in general agreement, and included one year of intensive monitoring of creek runoff.

Results from Analysis

The calculations based on the water balance model and the in-creek measurements yielded P loads from land runoff ranging from about 60 to 176 kg/yr for dissolved P, depending upon rainfall amounts. The average value is 90 kg/yr. The load is greatest during the wet winter months and is negligible over the dry summer months. By way of comparison, Nordin et al., 1983 estimated dissolved P loads in two years of 19 and 27 kg/yr (9 months) for Epron Creek alone. On the basis that the Epron Creek watershed represents 28% of the total watershed area, those values scale up to 68 to 97 kg/yr, which is in reasonable agreement with the range from the first method. The range for total P is 100 to 314 kg/yr. The annualized mean value derived using the Cusheon export coefficient is 45 kg/year.

Consequences of Being Wrong

A large error in estimates for P from runoff affects the interpretation of the total phosphorus balance for the lake, which could in turn affect the assessment of benefits from possible management actions directed at reducing this load. Given the convergence of independent estimates, however, a significant error is considered unlikely.

Uncertainties and Data Gaps

The model results depend upon generalized coefficients for the sources of P for different land uses and land cover. These coefficients are not calibrated specifically for St. Mary Lake. The sensitivity of estimates to the uncertainty in these coefficients has not been determined. Also, the transfer of the Cusheon export coefficient value requires the assumption that land use, land cover and soils are similar for these two watersheds on the island. Some general similarities are noted but, of course, conditions are not identical.

References

(1) http://agsci.psu.edu/aec/webinars-presentations/modeling-and-decision-support-tool-forum/mapshed/mapshed

Sprague, J.B. 2007a. Apparent sources of nutrient affecting Cusheon Lake, Salt Spring Island, B.C.

Background report for the Cusheon Watershed Management Plan, Salt Spring Island, B.C. Sprague Associates Ltd., Salt Spring Island, B.C., 55 p.

Impact Mini-Report - 1B and -1C. External sources of P from Septic and Groundwater

by Donald O. Hodgins

Impact Statement

External sources of P from lakeside septic fields is increasing the total available P in SML and may increase the frequency and distribution of algal / cyanobacterial blooms. (This applies to groundwater movement into the lake, as well)

Description

In saturated soil, P from on-site sewage treatment drain fields can form a plume with concentrations above background. This plume can slowly move from the vicinity of the drain field, down-slope to-ward the lake and eventually reach the margin of the lake where it can flow into the receiving waters.

External Influences

[None provided]

Assessment

In 2014-15 three properties were monitored to determine the extent of saturated ground water zones proximate to the drain fields, and the chemistry and bacterial content of the ground water. In addition, shallow ground water piezometers were installed down-slope of two drain fields, and in the margin of the lake itself. Samples from these wells were also measured for chemistry and bacterial content.

Results from Analysis

P-removal from two of the drain fields ranged from 95% to 99%. No evidence of P above background was found in any of the monitoring wells in the saturated zone, nor was there evidence of E. coli bacteria. At the third property, no saturated zone formed during the entire winter wet period and hence no P-plume could exist. There was some evidence of elevated levels of P in the shallow ground water piezometer immediately proximate to the drain fields (~ 2 m removed) but not at the intermediate or lake-side sites. Given the abundance of goose fecal matter surrounding the piezometers, and the heavily grassed terrain, it is not clear if the measurements correspond to P originating in the drain field or from other sources. However, there is no evidence to indicate P in shallow ground water reaches or enters the lake.

Consequences of Being Wrong

It is conceivable that the monitored sites are not completely representative of all properties surrounding the lake, although based on geological data this is considered unlikely. Accordingly, it is possible that some drain field P is reaching the lake. If so, it is considered a small contribution relative to storm water runoff, and is unlikely to be causing a net increase in lake P content.

Uncertainties and Data Gaps

[None provided]

References

[None provided]

Impact Mini-Report - 1D. Atmospheric Deposition of Phosphorus into St. Mary Lake

by John B. Sprague

Impact Statement

Atmospheric deposition contributes significant amounts of phosphorus to St. Mary Lake surface waters through rain and dust fallout.

Description

How much phosphorus is deposited from the air onto the surface of the lake, per year? (Fallout onto surrounding land is included elsewhere, in calculations of land runoff.)

External Influences

Industrial emissions could increase the fallout. A possible source might be in Crofton because it is westerly, in the general direction of some prevailing winds. However, phosphorus is not one of the substances that is elevated in a major way in industrial emissions; it is generally low in fallout, even in industrial regions, as discussed by Zeman (1973).

Assessment

Amounts of P in rain and dustfall (measured together = “fallout”) were assessed from the literature for this coastal region, and from contacting investigators, particularly Dr. R. Vingarzan, an Atmospheric Processes Scientist with Environment Canada.

Results from Analysis

There were a few estimates for this region in the scientific literature. One excellent set of measurements was taken near Chilliwack (Vingarzan et al., 2003). Somewhat elevated levels might be expected there, because of upwind industry and agriculture. However that survey indicated only 0.071 kg P/year falling on each hectare, after adjustment to the average rainfall on Salt Spring. Two studies in areas north of Vancouver subject to heavy rain provided estimates of 0.087 kg/ha (Zeman and Slaymaker, 1978) and 0.032 kg/ha (Zeman, 1973), both values adjusted to Salt Spring rainfall. Data for a coastal area of Washington state resulted in an estimate of 0.24 kg/ha onto St. Mary Lake after correcting for amount of rainfall and for total P rather than dissolved P (Ellsworth and Moodie, 1964, Gilliom, 1980). That value seems high compared to the others but was accepted.

A relevant study by Dr. Rick Nordin of Univ. of Victoria measured fallout at Sooke Lake during 14 months; his findings translated to 0.065 kg/ha for Salt Spring (Nordin, 2008).

These five estimates were averaged to estimate 0.099 kg P/ha onto St. Mary Lake each year. For the total lake area, that represents approximately 20 kg per year.

Consequences of Being Wrong

Rain plus dustfall constitute a relatively small annual load of phosphorus. Even doubling of that input would not be a major component of the lake's annual budget.

Uncertainties and Data Gaps

Three of the external values are close together (0.065, 0.071 and 0.087). That lends some credibility to our adopted value. Two other values are about equally divergent above and below the average value. No apparent explanation for the divergence was evident in the reports.

References

Ellsworth, N. and C.D. Moodie 1964. Nutrient inputs in rainfall at nine sites in Washington state, 1962 and 1963. State of Washington, Agricultural Experimental Station. Interim Report on Project 1670. 9 p plus unnumbered tables and figures.

Gilliom, R.J. 1980. Estimation of background loadings and concentrations of phosphorus for lakes in the Puget Sound region, Washington. U.S. Dept. of Interior, Geological Survey, Open File Report of 80-328. 37 p. [Cited through Truscott 1981.]

Nordin, R. 2006. Personal communication. [Phosphorus measured in precipitation at the Sooke reservoir] Dr. Richard Nordin, Senior Research Scientist, Environmental Management of Drinking Water, Dept. of Biology, Univ. of Victoria, Victoria, B.C.

Truscott, S.J. 1981. Quantitative models for integrated land use and lake quality planning: applications in the Brannen and St. Mary Lakes watersheds, B.C. Masters thesis, Faculty of Interdisciplinary Studies, Simon Fraser Univ., Burnaby, B.C. 92 p.

Vingarzan, R. 2006. Personal communication. Dr. Roxanne Vingarzan, Atmospheric Processes Scientist, Environment Canada, Vancouver, B.C.

Vingarzan, R., W. Belzer and R. Thomson 2003. Nutrient levels in the atmosphere of the Elk Creek Watershed, Chilliwack, BC (1999-2000). Environment Canada, Aquatic and Atmospheric Sciences Division, Vancouver, B.C. Tech. Rept # EC/GB-02-038. 74 p.

Zeman, L.J. 1973. Chemistry of tropospheric fallout and streamflow in a small mountainous watershed near Vancouver, British Columbia. Ph.D. thesis, Faculty of Forestry, Univ. of British Columbia. 154 p.

Zeman, L.J. and O. Slaymaker 1978. Mass balance model for calculation of ionic input loads in atmospheric fallout and discharge from a mountainous basin. Hydrological Sciences Bull. 23: 103-117. [Cited through Truscott, 1981.]

Impact Mini-Report - 2A. Phosphorus Loading From Sediments (Option A)

by Maggie Squires

Impact Statement

Internal phosphorus loading may occur in St Mary Lake and its magnitude may be similar to or less than that of external loading.

Description

What P-internal isn't: Net increase in the amount of P in the hypolimnion (during stratification) does not represent P loading to the lake (e.g. Hoffman et al., 2013). First, there is P-transport in the opposite direction through re-adsorption and precipitation (e.g. with iron) and re-settling and re-sedimentation

during break-down of stratification (turn-over) (Hupfer & Lewandowski 2008; Hoffman et al., 2013). Second, although P released from 'old' sediment may be the most prevalent form of P that accumulates in the hypolimnion of SML, from 15% to 30% of the hypolimnetic P-pool is probably derived from remineralisation of 'new' externally derived P (Premazzi & Provini 1985 and Nürnberg 2009).

What P-internal is: P released from sediments into the hypolimnion can become P-internal loading

to the lake as described below:

1) During stratification, when sediment-P is transferred out of the hypolimnion and into the epilimnion (surface waters) via eddy diffusion (e.g. Wodka et al., 1983) or via vertical migration of motile algae (e.g. Jones & Arvola 1984); and, when the euphotic zone (where light is sufficient for photosynthesis) extends into the hypolimnion resulting in algal uptake of sediment-derived P.

2) During fall turn-over, when hypolimnectic P is mixed with surface water as a result of entrainment (e.g. Soranno et al., 1997) P becomes available for algal uptake. Specifically, less than 100% of Hypolimnetic P is subsequently re-adsorbed and precipitated (with iron) and, in turn, some of the P released from sediments to anoxic bottom waters becomes available for algal uptake.

The P-sediment hypothesis asks 'on average, what amount of the P released from sediments into the hypolimnion becomes P-internal loading to the lake?'

External Influences

[None noted]

Assessment

To assess the amount of P in the hypolimnion that becomes P-internal loading to the lake, the following data sets were analyzed:

1) Time series (monthly) of total P (TP) concentration through the water column, and P mass in the lake for the period 1979-2015 (# of mo=293, # mo/y is variable).

2) 2x/mo time series of TP and SRP through the water column for July 2014 to March 2015.

3) Molar ratio of total iron to inorganic P in hypolimnetic waters prior to mixing compared with threshold ratio of 2 (i.e. the ratio that corresponds with precipitation and adsorption of P with iron at turnover) in 2014 (n=34).

4) Analysis of the P and iron composition of material accumulated in a sediment trap, deployed at depth through the period of fall turn-over (October to early February).

Results from Analysis

1) **Evidence from molar ratio of Fe to P**: During the 2014 period of hypolimnetic anoxia, molar ratio of total iron to inorganic P in anoxic bottom waters averaged ~8. Among 34 hypolimnetic water samples, only twice did the ratio drop modestly below the threshold level of 2. Molar ratio 4x greater than the threshold provides strong evidence of potentially substantial P-loss during fall turnover to adsorption (4 moles of iron sequester 1 mole of P) and precipitation (2 moles of Fe sequester 1 mole of P) (Gunnars et al., 2002).

2) **Evidence of re-sedimentation**: The TP time series (long term, & 2014-15) indicates there are P-losses from the water column following turn-over that are consistent with re-adsorption, and precipitation and re-sedimentation of some portion of the P that was released from sediments into the hypolimnion during stratification. Settling of iron-P colloids may be slow (Gunnars et al., 2002) therefore the time window (e.g. March to November, or December) for determination of P-internal loading as net change in P-stock from spring to post fall turnover must be sufficiently long that settling of precipitates is close to 100%.

3) **Evidence of P adsorption and precipitation with iron and re-settling re-sedimentation**: iron:P of 13 for material collected in sediment traps during the period of fall turn-over confirms involvement of iron in post turn-over P re-sedimentation. Although it is not possible to scale-up from a single trap to lake wide P-sedimentation, back-of- the-envelope calculations suggest on the order of 100s of kg of P may be re-adsorbed with iron and re-sedimented during and following turn over.

4) **Estimates of total annual P-internal loading**: Comparison of net change in P-mass in the lake for March to November versus for March to December (time window when P-external is low) suggests total annual P-internal loading to SML is on the order of 100 kg P (range 50-150 kg). Notes: P-internal estimates are not corrected for P-external loading or P-export that may occur in the March to December window; P-mass is calculated as P concentration of fully mixed water column multiplied by lake volume.

5) **Estimates of P-diffusion**: Estimates of the contribution of P-diffusion to total annual P-internal suggests diffusion may not contribute significantly to P-internal loading in SML. 2012-13 is a possible exception when, as a result of artificial aeration and mixing of the hypolimnion, there was a steepening of the P-concentration gradient across the thermocline and, in turn, a large increase in the potential for P-diffusion across the thermocline.

6) **Estimates of algal uptake of P in the hypolimnion**: In years when SML was relatively clear (i.e. 2007, 2014), it is likely that sufficient light penetrated across the thermocline to allow algal growth and P-uptake within hypolimnetic waters; however, the relative contribution of this process to total annual P-internal loading to the lake has not been determined. In particular, in years when surface waters become depleted in inorganic P, a large portion of total algal growth may take place in deeper waters where P is more available, i.e. in the thermocline and upper hypolimnion.

7) **Estimate of use of hypolimnetic P by motile algae**: That motile algae access hypolimnetic P during the period of stratification seems probable but the relative contribution of this process to total annual P-internal loading has not been determined.

8) **Relative contribution of P-internal to total annual lake loading**: Using step-wise linear regression to predict March TP concentration and March P-mass from lake conditions in the previous year (i.e. from net change in P-mass from March to November, net change in P-mass from March to December, & minimum water level, etc.) suggests P-internal loading may account for about 50% of the year-to-year variation in March P levels.

Key Findings:

P-internal may indeed occur in SML but the magnitude of total annual P-loading attributable to P released from sediments may be on average ~100 kg (not on the order of 500 kg as suggested by earlier investigations of SML, e.g. Nordin et al., 2003).

Consequences of Being Wrong

In the event P-internal was substantially larger than the estimates provided here (and substantially larger than P-external), one consequence might be over-emphasis on reducing P-external loading and too little or no effort to control P-internal loading and therefore no decrease over the long term in P and algal levels in SML.

Uncertainties and Data Gaps

1) Whether increases in P-internal or increases in P-external or some combination of the two explains why P level in SML is higher in some years than others has not been determined.

2) A large-scale (multiple depth and location) investigation of sedimentation in SML has not been undertaken. The iron content of sediments and sediment pore waters has not been measured (e.g. Orihel et al., 2015).

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Impact Mini-Report - 2B. Phosphorus Loading From Sediments (Option B)

by John B. Sprague

Impact Statement*

P released by bottom sediments (and decomposition) during fall overturn may increase the frequency and distribution of algal / cyanobacterial blooms.

Description

[None provided]

External Influences

Expected factors would be severity of reduced oxygen in the hypolimnion during summer stagnation, and duration of complete anoxia. Completeness of mixing at autumn turnover could also be a factor.

Assessment

One standard method of assessing the initial release of P from the sediments is to estimate the change in total load of P in the lake, from the time of mixing in spring, to the time just after autumn turnover. Contribution from the sediment is the major factor in the change; other inputs are relatively minor, as is the outflow. A slight weakness of this method might be erratic gains or losses during summer. A second method measures the differences in autumn load between (a) years of successful aeration of bottom waters and (b) years of no aeration. A weakness of that method would be year-to-year variation. Either method only measures the initial release. That is followed by major precipitation back into the sediment, and P-internal is the net result of those processes.

Results from Analysis

450 kg/year	(Nordin et al., 1983)
450 kg/year	(Hodgins, 2015)
563 kg/year	(Watson, 2013)
470 kg/year	(Sprague, 2014)

The first three estimates of initial release used the change from spring-time to just after autumn mixing. The fourth estimate used differences for aeration/ no aeration. Averaging the four estimates yields about 480 kg for the initial release of P. There is precipitation of P from the lake to the bottom sediments during winter. That precipitation involves P of all origins, and about 40% of it would be derived from initial release of P brought up at autumn turnover. The rest would be P that had been present in surface layers during the summer.

There has been a study of the relation between total load of P in the lake just after autumn turnover, and the total load at the following springtime mixing (Sprague, 2015). The relationship is variable but there is a clear trend for the load of springtime P to be about two-thirds of the autumn load of P. In other words, about one-third of the autumn load disappears during the winter, largely by precipitation into the bottom sediments. The data for this study are described in Impact Mini-Reports Sheet 5. Calculations indicate that in representative years, the P-internal, i.e. the net contribution from the sediment, would be in the range 120 to 220 kg.

Consequences of Being Wrong

- If P-sediment were grossly over-estimated, expenditures and efforts to reduce it might not be warranted by benefits.
- If P-sediment were under-estimated, efforts to control other sources could be ineffectual.

Uncertainties and Data Gaps

An uncertainty would be the variable behaviour of the lake from year to year.

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Impact Mini-Report - 3. Effect of Inter-Annual Variation of Phosphorus in St. Mary Lake

by Maggie Squires

Impact Statement

Inter-annual variation in the amount of phosphorus (P) corresponds with inter-annual variation in the level of algal biomass in SML.

Description

P-limitation of phytoplankton can occur when both light and temperature are adequate and losses to sinking and grazing are not overly substantial (Hecky & Kilham 1988). When P is limiting, increases in phosphorus availability can result in increases in phytoplankton (or algal) biomass. In SML, P availability in surface waters is relatively low during the summer period of stratification, and is relatively high during the winter period of lake mixing (seasonal, or intra-annual pattern); however, in some years summer and winter P-levels are relatively high and in other years P-levels are relatively low (annual, or inter-annual variation). The ‘phosphorus-algae connection’ hypothesis asks if increases and decreases in P levels correspond with increases and decreases in the amount of phytoplankton (or algal) biomass in SML.

External Influences

[None noted]

Assessment

To assess inter-annual variability in P levels, and whether increases in P correspond with increases in algal biomass, several data sets were analyzed, as follows:

1) Inter-annual variation in TP: Record of March and November surface water TP for the period 1979-2015 (March n=34; November TP n=22).

2) Inter-annual variation in algal abundance: Record of algal abundance on water treatment plant (WTP) intake filters for 2003-2015 (n=472).

3) Inter-annual P versus algal abundance: Paired measurements of total phosphorus (TP) and algal abundance on WTP intake filters (n=105 TP-algal abundance pairs for 2003-2015, TP range 1.7-74.5 µg/L, algal abundance range 18-18,300 cells/ml).

4) Seasonal P versus algal biomass: Measurements of soluble reactive phosphorus (SRP) and TP each paired with algal biomass in surface water grab samples (n=12 P-algal biomass pairs for July 2014 - January 2015,

SRP range 0-27 µg/L, TP range 6.4-51.2 µg/l, algal biomass range 45-927 µg/L).

Results from analysis

Inter-annual pattern:

1) Phosphorus: For the period 1979-2015, March TP is 12.3±22.7 µg/L, range is 6-57 µg/L; November TP is 43±15 µg/L, range 20-67 µg/L.

2) Algal abundance: For the period 2003 to 2015, mean algal abundance on WTP intake filters is 3140±2693 cells/ml, range 18-13,830 µg/L (there is too little data for a seasonal break-down).

3) TP versus algal abundance: There is a weak ($R2 = 0.084$) but highly statistically significant ($p=0.00263$) increase in algal abundance with increase in TP. Based on linear regression, an algal abundance increases of 36 algal cells/ml corresponds with 1 µg/L increase in TP.

Seasonal pattern:

1) Phosphorus: During the summer, in surface waters P availability is relatively low (near or below the limit of detection) and P may limit algal growth. Caveat: Algal growth and biomass in relatively deep waters where P is relatively plentiful may be greater than in surface waters despite lower light levels but has not been measured. During the winter, P is relatively abundant and probably underutilized (non-limiting) because light and temperature constrain algal growth.

2) Algal biomass: During the summer when P-loading is negligible and the lake is stratified, phytoplankton biomass in surface waters is relatively low. During the winter when the lake is fully mixed and receiving P-external, P is relatively plentiful and phytoplankton biomass is relatively high.

3) SRP versus biomass: There is a moderately strong ($R2=0.52$) and highly statistically significant ($p=0.00846$) increase in algal biomass with increase in SRP. Based on linear regression, an algal biomass increase of 20 µg/L corresponds with 1 µg/L increase in SRP.

4) TP versus algal biomass: There is a somewhat strong ($R2 = 0.34$) and statistically significant ($p=0.047$) increase in algal biomass with increase in TP. Based on linear regression, an algal biomass increase of 11 µg/L corresponds with 1 µg/L increase in TP.

Key Findings:

1) P and algal abundance: Across years (inter-annual variation) increases in TP concentration corresponds with increases in algal abundance.

2) P and algal biomass: Across seasons (intra-annual variation), increases in TP and increases in SRP correspond with increases in algal biomass.

3) P control of algal growth?: In SML, as a result of plentiful phosphorus in the winter and scarcity of phosphorus in surface waters in the summer, winter algal biomass exceeds by several orders of magnitude the amount of algal biomass found in the lake surface waters during the summer (there may be additional algal biomass in deep waters but it has not been measured). In the winter, phosphorus is under-utilized because phytoplankton growth probably is limited by light and temperature, not phosphorus.

Consequences of Being Wrong

If we are wrong that increases in P can lead to increases in algal abundance and biomass, and that relatively high and low algal biomass can be explained respectively by relatively high and low intra- and inter-annual P-loading, P-export, and P-sedimentation, then a possible consequence of being wrong might be no action to lower P-loading (and no action to maximize P-export and P-sedimentation) and, as a result, progressive eutrophication, i.e. over time more P and more algal abundance and biomass in SML.

Uncertainties and Data Gaps

1) More than one year of data is required to fully characterize how natural variation in P-loading may affect summer versus winter levels of algal biomass in SML.

2) Dissolved P is the most useful determinant of nutrient loading to lakes, and of nutrient availability for algal growth yet most P measurements in the long term data set are TP.

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Impact Mini-Report - 4. Potential Effect of Trophic Interactions on Total Phosphorus

by Maggie Squires

Impact Statement

Trophic interactions (food web dynamics) affect the frequency and severity of algal and cyanobacterial blooms.

Description

The trophic interaction-algal biomass hypothesis asks if top-down (fish-down) biomanipulation can reduce algal biomass by increasing zooplankton grazing of edible algae (Carpenter et al., 1985). Biomanipulation is accomplished via removal of fish that prey on zooplankton (planktivores) by increased stocking of fish that prey on planktivores (piscivores). Success can also require that planktivores be manually removed from the lake (Sondergaard et al*.,* 2000, 2007, 2008).

Two past 'conditions' have lead to consideration of biomanipulation as a remedial option to reduce algal biomass in SML. The first observation is apparent low relative abundance of the large zooplankton capable of consuming considerable amounts of edible algae that are also the preferred diet of planktivorous fish. The second is illegal introduction into SML of non-native perch (within the last 10-15 years) that in their first year are planktivorous. Adult perch are omnivorous eating zoobenthos associated the lake bottom, small fish including other perch, and plants.

There are number of reasons why biomanipulation may not work, including the following: the SML food web may not adhere to the 'classic' food web model; success depends on proliferation of edible algae yet in eutrophic lakes a greater proportion of phytoplankton biomass may be colonial and filamentous algae that interfere with feeding by large zooplankton leading to proliferation of small zooplankton less capable of reducing algal biomass; and, biomanipulation has been more successful in shallow lakes than in relatively deep stratifying lakes like SML.

External Influences

Assessment of this question is potentially impacted by on-going fish-stocking of SML by the MoE.

Assessment

Co-assessment of the abundance and biomass of edible and nonedible phytoplankton, of macro- and micro-zooplankton, and of piscivorous and planktivorous fish could indicate whether biomanipulation is an option for reducing algal biomass in SML.

Data sets (to be analyzed):

1) Abundance and biomass of micro- and macro-zooplankton size class data for July 2014 to January 15.

2) Abundance and biomass of edible and non-edible phytoplankton size class data for July 2014 to January 15.

3) Fish assemblage based on gillnet data for (2000 not yet received), 2005, 2009, and 2012.

Results from Analysis

Key Findings:

1) Zooplankton: Is abundance and biomass of large zooplankton indeed surprisingly low in SML for its mesoeutrophic status and much lower than the biomass of small zooplankton? It is possible that past sampling protocols have undersampled zooplankton, and that different methods, sampling locations, plus day- and night-time sampling are needed to quantify the abundance and biomass of large zooplankton in SML.

2) Is the predatory zooplankter, Chaoborus, competing with fish for zooplankton (possibly found in fish stomachs)? If Chaoborus is present in SML and a strong competitor with fish for large and small zooplankton, then its presence could thwart efforts to increase zooplanktivory and reduce algal biomass using biomanipulation.

3) Phytoplankton: Is biomanipulation suitable for a lake that experiences high algal biomass during the winter and only occasionally in the summer (one summer in a decade)? Zooplankton tend to be most active during the summer (which may be one reason for high water clarity during some SML summers). Whether zooplankton can control high algal biomass during the winter (when many zooplankton may be inactive) by grazing the edible portion of a phytoplankton assemblage swamped with phosphorus is questionable.

4) Can biomanipulation reduce the occurrence of, and biomass of cyanobacteria blooms in SML? Biomanipulation may not reduce the presence and biomass of cyanobacteria in SML.

5) Fish: Is there an under-abundance of piscivores and over-abundance of planktivores in SML? Gillnetting data for 2009 and 2012 suggest this could be the case in SML.

Relatively low abundance and biomass of bass and relatively high abundance and biomass of yellow perch would seem to make SML a good candidate for using biomanipulation to increase predation on yellow perch, reduce predation on large zooplankton, and increase the abundance and biomass of large daphnia capable of clearing the water column of algal biomass.

6) Food chain: Does SML fit the 'classic' food chain model' of piscivores eat planktivores eat large zooplankton eat phytoplankton even in years when nutrient levels are high? The SML food web may not conform to the 'classic' aquatic food chain (although not conforming doesn't necessarily rule out biomanipulation to lower algal biomass). An extensive littoral zone providing refuge for zooplankton, hiding places for piscivorous fish, and habitat for periphyton and zoobenthos combined with the exclusion of many fish and zooplankton from the hypolimnion for as long as six months in each year suggests that the food web of SML may rely more on shallow water benthic production (periphyton-zoobenthos) than on deep water pelagic production (phytoplankton-zooplankton).

Conclusion

It is unclear whether biomanipulation would improve water quality in SML by preventing high summer algal biomass in years when spring phosphorus is relatively high, or by moderating high levels of winter algal biomass when phosphorus loading swamps phytoplankton growth. Without also reducing external phosphorus loading (which occurs during the winter), a reduction in summer algal biomass seems a more likely outcome of biomanipulation than a reduction in winter algal biomass. While heavy stocking with piscivores to drastically reduce planktivore abundance could bring about improvements in SML water quality, desired outcomes of biomanipulation are rarely achieved and, in addition, unintended consequences are just as likely to occur as those desired outcomes.

Consequences of Being Wrong

The expense, effort, and disruption of the recreational fishery caused by removal of 80% of the planktivorous fish stock followed by repeated stocking with piscivores may not necessarily reduce the abundance of planktivorous fish below the critical threshold needed to substantially lower algal biomass in SML..

Uncertainties and Data Gaps

While existing data seems to provide a basic outline of change over time in SML, an additional year of gillnet data for circa 2005 is needed (and available, but not in digital format – expected by end of June 2015) to confirm change over time in the fishery that is evident in 2009 and 2012 data. As well, an assessment of total fish abundance and biomass (acoustics, gillnetting, trawling), depth-stratified sampling of phytoplankton, day-time and night-time, and near- as well as off-shore zooplankton tows, would bring greater clarity to the structure and function of the SML food web and the assessment of biomanipulation potential.

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Impact Mini-Report - 5A. Effect of Hypolimnetic Aeration on Total Phosphorus in SML (Option A)

by Maggie Squires

Impact Statement

Hypolimnetic aeration is not an effective tool to reduce phosphorus (P) loading (i.e. P-internal total loading) in SML or to reduce the occurrence of cyanotoxins.

Description

The 'artificial aeration hypothesis ' is considered in three parts, as follows:

1) Is there evidence that artificial aeration of the hypolimnion can significantly reduce P-internal loading in SML?

2) Is there evidence that artificial aeration of the hypolimnion in 2009-2013 lowered the occurrence in SML of cyanobacteria and cyanotoxins?

3) Is there evidence that water quality (water clarity, algal abundance, presence of toxins) improved in SML during the 2009-2013 period of artificial aeration?

External Influences

[None noted]

Assessment

To assess the effectiveness of artificial aeration in reducing P-internal loading and decreasing the occurrence of cyanotoxins in SML, the following data sets and data analyses were utilized:

1) Time series (monthly) of total P (TP) concentration through the water column, and P- mass in the lake for the period 1979-2015 (# of mo = 293, # mo/y variable).

2) Statistical comparison of net change in P-mass in the lake between March and November, and between March and December for years before, during, and after artificial aeration.

3) 2x/mo time series of algal biomass in surface water grab samples July 2014 to March 2015 (n=12).

4) NSSWD record of cyanotoxin occurrence in SML (2003-2015).

5) Estimates of potential P-diffusion across the thermocline (hypolimnion to epilimnion) in selected years before, during, and after artificial aeration.

6) Time series of dissolved oxygen concentration (DO) through the water column for the period 1979-2015.

Results from Analysis

1) P-internal loading in aerated versus non-aerated years: Statistical comparison of net change in P-mass for March to November, and for March to December suggest no significant difference in P-internal loading in SML in aerated versus non-aerated years.

2) Water quality in aerated versus non-aerated years: Compared with 2007-2008 (before aeration) and 2014-2015 (after aeration): water clarity during the 2009-2013 period of artificial aeration was relatively low; cyanotoxins occurred in summer 2013; TP concentrations were relatively high in January 2012, 2013, and 2014; and, algal abundance reached relatively high levels in summers of 2009, 2012, and 2013.

3) Cyanobacteria and cyanotoxins triggered by low N:P in non-aerated years? Between July 2014 and January 2015, there is no evidence that mixing of low N:P bottom waters with surface waters (at turn-over) triggered significant increase in the biomass of cyanobacteria or in the occurrence of cyanotoxins in SML.

4) P-diffusion in aerated versus non-aerated years: Estimates of potential P-diffusion across the thermocline suggest artificial aeration may have greatly increased (relative to non-aerated years) P-diffusion in 2012-2013 (by steepening the P gradient across the thermocline) possibly explaining the surprising increase in surface water TP in the middle of summer when external loading is expected to be negligible.

5) Relation between level of anoxia and P-internal in aerated versus non-aerated years: Analysis of the effect of depth and duration of anoxia on the magnitude of P-internal loading (net change in P mass in the lake for March to December) suggests severity of anoxia may not control the magnitude of P-internal in SML. Alternatively, the timing and intensity of fall mixing may strongly affect the amount of P-internal loading to SML.

Key Findings:

1) Is there evidence artificial aeration of the hypolimnion can significantly reduce P-internal loading in the lake? Hypolimnetic aeration (2009-2013) does not appear to have been an effective tool to reduce P-internal loading in SML. Indeed, SML appears to have sufficient Fe to re-sequester P in lake sediments during natural re-aeration of bottom waters at fall over-turn. Further, rather than control of P-internal by the severity of anoxia

(potentially lowered by artificial aeration), possibly external factors such as wind speed at turn-over affect to some degree the amount of P-internal loading in SML.

2) 2) Is there evidence artificial aeration of the hypolimnion in 2009-2013 lowered the occurrence in the lake of cyanobacteria and cyanotoxins? Hypolimnetic aeration does not appear to have been an effective tool to reduce the occurrence of cyanobacteria or cyanotoxins in SML.

3) 3) Is there evidence water quality (water clarity, algal abundance, presence of toxins) was improved in SML during the 2009-2013 period of artificial aeration? On the contrary, evidence suggests artificial aeration may have disrupted normal chemical, physical, and biological regimes in SML (e.g. retardation of algal settling/sedimentation) and in so-doing contributed to the relatively poor water quality (including the occurrence of cyanotoxins) in SML in some aerated years.

Consequences of Being Wrong

Because the aerators remain in the lake, they could be restarted in the future at an annual cost of several tens of thousands of dollars. If effective at improving water quality, than the expense might be justifiable. The risk is that water quality might remain the same or worsen and/or production of cyanotoxins might be triggered.

Uncertainties and Data Gaps

1) The amount of error in P-internal loading estimated as net change in P-mass in the lake between March and November, and between March and December (based on monthly data) is an unknown but could be >10% as a result of variation among years in P-external, P-export, and timing, etc, of turnover.

2) For the period of artificial aeration (2009-2013), it has not been ruled out that increases in external loading could have contributed to the observed increase in TP content and to the occurrence of cyanotoxins in SML in 2012-13.

References

[None provided].

Impact Mini-Report - 5B. Effect of Hypolimnetic Aeration on Total Phosphorus in SML (Option B)

by John B. Sprague

Impact Statement

Hypolimnetic aeration is an effective tool to reduce phosphorus (P) loading (i.e. P-internal total loading) in SML and to reduce the occurrence of cyanotoxins.

Description

[None provided]

External Influences

For the aerators, these are not understood.

Assessment

Various methods can be used to evaluate the performance of aerators.

Analysis no. 1, One method outlined here compared P loads in the lake at autumn turnover, after summers of successful aeration, with the P loads for nearby years when no aerators were in use.

Successful years for the early aerator were 1988, 1989, and 1990. (Probably 1991 and 1992 were also successful, but there is insufficient data on P load.) Successful years for the recent aerators were 2009 and 2010. For comparison, early years without aerators were 1979, 1980, and 1981.
Recent years without aerators were 2004 to 2008.

Analysis no. 2. Another study compared the total load of phosphorus in the lake in the springtime, with the total load that had prevailed just after the previous autumn turnover.

Results from Analysis

Analysis no. 1.
Detailed analysis is given in Sprague (2014). Differences were statistically significant. Because there has been no great change in nutrient status of the lake in recent decades, all results can be bundled to yield the following averages.

- No aerators in use: average P after autumn turnover = 884 kg
- Aerators working: average P after autumn turnover = 414 kg

Apparent reduction in autumn load of P-sediment = 470 kg.

Aerators were overwhelmed in three recent years and essentially non-functional. In 2011 there was generation of H2S and uncertainty what was happening at the bottom. In 2012 they were again overwhelmed, and in 2013 they were again unsatisfactory and were shut down during the summer. P-loads just after autumn turnover were 895, 970, and 858 kg, essentially the same as loads without aerators.

Analysis no. 2.

The same five years of successful aeration provided autumn-to-spring change in total load of P in the lake. Another eight such comparisons were obtained for years when there was no aeration. Five more sets of data were provided for years when the aerators were overwhelmed (Sprague 2014).

The five years of successful aeration provided autumn loads that were lower (303 to 540 kg of P) than any of the other twelve years (551 to 1273 kg of P). The autumn-to-spring relation was variable, but the trend was clear – the springtime load averaged about two-thirds of the autumn load. In other words one-third had disappeared during the winter, presumably by deposition into the sediment and outflow.

The conclusion is that a lower total load of P in autumn results in a lower load next spring. The implication is that the status of the lake could be improved if sediment-P could be prevented from mixing into the lake in the autumn. The lower levels would result in less P being deposited into the sediment. The implication would be that surface layers of sediment, which are the active contributors to recycled P, would contain less P. Less would be recycled, and levels of P in the lake would be expected to gradually decrease.

In certain years of successful operation, aerators did what they were supposed to do; they achieved a great reduction in P-sediment at autumn turnover. In turn, that resulted in lower springtime loads (and concentrations) of P in the lake. The implication is that if continued successful operation of the aerators were achieved, the trophic status of the lake would improve.

However, in other years the aerators were overwhelmed and of no benefit. Exact reasons for failures are not understood. Investigation of the reason(s) is warranted.

It has not been documented for SML that lower phosphorus in any given year has resulted in reduction of blooms. Behaviour of algal blooms is difficult to predict in the short term because of the variety of causal factors. In the long term, it is safe to assume that lower nutrient will, on average, result in lower algal populations.

Consequences of Being Wrong

A decision to improve aerators and use them, followed by their failure, would entail very high financial costs.

If aerators could be made functional, failure to use them would miss an opportunity for probable overall reduction of trophic status of the lake.

Uncertainties and Data Gaps

The chief uncertainty is why the aerators failed in certain recent years. (The earlier aerators, in 1988-1990, ceased operation because of corrosion and mechanical breakdown, not because they were ineffective.)

References

Sprague, J.B. 2014. Amount of phosphorus released yearly by sediments of St. Mary Lake. Report for Technical Advisory Committee of the Salt Spring Island Watershed Protection Authority. November 4, 2014. 9 p.

APPENDIX 14. Summary of Public Consultation for this IWMP

Public consultation was conducted July 21, 2015 – August 14, 2015.

Information was provided to the public, and received from the public, with regard to the St. Mary Lake IWMP (and other watershed and water management topics) through 12 hours of display booth interactions at local café's on Salt Spring Island, one 2 hour evening session at a hall, and 6 hours of display booth interactions at "Planner in the Park" in the Tuesday Farmer's Markets.

Feedback was provided in written format on hard copies made available at Islands Trust, the SSI Public Library, each display booth session, and in electronic (anonymous) format, on the SSIWPA website.

All public feedback suggestions to the IWMP was considered (from 12 members of the public) by SSIWPA Steering Committee (see Agenda Package August 21, 2015), and several of the suggested changes were incorporated in the final editing process conducted September 2-11, 2015.

Some feedback received was of a general nature, not referring to the IWMP, and was recorded in the SSIWPA files and received as information by the Steering Committee.

A significant amount of feedback and edits were also made by SSIWPA steering committee, and technical advisory committee members.