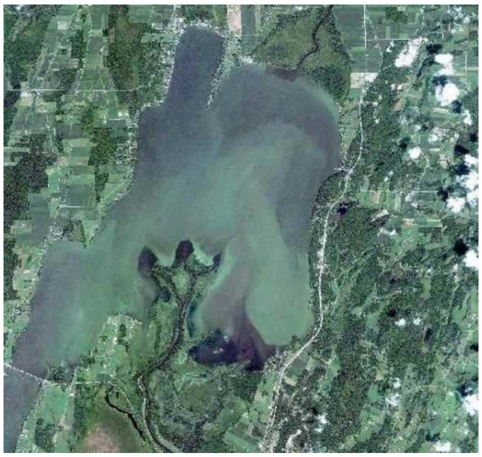
Nutrient Loading and Impacts in Lake Champlain – Missisquoi Bay and Lake Memphremagog



Missisquoi Bay. IJC Collection

Lake Memphremagog. IJC Collection

Missisquoi Bay Cyanobacteria. Pierre Leduc

Prepared by the International Joint Commission

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Acronyms
BMP - Beneficial Management Practices
CSA -Critical Source Areas
HAB - Harmful Algal Bloom
IJC –International Joint Commission
LCBP –Lake Champlain Basin Program
MOU - -Memorandum of Understanding
NAS - Nutrient Accounting System
RAP - Required Agricultural Practice
REA - Regulation on Exploitation of Agriculture
SAG - Study Advisory Groups
SPARROW - SPAtially Referenced Regression on Watershed attributes
TMDL – Total Maximum Daily Load

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I. Synthesis Document

A. Context

Public concern for blue-green or harmful algal blooms (HABs) has continued to intensify over the past decade within the entire Champlain / Memphremagog region. Summer season HABs, including cyanobacterial blooms and associated microcystin toxins, have resulted in socioeconomic losses (see Sections II and III) and have raised concerns about public health, recreation, and safety of drinking water. These effects and losses are anticipated to persist in the future, from continued anthropogenic impacts and will be exacerbated by climate change and extreme weather.

Cyanobacteria

Algal blooms can occur in water bodies with excess nutrient inputs as part of the natural eutrophication process but may be exacerbated by inputs from anthropogenic sources. While most algal blooms are benign, some can be toxic to humans and wildlife. For example, the cyanobacteria *Microcystis* can produce both neurotoxins and hepatotoxins. Exposure is through ingestion by drinking contaminated water or by consuming fish or other biota that have accumulated the toxin.

In Lake Champlain and especially in Missisquoi Bay (see Section II for description) 400 years of settlement has impaired aquatic life and major water uses including recreational and potable waters. Drastic and sustained measures over the long-term are now needed to remedy the situation. Due to the Bay's shallow depth and restricted flow dynamics, discernable improvements will not be observed for decades to come. In contrast, Lake Memphremagog is relatively pristine (see Section III for description). Although some eutrophication and cyanobacteria occur naturally in the lake (*e.g.*, Fitch Bay) anthropogenic input at its southern end have caused periodic water impairments such as beach closures. Because of the differences between Missisquoi Bay and neighbouring Lake Memphremagog governments should consider unique approaches in each basin to address their water quality issues. The former basin requires intense remediation; the latter requires protection.

Actions and Consequences of Non-action

Public concern about water quality in Lakes Champlain and Memphremagog is growing in both Canada and the United States. The focus is on the impacts of elevated phosphorus levels causing the proliferation of algal blooms which have adversely affected recreation, human health, and ecosystems on both sides of the border. HABs in Missisquoi Bay (the Bay) have been a concern since the 1950s. The Lake Champlain Basin Program's (LCBP), *2015 State of the Lake Report*, noted that excess phosphorus is a concern in most segments of the lake, these being highest in the Bay and that algal blooms will continue to develop until concentrations are reduced. Governments, lake organizations and academia have invested and studied the problem for decades and all recommended the need for major reduction in phosphorus inputs to the Bay. Studies of the Bay, conducted by the International Joint Commission (IJC) in response to References from the governments of Canada and the United States in 2004 and 2008, identified the Bay's specific conditions and constant excessive nutrient loading as the cause of HABs. In an attempt to increase the flow of water out of the Bay, the Swanton Bridge was built, and part of the causeway removed. Although government actions throughout the basin are occurring, the trend is towards concerted site-specific efforts that integrate all aspects of the problem (*e.g.*, hydrological, socioeconomic, regulatory; see Global Review, Section IV). Should the *status quo* prevail, the bay will continue its path of accelerated eutrophication.

Although similar concerns surrounding water quality are evident in Lake Memphremagog basin, the extent of the problem is small in comparison to Missisquoi Bay. The problem is not going unnoticed however and basin and lake organizations have established surveillance plans and actions plans according to their means. Governments have a presence in Lake Memphremagog and are investing in it in a manner that is in proportion to the scale of all basins under their responsibility. With only about 15% of land used for agriculture in the basin and most of the rest forested, even an occasional HAB should send a strong signal to governments that site-specific attention at the watershed-level is required rather than reliance upon jurisdiction-wide policies and investments.

Cyanobacteria city of Magog. IJC Collection

The Governments' Reference

In the October 19, 2017 letter of Reference, Governments asked the IJC to solicit recommendations on how to address nutrient loading in both Lake Champlain-Missisquoi Bay and Lake Memphremagog. Specific to the former, the IJC was asked to gather and review information from federal, provincial, state, and municipal agencies, academic institutions, and other entities in the region on existing monitoring programs and measures being taken to address water quality concerns. Based on the information collected, the IJC was to provide Governments with recommendations on how current efforts and programs can be strengthened. The Governments asked that the recommendations include a summary of gaps or opportunities and that the recommendations identify possible approaches to strengthen collaboration, efficiency, or impact. Specific to the latter, Governments asked IJC to collaborate with relevant government agencies, academic institutions and other entities in the region to identify the range of nutrient loading issues that are of concern in the Basin and to make recommendations on how current efforts can be strengthened. For that basin, the recommendations should also include the consideration of management approaches currently applied in Lake Champlain and Missisquoi Bay, and the effectiveness of those approaches in combatting HABs.

The IJC has had a presence in the Bay in response to two references by governments in 2004 and 2008. For Lake Memphremagog, the IJC had not had previous involvement until now. The water level of the lake is regulated by a hydroelectric dam on the Magog River which is governed by a treaty signed in 1935 between the U.S. and Canada.

IJC's Approach to the Reference

Resources/Time

The government reference states, "The governments understand that the Commission can conduct the work under this Reference within its current budget and does not intend to seek additional funding." To manage and accommodate this pressure on its resources, the IJC undertook the work by reprioritizing and shuffling its activities. Both IJC Sections allocated funds and equally resourced the project for a total budget of $500K. Due to a US Government shutdown in late 2018 early of 2019, the Reference was granted a six-month extension resulting in a total duration of 2 ½ years from October 19, 2017 until April 17, 2020.

Formation of Study Advisory Groups

The Commission established Study Advisory Groups (SAGs) to assist in responding to the reference. The SAGs comprised representatives from federal, state, provincial, municipal and basin organizations. They had an equal number of members from the United States and Canada (12 members were in each SAG). Members served the Commission in their professional capacity, contributing their knowledge and expertise for the common good of both countries. The role of SAG members was to provide high level direction and advice to the basin organisations on all aspects of the project, including providing recommendations to the IJC.

Basin organisations (LCPB, Organisation de basin versant de la Baie Missisquoi, Memphremagog Watershed Agency, and lake organisation Memphremagog Conservation Inc.) produced technical reports for the IJC identifying the range of nutrient loading issues that are of concern in the Lakes and made preliminary recommendations to the SAGs on how current government and other organization efforts could be strengthened. The SAGs refined these recommendations and submitted their final reports to the IJC on January 19, 2020.

Work Plans

To deliver on the reference, the IJC developed workplans and tasked basin and lake organizations with five major work components:

1. Networking with key agencies, review of the state of the basin reports, review of research and monitoring information as well as domestic and binational nutrient loading reduction management efforts
2. Analysis of assembled materials
3. Identification and description of approaches that address the reduction of nutrient loading and causes of HABs
4. Consultation with agencies in the watershed and the public on approach options
5. Development of recommendations to strengthen current efforts.

Champlain SAG Meeting, LCBP Grand-Isle Office, Vermont. IJC

The SAGs delivered and deliberated on the five workplan items through a mix of teleconferences, face to face meetings, workshops and correspondence. The workplans can be found at: https://www.ijc.org/en/lclm/project-one.

Workshops to Review Science and Policy on Nutrient Loading

The basin organizations held workshops to bring together scientists and policy makers to discuss the technical reports provided by basin organizations and receive feedback from workshop participants. These experts were from a range of organisations active within or in the vicinity of the basins (Vermont, New York and Québec). SAGs and IJC staff were also present. Under the guidance of SAGs, basin organizations used the workshop reports to revise and improve the study reports. Workshops also allowed for an exchange information, identification of common interests, and an overall strengthening of networks for future collaboration.

Workshop, University of Vermont Burlington. IJC Collection

The two SAGs developed their reports differently. The Champlain SAG organized a U.S. and a Canadian element to pull together information from each country with consolidation of the information from each country at the end. The Memphremagog SAG compiled information from both counties jointly. To ensure the SAGs were aware of, and could complement and build on each other's work, the IJC organized special calls between them, mutual invitations to the Science Policy workshops and finally, a face to face alignment meeting.

Public Meeting and Online Consultation

Public meetings related to the Bay component of the reference were held in November 2019 in Venise-en-Québec and St. Albans, Vermont to obtain public feedback on the draft reports. The IJC communications team assisted the Champlain SAG and the basin organizations with the delivery of these meetings and ensured that simultaneous translation was provided (French and English). Communication products were developed including a news release, social media, and website content. In both locations, the meetings proved to be an effective way of interacting with the public and listening to their concerns.

Champlain SAG Panel, Venise en Québec. IJC Collection

Due to limited resources, the IJC communication team assisted the SAGs in conducting an online public consultation on the technical report in November 2019 for the Memphremagog component of the reference. Public comments were reviewed and integrated as appropriate into the report.

B. IJC Analysis of SAG Reports

Although the Bay and Lake Memphremagog are unique from a socioeconomic, demographic and physical point of view, because they are both located within the same transboundary jurisdictions (Vermont and Québec) there are some commonalities and overlap in their science and policy evaluations. Both SAGs see governance as fundamental and stress the importance of establishing watershed goals and nutrient reduction loading targets. The Lake Memphremagog Steering Committee is active but lack the resources needed to be as effective as it could be. There is minimal binational governance for the Bay and a new binational committee would have to be formed. The groups agree that monitoring information and watershed-scale models can help to understand the nutrient and HABs problem and its evolution. As such, both SAGs identified the need to better harmonize binational science efforts including protocols for monitoring, sampling, and analysis through a strengthened governance. Enhancing governance is also essential to the development of long-term strategies that address climate change. The reports however provide limited information on these long-term strategies.

Both reports also provide a suite of measures to reduce nutrient loads from agriculture and from other developed lands. The SAGs recommend that BMPs proven to substantially reduce nutrient inputs and outputs and lessen loadings to lakes and tributary waterways be utilized. For example, using crops such as grains and natural grasses for livestock fodder will cause less erosion and require less fertilizer than crops such as corn and soybeans. Appropriate cropping systems (grain and grass crops, crop sequence and management techniques) suitable for agricultural land (*e.g.*, slope, soil type) have proven to be relatively more effective in Québec and Vermont than corn and soybean. BMP financial incentives, when available, can also be effective in instilling change in cropping systems but as observed in Vermont, the limited uptake needs to be investigated.

Federal, Provincial, or state policies intended to achieve one type of socioeconomic benefit may have adverse impacts on lakes. For example, housing developers who may be implementing government policies to bring residents and tax revenues to a given municipality may not be implementing actions that will reduce run-off or conserve natural infrastructure such as wetlands and extended riparian zones if those actions will reduce their profits. As such, land-use planning to minimize nutrient inputs may require additional funding, policies, or regulations in order to be implemented or be more effective. Similarly, with respect to regulations and their enforcement, simply having a regulation does not ensure its application. Resources to ensure staff exists to enforce regulations need to be an integral part of land planning, regulation and enforcement. An additional challenge is that these lakes are bi-national and require customized and coordinated approaches.

An identified deficiency in the reports carried out by the two basin organizations is the lack of evaluation of program efficiency or a measurement of the gains made, or not made, by each program relative to the resources invested. An evaluation of existing programs' efficiencies and those of new ones could provide an initial framework for moving forward. Armed with this type of a report card, basin organizations, in conjunction with governments, can better define allocation of finite resources in an integrated fashion and focus on key zones such as Critical Source Areas (CSAs). The basins could also benefit from a regional contaminant loading model such as SPARROW (SPAtially Referenced Regression On Watershed attributes) to determine how to reduce loads of contaminants from CSAs and design protection strategies; design strategies to meet regulatory requirements; predict changes in water quality that might result from management actions; and identify gaps and priorities in monitoring. The reports also pointed to immediate effective action that could be taken by governments. One example would be to address industry requirements for crop insurance that obligate farmers to apply fertilizers for maximum yield without accounting for the soil nutrient content. Another would be for manure application regulation based on soil nitrogen requirements rather than phosphorus in soils already over-saturated with phosphorus.

Both groups see the need to address the nutrient problem through an understanding of the inputs and outputs of nutrients into the basins. This mass-balance approach will assist jurisdictions better focusing their management plans and resources to mitigate nutrient impacts. A binational model can effectively act as a Nutrient Accounting System (NAS) which facilitates not only an understanding of what is entering and exiting each watershed (and eventually each lake) but also for examining which BMPs or reduction efforts pay dividends. Current scientific thought has focused on phosphorus as the key nutrient parameter, however other water quality and quantity data are also essential in order to understand the dynamics of cyanobacteria blooms. In addition to nutrient loads and concentrations within a system (nitrogen and phosphorous) other important factors include chlorophyll a, silica, iron and temperature. Climate change is the new wild card wherein extreme rainfall events and frequent record-breaking summer temperatures can accelerate algal growth and increase the frequency and intensity of blooms thereby annulling a large part of government efforts.

It is important to recognize that all levels of government on both sides of the Canada- US border in the Lake Champlain and Lake Memphremagog area have made substantial effort to combat the HABs crisis plaguing the lakes. For this they must be commended, however, it must also be noted that the problem is not going away and has yet to be solved, either locally or globally. The IJC contracted a review of how the issue of nutrient loading and HABs is being addressed by governments world-wide (see section iv below). The review found that, for comparable size watersheds, the issue was addressed with integrated watershed management planning and water quality standards. National standards were not stringent enough. Methodologies were based on key regulatory, market based, incentive-based and risk mitigation approaches. A systematic review of the elements of these world approaches could assist in tailoring specific binational actions for the Bay and Lake Memphremagog.

Despite progress being made, existing programs in Vermont and Québec can be improved. Newer programs are being implemented such as Act 64 in Vermont stating that RAPs (required agricultural practices) “address nutrient stacking/storage, soil health and loss tolerance, vegetated buffer zones, livestock exclusion, nutrient management plans, and tile drainage”. With this program and others (*e.g.*, Stratégie Québecoise de l’eau) in Québec, governments are better addressing water quality issues and are doing so in a more integrated fashion. While laudable, these programs are still state-wide or province-wide and do not necessarily hone actions to suit a particular region (in this case binational) with its own set of problems and circumstances, and do not consider the additional impacts of climate change. A more concerted effort at the site-specific level to more effectively curtail HABs is required.

Current jurisdictional nutrient reduction strategies such as the LCBP's Phosphorus Reduction Strategy, Québec 's Regulation on Exploitation Agricultural (REA), and the Vermont TMDL approach are all aimed at lowering inputs of nutrients into waterways. In order to enhance their effectiveness, more holistic basin specific long-term plans need to the considered. These plans would focus on Critical Source Areas (CSAs) and aim to realistically meet agreed-upon nutrient objectives within a given time frame by methodically implementing appropriate BMPs and modifying cropping systems. This would be done through market-based incentives and other financial incentives but carried out in conjunction with enforcement of existing regulations ("carrot and stick" approach). Defining and agreeing to a long-term plan (*e.g.*, 25 to 50 yrs.) necessitates comprehensive coordinated consultation amongst all levels of government, public, and stakeholders including local and indigenous communities. This definition could be aided by socioeconomic analysis and understanding why people act the way they do. Some avenues to analyze may include understanding the driving force behind major crop types like corn and soy; municipal planning and zoning trends; stakeholder interactions; and regional beliefs and behaviors. The analysis can also look at other questions related to cropping trends such as the corn for ethanol program, which has been highly profitable for farmers, in order to understand how it is employed and how local and regional needs may be met in an alternative way. This could include implementation of locally defined corrective plans and instilling behavioral change towards identified societal goals. These goals and social objectives would describe a desired outcome for the identified long-term plans that would be related to the interaction of the social fabric within the local society. The goals should aim at improving the well-being of those living in the respective basins. Indicators would then be developed to monitor the attainment of these predefined goals and objectives.

The setting of nutrient loads and nutrient specific objectives for lake segments, tributaries or river reaches could also be considered. These may take the form of desired nitrogen and phosphorous concentrations informed by the mass balance or loading of nutrients into the watershed or may describe a desired trophic state of the lake throughout the year (*e.g.*, oligotrophic 12 months of the year). This would enable a preferred human and/or ecosystem health outcome.

C. Common Basin Recommendations and IJC Recommendations

The Commission is pleased with the SAG technical reports and endorses all recommendations contained within them. These are well-founded and aim to address the nutrient problem. Because of the large number of recommendations in the SAG reports (total of approximately 90 recommendations), and to facilitate their comprehension and readability, the IJC's analysis of the two reports has grouped the common elements in the recommendations into the following four recommendations. The SAG recommendations below, the term governments refer to all levels of governments according to their mandates. The SAG recommendations below do not necessarily reflect the official positions and opinions of the organizations, departments and ministries that contributed to or participated in the study or its drafting.

SAG Recommendations

1. **Strengthened governance** to enable binational integrated watershed planning and collaboration and effectively implement nutrient reduction plans. Governments need to renew the Memorandum of Understanding (MOU) between Québec and Vermont which expired in 2016 and provide support to the Québec-Vermont Steering Committee on Lake Memphremagog. For the Bay, governments need to create and support a permanent binational Phosphorus Reduction Task Force. Under this strengthened governance, governments need to assist in the provision of watershed-level nutrient loading reduction goals.

2. **Reduction of agricultural land nutrient loading** from agricultural land involves:
    - Using the most appropriate cropping systems to achieve crop yield and nutrient reduction goals.
    - Implementation of newer and more adapted agricultural and environmental best management practices (BMPs)
    - Financial incentives to implement BMPs

3. **Reductions on other developed lands,** through:
    - Support for land use planning to reduce stormwater runoff from other developed lands
    - Updating of regulations for state, provincial and municipal infrastructure including those relevant to stormwater, fertilizer application, erosion control, and pervious surfaces
    - Targeted enforcement to ensure compliance with regulations and legal frameworks.

4. **Improved binational harmonization of science and monitoring efforts** in order to better understand nutrient inputs and outputs in respective basins and work towards nutrient reduction goals. For example, jurisdictional collaboration and exchange by technical staff on data collection and quality assurance, monitoring, sampling and modelling approaches would help with such harmonization. Common platforms for outward facing basin-wide communication, data and information display are also essential for both public users and agency decision-makers.

IJC Recommendations

In addition to the recommendations in the SAGs' reports, the IJC proposes the following additional recommendations which are grouped in a management approach to facilitate governments' actions:

1. **Strengthen current government efforts (estimated 10 years to complete)**: Federal Governments should accelerate the pace of recovery and protection working with

provincial, state and local and indigenous governments to strengthen current efforts to systematically implement the recommendations in the SAGs' reports.

2. **Improve existing governance mechanisms (estimated 2 years to complete)**: Federal Governments should provide resources to support existing provincial, state, and local governance mechanisms that coordinate binational oversight of the basins to more effectively sustain long-term management of joint efforts and actions.

3. **Understand nutrient inputs and outputs (estimated 3 years to complete)**: Federal Governments should assist in providing an improved understanding of nutrient input/outputs in each of the two basins by supporting more harmonization of provincial, state, and local science efforts to create a comprehensive binational mass balance model that enables jurisdictions to efficiently and effectively evaluate and manage measures to mitigate nutrient loading.

4. **Develop and initiate implementation of basin-specific action plans (estimated 7 years to initiate)**: Using the mass balance model, Federal Governments should work with provincial, state and local and indigenous governments to develop and implement basin specific binational sustained action plans (approximately 20-30 years) to address nutrient loading in both basins. These action plans should set out the following, with accompanying timelines and should occur in consultation with the public, stakeholders, and local and indigenous communities:

    a. Set societal sustainability goals and objectives;
    b. Ensure an understanding of nutrient inputs and outputs (i.e., mass balance);
    c. Set nutrient specific objectives that target critical source areas and are enforced by the relevant government;
    d. Implement targeted adaptive management plans that include BMPs, market-based mechanisms and financial incentives to meet nutrient specific objectives;
    e. Develop a sustained communication strategy for the duration of action plans; and,
    f. Create an ongoing adaptive oversight and evaluation plan with systematic review of management plans.

    Basin-specific action plans should systematically review the goals and nutrient specific objectives to adapt to anticipated effects of climate change. Climate change is expected to exacerbate the impacts of HABs and current efforts by governments may not be enough to remedy the situation.

Innovation and investments in new and emerging BMP technologies such as *in situ* nutrient soil injection applications will be needed. Other changes in the basins that will have an impact on the nutrient mass balance will need to be monitored and plans adjusted accordingly. For example, there are current government efforts to regain hydrologic connectivity within Lake Champlain and return it to a more natural state while restoring ecosystem services. This will enhance water quality through functioning and connected wetlands.

D. Concluding Remarks

The water quality reference to address excessive nutrients in Lakes Champlain Missisquoi Bay and Memphremagog is unique in that it includes two very different lake systems at very different stages of trophic decline. The IJC recommends that basin-specific plans need to be developed with the view that the Lake Champlain Missisquoi Bay necessitates intense remediation, while the Lake Memphremagog system requires both remediation and protection.

The relatively pristine Lake Memphremagog (oligo-mesotrophic) has only about 15% of its watershed lands under agricultural use yet is experiencing HABs. A governance mechanism, although limited in its actions, is in place through the Québec-Vermont Steering Committee. The Committee is working on a binational watershed model but lacks the means to make it scientifically defensible. The model also lacks precise basin-wide targets. More specifically, actions will have to focus on containing nutrient inputs from the existing 6% developed and 15% agricultural land-uses. Shifts in cropping systems that augment nutrient loads or increases in agricultural land-use should be minimized until management plans have been shown to address the problem at hand under current agricultural intensity.

Lake Champlain has well-defined targets for different segments/bays of the lake but no current governance mechanism in place for Missisquoi Bay. As one of the first European inland settled areas the Bay sub watershed is in grave danger. Eutrophic conditions threaten not only the beauty of the area, but also all water uses and hence the socioeconomic well-being and way of life for its residents. The stress of HABs is particularly heightened when water uses become affected late in the summer and in the early fall. For example, the small town of Bedford spent $1 million to deal with water quality issues affected by HABs and coincident microcystin toxins. Not knowing how effective nutrient reduction programs may be in the future could lead to consideration of adaptive management approaches wherein costly water treatment and water use restrictions become the norm. A strong communication plan setting realistic short and long-term expectations will be necessary to inform the Bay's permanent communities and seasonal occupants.

For Lake Memphremagog communities a harbinger of what the future may hold can be witnessed in the concern of communities from nearby Lake Champlain-Missisquoi Bay. In that system, Governments are now faced with difficult choices and costly investments. It is imperative that remediation efforts go hand in hand with prevention for both these lakes so that lessons-learned and positive actions can lead to sustained recovery and protection of these important lakes for the benefit of their communities.

II. Champlain

III. Memphremagog

IV. Global scan

Nutrient Loading and Impacts in Lake Champlain, Missisquoi Bay, and the Richelieu River

Final Report prepared by:
New England Interstate Water Pollution Control Commission
Lake Champlain Basin Program
Organisme de basin versant de la baie Missisquoi
For the International Joint Commission
January 19, 2020

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Executive summary

The governments of the United States and Canada, in consultation with Vermont and Québec, requested the International Joint Commission (IJC) assistance to develop a summary and analysis of work done by governments and others to date addressing harmful algal (cyanobacteria) blooms in Missisquoi Bay. These algal blooms have become increasingly persistent in recent years in this binational cove of Lake Champlain.

A key component of this project has been the development of a suite of recommendations to be considered by management agencies and organizations in both countries to help achieve common management goals and ultimately to work towards mitigative solutions and reduce the frequency of harmful algal and cyanobacterial blooms.

Missisquoi Bay, a Sub-Basin of the Lake Champlain basin, is shared between the Province of Québec (42%) and the State of Vermont (58%). Missisquoi Bay has long been impaired by excessive phosphorus loads and has one of the highest in-lake phosphorus (P) concentrations of any segment of Lake Champlain (Lake Champlain Basin Program, 2018). The 2016 Vermont phosphorus (P)Total Maximum Daily Load (TMDL) for Missisquoi Bay estimates that a 64.3% reduction in load is needed to meet the TMDL allocation for the Missisquoi Bay segment (US EPA, 2016). The largest source of P loading to the bay is from agricultural activities (Vermont DEC, 2013; OBVBM, 2015). Phosphorus rich sediments have accumulated in Missisquoi Bay over many decades, and the potential release of this phosphorus to the water column presents an additional management challenge.

The project has included five main tasks:

1. Compilation of materials for a review of existing literature on nutrient loading and impacts on Missisquoi Bay
2. Analysis of materials assembled through the literature review. This task included interviews with experts in Vermont, New York, and Québec to assess the effectiveness of existing efforts, data gaps, and opportunities for strengthening coordination and governance
3. Development of recommended approaches to strengthen current efforts
4. Consultation with the public and agencies in the Basin on recommended approach options
5. Development of a Project Final Report summarizing key findings and recommendations

The key management recommendations for reducing the nutrient loads causing the proliferation of cyanobacteria in Missisquoi Bay include:

1. Establish and coordinate a binational phosphorus reduction working group to enhance cooperation and accountability of parties to achieve mutually agreed upon goals.
2. Develop a binational mass balance for phosphorus imports and exports in the Missisquoi Bay watershed.
3. Reduce the use of phosphorus on the lands of the Missisquoi Bay watershed.
4. Increase the proportion of crop systems that contribute less phosphorus to the system.
5. Increase the protection and enhancement of river corridors and buffers, floodplains, wetlands, and forest lands and ensure their reconnection for nutrient storage.
6. Engage with public stakeholders to commit to clean water and healthy ecosystem goals.

Beyond these six priority recommendations, the report also includes several additional recommendations organized around the themes of agriculture, regulation and funding, research, developed areas, and legacy sediments in Missisquoi

Bay. The development of the recommendations and project report was guided by a Champlain Study Advisory Group comprising lake and watershed science and policy experts in the U.S. and Canada.

The Missisquoi Bay basin has been significantly impacted by human activities since the region was settled by Europeans over 400 years ago. In addition to the actions and policies recommended herein, time will be required for the system to recover from these long-term nutrient inputs and landscape impacts. While it is difficult to predict how long the recovery will take, especially with the uncertainties posed by climate change and extreme events, the Champlain Study Advisory Group believes that the actions recommended in this report will accelerate the pace of recovery and increase the likelihood of successful restoration.

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U.S. Membership	**Canadian Membership**
Eric Perkins – EPA – Chair	Pierre Leduc – OBVBM - Président
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2 Introduction

The International Joint Commission works to prevent and resolve water disputes between the United States of America and Canada under the Boundary Waters Treaty of 1909, and ensures the common good of the two countries as an independent and objective advisory organization (Mission statement, IJC).

Cyanobacteria blooms are common in binational Missisquoi Bay, and the International Joint Commission contracted with *Organisme de basin versant de la baie Missisquoi* (OBVBM), the Lake Champlain Basin Program (LCBP), and the New England Interstate Water Pollution Control Commission (NEIWPCC) to develop a report on Missisquoi Bay's phosphorus loading, cyanobacteria blooms, and related management actions. This summary of work includes a suite of research, policy, and management recommendations to be considered by management agencies and organizations in both countries, with the goal of achieving common management goals and ultimately reducing the frequency of harmful algal and cyanobacterial blooms. A parallel IJC project is underway in the Lake Memphremagog watershed, a binational lake with similar nutrient pollution and cyanobacteria challenges. Both projects are designed to encourage collaborative work across the U.S.-Canadian boundary to achieve common water quality goals.

2.1 Background, purpose, and scope

Lake Champlain's Missisquoi Bay Sub-Basin, straddling the Vermont-Québec border, includes the drainage areas of the Pike, Rock and Missisquoi Rivers, and the shoreline areas around Missisquoi Bay. The drainage area of 3,105 km^2 is shared between the Province of Québec (42%) and the State of Vermont (58%). Missisquoi Bay has long been impaired by eutrophication caused by excessive phosphorus loads from its sub-basin and has one of the highest in-lake phosphorus (P) concentrations of any segment of Lake Champlain (Lake Champlain Basin Program 2018). The 2016 Vermont phosphorus TMDL for Missisquoi Bay estimates that a 64.3% reduction in load is needed to meet the TMDL allocation for the Missisquoi Bay segment (U.S. EPA 2016). These water bodies are particularly vulnerable to the effects of agricultural nonpoint source pollution and stream bank instability (Vermont DEC 2013). Missisquoi Bay sediments are rich in phosphorus and present an additional management challenge.

Cyanobacteria (also known as blue-green algae) blooms have been a significant issue in Missisquoi Bay since the 1990s, and pose potential hazards to drinking water of the won of Bedford, Québec, recreational activities, human health, and wildlife habitat. In recognition of the degraded water quality of the bay, on August 26, 2002, the governments of Vermont and Québec established a formal commitment to reduce their share of the pollution entering the bay. The agreement stated that Vermont will have 60% of the responsibility for reducing phosphorus loads to the bay, and Québec will assume 40% of the responsibility (*Agreement between the Gouvernement du Québec and the Government of the State of Vermont Concerning Phosphorus Reduction in Missisquoi Bay* 2002). While the governments and citizens of Vermont and Québec have made progress to reduce phosphorus loads to the bay, these load targets have not yet been met.

International Joint Commission

In October 2017, the governments of Canada and the United States mandated the International Joint Commission to collect and review information on reducing nutrient loads and harmful algal blooms in Missisquoi Bay, to make recommendations to enhance the combined efforts of Vermont and Québec and accelerate progress toward reaching water quality goals for Missisquoi Bay.

A literature review was completed to provide a picture of the current situation and the state of knowledge concerning Missisquoi Bay and its watershed, including an overview of the programs and policies already in place in both countries. Experts in water quality, including researchers and practitioners from governmental, municipal and agricultural organizations were also consulted to assess legislation and regulations, governance, financial support programs and actions taken, and to help develop a set of water quality management recommendations.

This literature review was conducted with funding from the IJC, awarded to OBVBM for the Canadian components and NEIWPCC on behalf of the Lake Champlain Basin Program for the U.S. components of the project.

For the Champlain/Missisquoi portion of this Reference, the IJC created a Champlain Science Advisory Group (CSAG), consisting of 13 individuals representing Canada and the United States. The CSAG membership includes areas of expertise ranging from water quality, nutrient loading and modeling, agriculture, cyanobacteria, public policy, and community engagement in the focus area for this study, Missisquoi Bay and its sub-basin of the Lake Champlain watershed. Text of the IJC appointment letter is included as Appendix 1 to this report.

2.2 Prior IJC work in the Lake Champlain Basin

Over the past several decades, The International Joint Commission (IJC) had been actively involved in furthering the understanding of the environmental challenges faced in the Missisquoi Bay Sub-Basin and helping to foster management strategies to address those difficulties. This section provides a brief summary of several of the relevant studies in which the IJC has been involved.

2.2.1 Causeway removal water quality study

The Swanton-Alburgh Route 78 Bridge was constructed in 1937 and consisted of a causeway section extending from each shore, connected by a bridge 170 m in length. After significant deterioration of the structure, a new fixed-span bridge was constructed in 2004-2005.

In 2004, the governments of the United States and Canada asked the IJC to assess the impact of the causeway at the Missisquoi Bay outlet on the Vermont side. In its 2005 report, the IJC concluded that the causeway produces an increase of about 1% in the concentration of phosphorus (average for the entire bay) and sedimentation rate (fine fractions only) in Missisquoi Bay. It was also determined that the causeway does not hydraulically restrict the flow of water between Missisquoi Bay and the rest of the Northeast Arm (Mendelsohn, Swanson, and Isaji 1997).

The IJC recommended that the improvement of Missisquoi Bay’s water quality is dependent on the international agreements and plans and that those agreements should be the focus of future government actions. The IJC also recommended the removal of the causeway. A 100 m section was removed in 2007 when the new bridge was built.

2.2.2 Identification of critical source areas

From 2004 to 2007, the Province of Québec invested more than $1 million in research, monitoring and modeling of agricultural nonpoint phosphorus loading to identify sensitive areas and critical source areas (CSAs) of nutrient loads and the effectiveness of best management practices in Missisquoi Bay (IJC reference, 2008).

As an example, the results of a Soil and Water Assessment Tool (SWAT) modeling study in the Ewing subwatershed, a Pike river downstream tributary, concluded that “the four components hydrograph model revealed that 46 to 67% of the [total phosphorus] load at the outlet originated from surface runoff during peak flow. Preferential flow was responsible for most of the particulate P and dissolved reactive P loads lost through tile drainage. Groundwater resurgence was a minor source of Total P, whereas other sources such as stream channel erosion and resuspended sediments contributed up to 21% of the TP load and from 36 to 41% of the particulate P load at the subwatershed outlet” (Michaud, et al., 2007). Recognizing these recent research contributions in Québec, the IJC asked LCBP to compile and analyze information on critical sources areas (CSAs) of phosphorus loading of the tributary drainage in the Vermont sector of Missisquoi Bay in 2008, with the goal of combining this information with research from QC to provide a comprehensive transboundary assessment of nutrient loading to Missisquoi Bay (Phosphorus Loading in Missisquoi Bay, IJC, 2012).

Identification of CSAs is important for basin management, as it allows managers to prioritize areas of focus and implement the most appropriate best management practices on a local scale. SWAT was used to conduct basin model simulations using 30 years of historical climate data, with input parameters including land use categories, sub-basin characteristics, and field-level assessments of phosphorus source areas to identify CSAs (Winchell et al. 2011, Winchell et al. 2015).

These Vermont-based SWAT analyses showed that about 74% of the phosphorus load comes from just 20% of the Missisquoi Sub-Basin area, and 92% of the total phosphorus comes from only 50% of the sub-basin. Approximately 60% of sediment and phosphorus come from upland sources, with the agricultural land use classification accounting for 64% of that area (Winchell et al. 2011). As such, the sub-watersheds with the highest agricultural usages, which includes the Rock, Mud, Pike, and Hungerford drainage areas, are the biggest contributors to phosphorus loading. The remaining 40% of the phosphorus load is due to stream channel erosion. Several setting characteristics, including hydrologic soil group, compound topographic index, and slope, were the most important factors to determining the phosphorus export quantity and CSA location. Model simulations also evaluated the effectiveness of strategic implementation of three BMPs: manure phosphorus reduction, cover cropping, and changes in crop rotation. Finally, analyses determined that the magnitude of phosphorus loading rates is predicted to increase with of climate change, with a projected 21-57% increase in sediment load. However, these trends do not appear to reorder CSA location or implementation priorities (Winchell et al. 2011). Complementary work should be completed for the Québec portion of the Missisquoi Basin for a complete CSA analysis of the entire Missisquoi Basin.

2.2.3 Lake Champlain-Richelieu River flood mitigation studies

In response to catastrophic flooding in 2011, the IJC established a workgroup to evaluate the causes and impacts of Lake Champlain-Richelieu River flooding and determine possible mitigation strategies. This newly formed International Lake Champlain-Richelieu River Workgroup developed a Plan of Study to address the concerns of the IJC. The Plan of Study was composed of three options and meant to be scalable to best utilize any available resources. These options include basic modeling of the system to evaluate the impacts of past flooding, explore BMPs for floodplain management, investigate potential adaptation strategies, and examine the benefits of flood forecasting and real-time mapping approaches (International Lake Champlain and Richelieu River Plan of Study Workgroup 2013). In addition, the Plan of Study included quantitative and qualitative assessment of possible flood mitigation measures. The workgroup recommended that the IJC conduct an in-depth investigation of current public perceptions on flooding mitigation measures to better inform the individual components of the Plan of Study.

In 2015, the International Lake Champlain – Richelieu River Technical Working Group produced a report detailing their work ("Progress towards an Operational Real-Time Flood Forecasting and Flood Inundation Mapping System for the Lake Champlain and Richelieu River: Preparatory Works and Static Flood Inundation Maps" 2015). The study components addressed in this phase of the project were the development of real-time hydrologic and hydraulic models for predicting water levels in Lake Champlain and the Richelieu River, as well as the creation of static flood inundation maps for the public. This international effort required extensive data collection, organization, and normalization, including the development of vertical datum corrections. While the initial hydrodynamic modeling was found to work well for the lake and Richelieu River to Chambly, more bathymetric data from Chambly to Sorel is needed to more accurately simulate flooding and river flows ("Progress towards an Operational Real-Time Flood Forecasting and Flood Inundation Mapping System for the Lake Champlain and Richelieu River: Preparatory Works and Static Flood Inundation Maps" 2015). The technical working group had many recommendations for the IJC moving forward, including suggestions for model enhancement and refinement, sites for continued data collection, and additional data needs (e.g., a single digital elevation model for the entire Lake Champlain – Richelieu River Watershed). Additionally, the technical working group recommended an entity to coordinate the efforts of the governmental agencies responsible for forecasting and water-level predictions.

2.3 Study areas

2.3.1 Lake Champlain

Lake Champlain has a total area of 1,127 km^2 and a watershed area of 21,326 km^2. The Lake Champlain Basin is home to more than 600,000 people in the states of New York, Vermont, and the province of Québec (Fig. 1). Spanning 193 km in length and holding 26 million m^3 of water, Lake Champlain flows north to the Richelieu River and subsequently to the St. Lawrence River. The Watershed's rich soils provide extensive agricultural opportunities and its waters provide recreation, drinking water, and habitat for abundant wildlife. With waters in the U.S. states of New York and Vermont and the province of Québec, Lake Champlain has a rich history and supports a vibrant, binational economy. Lake Champlain comprises five major unique lake segments (the South Lake, Main Lake, Malletts Bay, Northeast Arm, and Missisquoi Bay) with distinctive bathymetry, water quality issues, and community character. In addition to the challenges associated with several governmental entities managing the lake, each of the lake's segments influences the others, making it critical that a basin-wide approach to management continue to be employed.

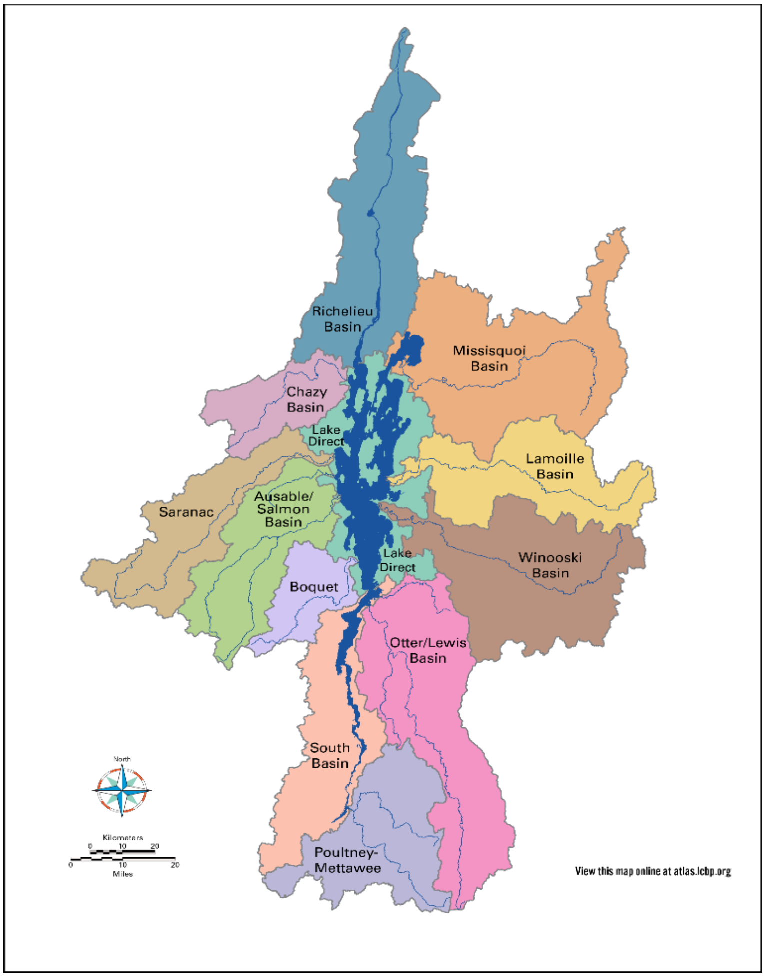

Figure 1. The Lake Champlain Watershed is 21,326 km² and made up of 11 major sub-watersheds. Map from the Lake Champlain Basin Atlas (2018)

2.3.2 Richelieu River

The Richelieu River is 124 km long, and flows north out of Lake Champlain. It is one of the main tributaries of Lake Saint-Pierre and the St. Lawrence River. The Richelieu River watershed covers an area of 2,546 km^2. Due to rich soils and a mild climate, agriculture is a major land use throughout the watershed, covering nearly 70% of the land, of which 76.9% consists of field crops. Anthropogenic habitats account for 9.7% of the total area, while forest and wetland habitats account for 15% and 2.4% respectively (Simoneau *et al.,* 2017). In 2014, the permanent population of the Richelieu River watershed was 469,113, with a population density of 184/km^2 (COVABAR 2015).

2.3.3 Missisquoi Bay

Missisquoi Bay covers an area of 77.5 km^2, representing approximately 7% of the total area of Lake Champlain. The bay has an average depth of 2.8 m, and a maximum depth of 5 m. The ratio of the Missisquoi Bay watershed to that of the area of the Bay itself is 40:1 —a relatively high ratio, which magnified the negative effects of land use in the bay (Levine *et al.,* 2012). In addition, the natural features of Missisquoi Bay make it particularly vulnerable to eutrophication: low mean depth and complex hydraulic circulation, relatively high bottom temperature, and lack of thermal stratification (EXXEP 2004). Drainage areas and jurisdictions of Missisquoi Bay's main tributaries are summarized in Table 1.

Table 1. Area of Missisquoi Bay Sub-basins

Sub-basin	**Area in Québec**		**Area in Vermont**		**Total area**	
	km^2	*% in QC*	*km^2*	*% in VT*	*km^2*	*% of total*
Direct drainage to Missisquoi Bay	56	51%	54	49%	110	4%
Rock River	52	36%	92	64%	144	5%
Pike River	552	84%	102	16%	653	21%
Missisquoi River	652	29%	1562	71%	2214	71%
TOTAL Missisquoi Bay basin	**1311**	**42%**	**1810**	**58%**	**3122**	**100%**

Sources: DEH, 2018; LCBP, HUC12 2013 v2

The permanent population for the Québec portion of the Missisquoi Bay watershed was approximately 23,650 in 2017, and has increased by 17% since 1996 (ISQ, 2018). The seasonal population, which includes occupants of secondary residences and cottages mainly located in Sutton, Venise-en-Québec, Potton, and Eastman, is estimated to be approximately 15,300 (MRC Brome Missisquoi, 2013). The total summer population of the Québec portion of the watershed is therefore approximately 39,000. In 2010, the Vermont portion of the watershed had an estimated population of 25,620 (US *Census Bureau*, 2010). However, seasonal population data are not available for the Vermont portion. The total year-round population of the Missisquoi Bay watershed (Québec and Vermont) is estimated to be 49,270 permanent residents.

Missisquoi Bay is the source of drinking water for thousands of people, an important economic and recreational resource for the region. The bay has several beaches and campgrounds that include about 900 sites, and contains internationally significant wetland and wildlife habitat**.** Missisquoi Bay is a popular spot for boating and other recreating, including wind- and kite-surfing.

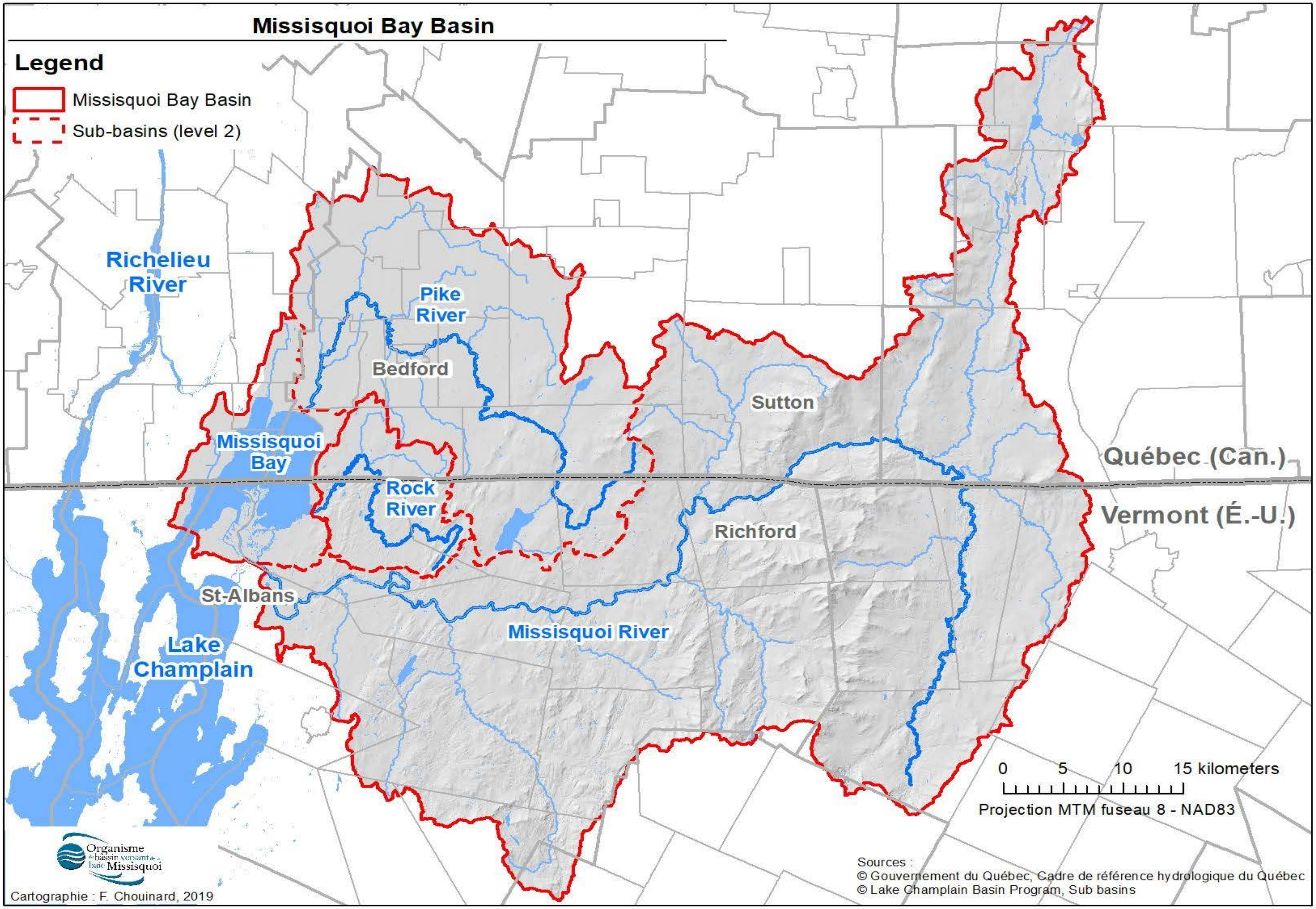

Figure 2. Missisquoi Bay watershed is 3,108 km² in area. OBVBM 2019

2.4 Literature review and quality assurance

This literature review is intended to be representative of the current state of knowledge of nutrient loading and cyanobacteria issues in Lake Champlain, the Richelieu River, and Missisquoi Bay. The review addresses the major sources, causes, and dynamics of nutrients in the study areas and how those nutrients impact the growth of cyanobacterial blooms. Additionally, this review provides an analysis of the efficacy of various policies and programs that have aimed to manage nutrients and cyanobacteria and control their impacts on public health and the environment.

This review was conducted in accordance with an approved Quality Assurance Project Plan (QAPP). Information was obtained from peer-reviewed journals, approved graduate theses, government and other technical reports, as well as active research information from the Lake Champlain Basin Program. Original sources were collected for references that cited the data of other studies. Zotero, a free, open-source reference management software, was used in order to collectively manage and organize reference documents.

The authors reviewed over 300 references, nearly 200 of which are cited in this report. Work concerning the study areas of Lake Champlain, Richelieu River, and Missisquoi Bay was given precedence over studies conducted elsewhere. OBVBM and LCBP supplemented these references by conducting interviews with watershed professionals; the information collected in these interviews was used to craft a set of management recommendations.

Regarding the mention of phosphorus throughout this report, this nutrient is measured and reported several ways including total phosphorus (TP), soluble reactive phosphorus (SRP), and particulate phosphorus (PP). Moore offers a thorough description of the various forms of phosphorus and the associated nomenclature (2016). Unless otherwise indicated, the term “phosphorus” in this report refers to total phosphorus.

To reduce confusion in this report the Lake Champlain Basin is referred to as “the basin” or “the watershed” and the Missisquoi Bay Sub-Basin is referred to as the “the sub-basin”.

2.5 Vermont EPSCoR

Two recent Vermont/NSF EPSCoR research projects initiated large cross-disciplinary studies focused on understanding the social and ecological drivers of water quality in Missisquoi Bay (https://epscor.w3.uvm.edu/epscor/). This research has generated a large body of process-based studies that link distinct environmental conditions (e.g. climate, weather, watershed inputs, bay physics) that operate on multiple timescales (e.g daily, seasonal, inter-annual) to internal and external nutrient loading in the bay and consequent cyanobacteria blooms. Additionally, an integrated assessment model (IAM) that consists of linked social, governance, climate/weather, hydrologic, hydrodynamic, and water quality models of the Missisquoi Basin has been developed under this body of research (e.g., Zia et al., 2016). Development of this powerful tool is ongoing, but this IAM has and will continue to be a useful tool for the stakeholder community to explore the coupled impacts of different climate change scenarios and/or watershed and in-lake management initiatives on the bay’s water quality, and how water quality in the bay could evolve over future decades in response to such changes. As such, this is a tool that the community should continue to utilize when possible and relevant to help inform future initiatives that aim to promote water quality in the bay.

3 Key nutrient loading and cyanobacteria issues

3.1 Overview of nutrient loading and cyanobacteria issues in Lake Champlain and Missisquoi Bay

Lake Champlain faces several water qualities challenges, including climate change, aquatic invasive species, and nutrient pollution (Smeltzer, Shambaugh, and Stangel 2012; Lake Champlain Basin Program 2018). One of the greatest obstacles that Lake Champlain communities face is cyanobacterial blooms. These blooms pose a multitude of obstacles for local economies and public health, including reductions in recreational use and potential health impacts from exposure to cyanotoxins in drinking and recreational waters. The location, timing, and intensity of cyanobacteria blooms vary from year to year, but often occur in the late summer on Missisquoi Bay and can persist for weeks at a time (Shambaugh 2016; Pearce et al. 2013).

Not all cyanobacteria species produce toxins, and those that can produce toxins do not always do so. Cyanobacterial toxins can be harmful to humans, pets, and wildlife, and can act on several different human systems. In addition to the skin irritation and gastrointestinal symptoms that may be caused by contact with cyanobacteria, hepatotoxins (e.g., microcystin and cylindrospermopsin) can cause liver damage, and neurotoxins (e.g., anatoxin and BMAA, or Beta-Methylamino-L-alanine) can damage the nervous system (Shambaugh 2016). A short-term study which analyzed microcystin and anatoxin-a in the Burlington Water and Champlain Water treatment plants found low levels of these toxins in both raw and finished water samples (Boyer et al. 2004), however, recent improvements to water treatment systems have reduced this risk in many systems. Ongoing sampling of drinking water facilities utilizing Lake Champlain as a source of supply is discussed further in Section 2.2.3. Aside from Missisquoi Bay and the Northeast Arm, microcystin concentrations are generally very low in both the lake as a whole and only very rarely found in raw drinking water, and have not been detected in finished water (Boyer et al. 2004; Lake Champlain Basin Program 2018; Shambaugh et al. 2017).

While cyanobacteria are present in Lake Champlain's paleolimnological sediment record (Levine et al. 2012), cyanobacterial blooms are occurring more frequently in concurrence with higher phosphorus inputs from changes in land use and increasing water temperatures (Facey et al. 2012). Climate change projections for Lake Champlain suggest that the basin's air and water temperatures will increase, leading to more favorable conditions for cyanobacterial growth (Shambaugh 2016; Isles 2016). The *Direction de l'expertise hydrique* of Québec (DEH) has produced the *Hydroclimatic Atlas of Southern Québec,* which presents a portrait of the impact of climate change on the hydrological regimes (floods, low water periods, hydraulicity) of southern Québec by 2050 (CEHQ, 2013 and 2015). In terms of hydraulicity calculated for the Missisquoi River and the Pike River, the DEH predicts a very likely increase in average winter-spring flow and a likely decrease in average summer-fall flow (DEH, 2018). According to data from the DEH and USGS, all hydrometric stations in the bay's watershed have experienced an increase in average annual flows since they began to operate (CEHQ, 201). The spring melt is expected to begin earlier, gradually moving towards February, and likely reaching its maximum in March instead of April (Mehdil, 2013).

Cyanobacterial growth is dependent upon the concentration of bioavailable phosphorus, which is often a limiting nutrient in freshwater systems (Wetzel 2001; Isles 2016). Excessive phosphorus continues to be an issue in Lake Champlain and work beginning to establish total maximum daily loads (TMDLs) for phosphorus began in the 1990s. For phosphorus concentration management purposes, the lake is divided into 13 segments, 12 of which have a TMDL established by the EPA addressing phosphorus loads from the Vermont portion of the basin (U.S. EPA 2016). A TMDL developed by NYSDEC in 2002 addresses phosphorus loads from the New York portion of the basin. No established long-term trends have been identified in any of the lake segments, other than the Northeast Arm, which demonstrates an increasing trend from 1990-2017 (Lake Champlain Basin Program 2018). Missisquoi Bay, St. Albans Bay, South Lake A, and Northeast Arm segments all typically exceed their established phosphorus limits (Figure 3).

Frequently, phosphorus is imported to the watershed via widespread fertilizer and manure use and animal feed, and agricultural production the largest source of phosphorus input to the lake (U.S. EPA 2016). Animal feed import has been a source of phosphorus increase as well: importing feed into the Lake Champlain watershed allows farmers to increase animal density and improve animal productivity. While much of the phosphorus transfers into milk and dairy products that are exported from the watershed, some of this phosphorus remains in the watershed in the form of increased manure, and manure of higher nutrient content (Wironen, Bennett, and Erickson 2018). In addition, a major challenge to addressing the phosphorus loading to the lake is that part of the contribution is from legacy phosphorus that has been added to the soil from long-term agricultural practices. This legacy phosphorus will continue to reach the waterways in the foreseeable future despite active reduction efforts (Lake Champlain Basin Program 2018).

Two other phosphorus sources of concern are developed lands and stream channel sediments. Developed lands account for around 4% of the Lake Champlain Basin's total area, but a disproportionate 16% of its total phosphorus load (U.S. EPA 2016; Lake Champlain Basin Program 2018). This is due generally to a higher proportion of rainfall that runs off of developed land due to impervious surfaces. Those impervious surfaces generate pollutant loads associated with the runoff of accumulated sediment, and the increased surface runoff can also exacerbate stream channel erosion. Streambanks are particularly vulnerable to sediment erosion in areas lacking sufficient vegetation and functioning floodplains. Stream channels contribute 165 metric tons (mt) of phosphorus to Lake Champlain each year, accounting for approximately 18% of the total phosphorus load into the lake (Lake Champlain Basin Program 2018). As shown in Figure 3, Missisquoi Bay remains the most problematic lake segment for phosphorus concentration.

Point source discharges from wastewater treatment facilities are a relatively minor contributor to the phosphorus problem in Missisquoi Bay, adding up to just 1.7% of the total load to the bay between 2001 and 2010 (USEPA, 2016). Lake-wide, from 1991 to 2009, improved phosphorus removal by wastewater treatment facilities has resulted in an 83% decrease in wastewater phosphorus loading to Lake Champlain. As of 2016, wastewater treatment facilities contribute less than 2 % of the lake's total phosphorus load (US EPA 2016).

In addition to the external contributions, internal phosphorus loading is an issue in the bay. Sediments that have been deposited into the lake bottom store phosphorus and act as a reservoir that can release phosphorus over time when the water conditions are conducive. The amount of phosphorus released from bottom sediments is dependent on wind, river discharge, and other factors affecting mixing, water column stability, and oxygen levels at the sediment/water interface (Giles et al. 2016). A study by Levine et al. (2011) on the evolution of Missisquoi Bay sediments found that the rate of accumulation of the oldest sediment characterized was approximately 0.6 kg/m^2/year by the end of the 19th century. This rate grew gradually, followed by a significant increase from the 1990s to 1.4 kg/m^2/year. Phosphorus in sediments contributes to cyanobacteria blooms, the accelerated eutrophication of the lake and the degradation of its aquatic ecosystem. In addition, this internal loading makes reaching the target attainment of phosphorus concentration of 0.025 mg/L for Missisquoi Bay more difficult.

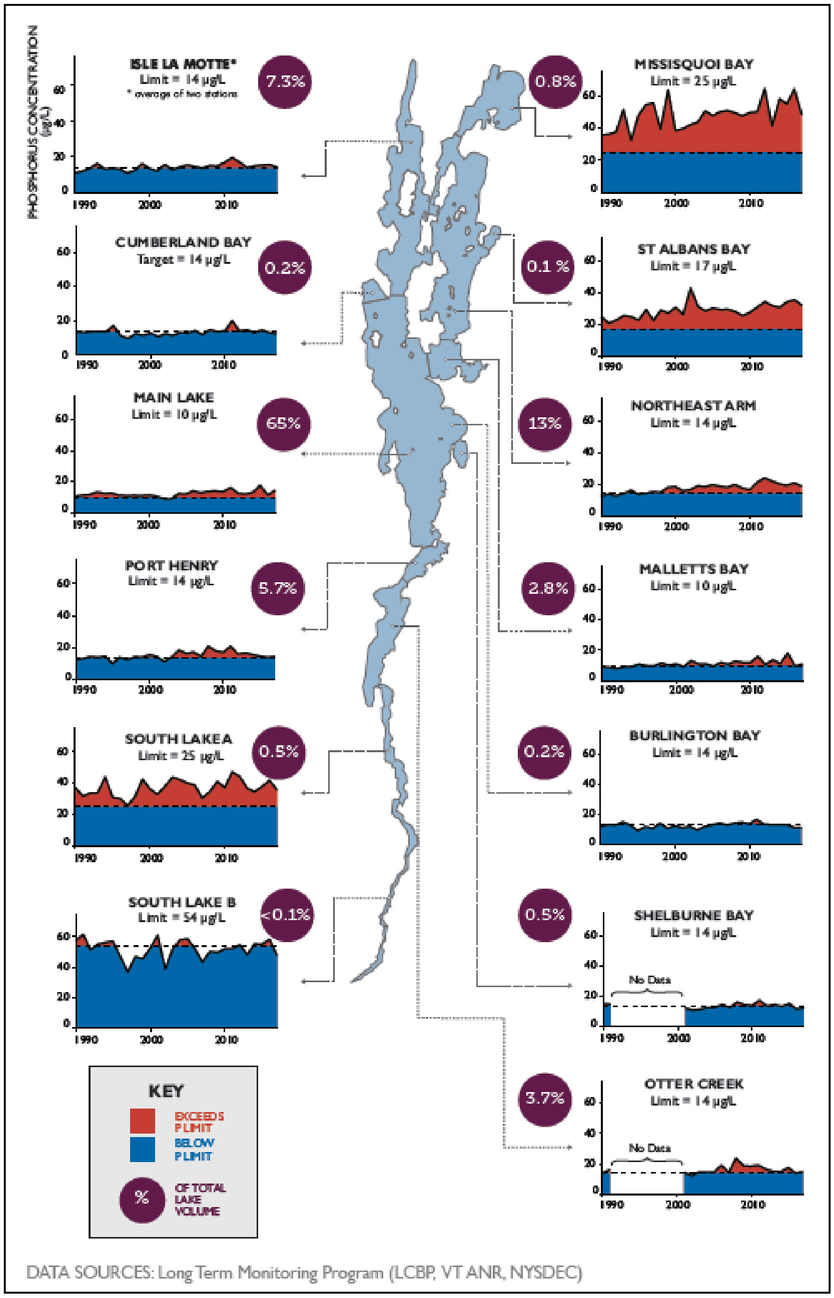

Figure 3. Annual phosphorus means concentrations and TMDL targets for the 13 lake segments from 1990-2017 (Lake Champlain Basin Program 2018).

3.2 Detailed analyses of Missisquoi Bay and its sub-basin

Missisquoi Bay has been negatively affected by eutrophication for decades. For example, from June to September 1967, the average phosphorus concentration was 0.085 mg/L at the Canada-U.S. border (Fontaine et al., 1968). Examination of the data shows that from 1979 to 2009 the concentration of phosphorus increased by 72% and that of chlorophyll a doubled (Smeltzer et al., 2012). Figure 4 illustrates the magnitude of exceedances of annual average phosphorus concentrations at Station 50 since 1992, relative to the target of 0.025 mg/L (LCBP, 2018).

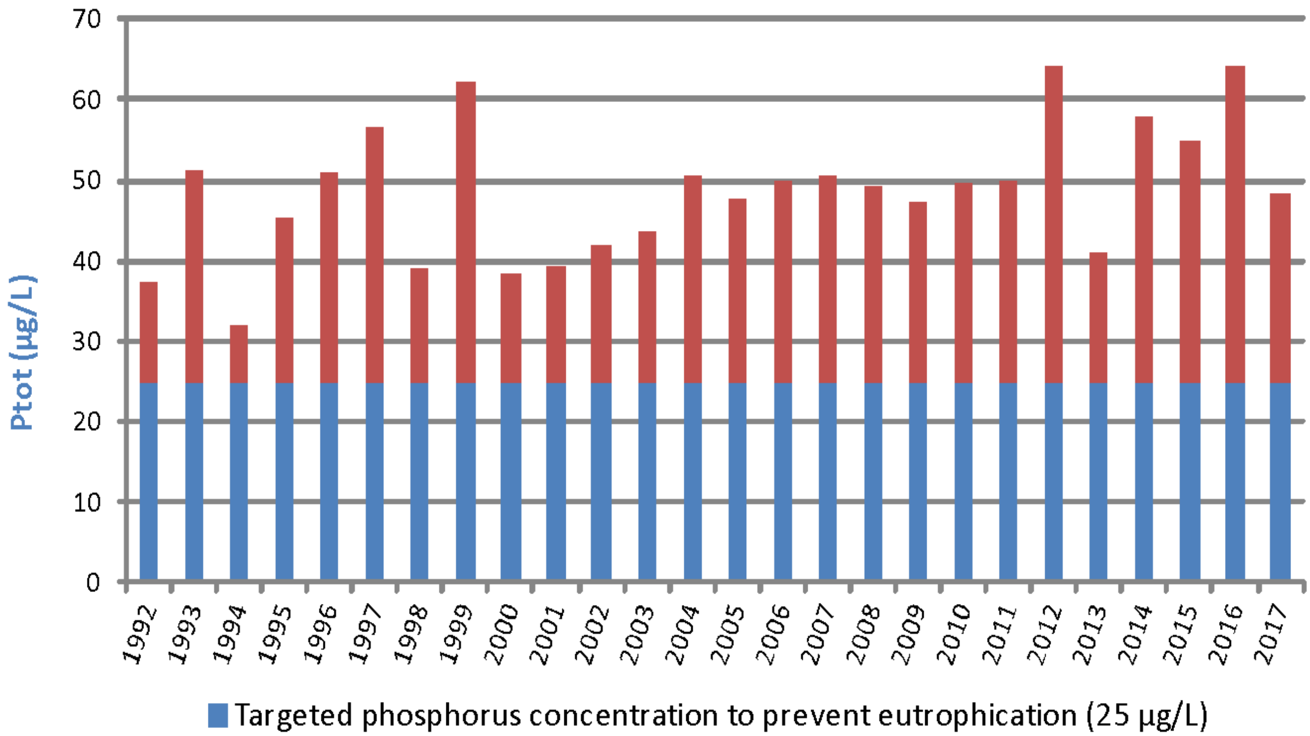

Figure 4. Concentrations exceeding the 25 µg / L phosphorus criterion at the Missisquoi Bay outlet (Station 50; LCBP 2018)

Based on the 2016 TMDL, the estimated load from 2001 to 2010 was 72.4 metric tons (35%) for Québec and 136.3 metric tons (65%) for Vermont, for a total of 208.7 metric tons (TetraTech, 2015). The total target loading to be achieved under this new TMDL, to reach the target concentration of 0.025 mg/L in Missisquoi Bay, would be 81.0 metric tons of phosphorus per year—32.4 metric tons for Québec and 48.6 metric tons for Vermont (TetraTech, 2015). The internal loading of phosphorus was considered in the review of this 2016 TMDL, which required Vermont and Québec to further reduce inputs from tributaries.

Table 2. Missisquoi Bay total maximum daily loads (base loads and loading capacities) 2002 and 2016

	QC-VT Agreement (TMDL 2002)		TMDL 2016	
	Base load (Mt yr^{-1}) (1991) (% allocation)	Total loading capacity (Mt yr^{-1}) (% reduction)	Base load (Mt yr^{-1}) (2001-2010) (% allocation)	Total loading capacity (Mt yr^{-1}) (% reduction)
Québec	66.2 (40%)	38.9 (41%)	72.4 (35%)	32.4 (55%)
Vermont	101.1 (60%)	58.3 (42%)	136.3 (65%)	48.6 (64%)
TOTAL	167.3 (100%)	97.2 (42%)	208.7 (100%)	81.0 (61%)

Sources: Hegman et al., 1999, TetraTech, 2015. Mt = Metric ton.

Despite an actual increase in phosphorus loadings to Missisquoi Bay, the comparative analysis of phosphorous concentration to -water flow relationships between 2001-2005 and 1990-1992 showed a significant decrease in phosphorus concentrations for the low flow range (<10^8 m^3/year), reflecting the effect of urban and industrial remediation measures. A significant decrease in phosphorus concentrations in the high flow range (≥10^8 m^3/year) also was found, suggesting an improvement associated with agricultural remediation (Smeltzer and Simoneau, 2008). For example, in comparison to 1991 data, phosphorus loadings from wastewater treatment decreased by 73% in Vermont and 74% in Québec between 2001 and 2005 (Simoneau and Smeltzer, 2008.). The study of trends for the period 1990-2008, published in 2009 by the LCBP in collaboration with the Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC), indicated that phosphorus loadings from the Missisquoi River, calculated based on two-year blocks, have remained stable (Smeltzer et al., 2009). In both the Missisquoi and Pike Rivers, loads decreased between 1990 and 2000, and then increased between 2000 and 2008, as average flows increased over that period (Smeltzer et al., 2009).

There have been several efforts by the US Geological Survey and LCBP to estimate load trends for 18 of Lake Champlain's major tributaries using the weighted regression on time, discharge, and season (WRTDS) model (Medalie, 2012; Medalie, 2014; Medalie, 2016; Vaughan, 2019). Patoine (2017) used the same model to estimate phosphorus loads from 2009 to 2012 for all MELCC monitored streams in Québec, including the Pike River. The WRTDS model includes a method to reduce the influence of annual hydrologic variability to investigate water quality trends. The most recent report showed no significant trends in total phosphorus loading from the Missisquoi or Pike Rivers over the full 1991-2017 available data record. However, there was a significant increase in total phosphorus loading from the Missisquoi River during the 2004-2017 time period. This analysis also showed significant decreases in Pike River total phosphorus loading during the 1991 – 2004 time period, which supports similar findings mentioned above (Vaughan 2019).

In the Québec portion, the downward trends observed since 1999 in some tributaries of Missisquoi Bay show significant improvements in low flow ranges and point source inputs, with positive signals coming from some agricultural sub-watersheds. However, since 2006, loadings appear to remain stable despite phosphorus reduction efforts. The relative stability of phosphorus loadings observed from 2006 onwards can be explained by the fact that residual loadings are mainly from diffuse sources (Simoneau, 2019; OBVBM Interviews, 2019). The combination of remediation efforts has helped to reduce phosphorus inputs. However, the high concentrations that are still associated with the river's high flows mean that the reduction in loads is slower (Simoneau, 2019; OBVBM Interviews, 2019).

There are several possible explanations for the lack of trends of concentrations in some streams:
- Inadequate and unsustainable management actions to drive measurable change,
- Interventions did not sufficiently affect critical areas,
- Insufficient time has passed since an intervention for it to have a measurable effect, and/or
- The implementation of nutrient reduction practices cannot erase the effects of legacy soil phosphorus.

While evidence of improvements in phosphorus loading have not been documented since 2006, the lack of trends of phosphorus concentrations does suggest that interventions may have prevented some additional nutrient increases (Simoneau, 2019). However, in the main tributaries of Missisquoi Bay, nutrient and sediment concentrations and loads remain excessive in relation to targets and criteria for the protection of ecosystems and the bay. Significant efforts are still required to reduce phosphorus inputs, including those from nonpoint sources, into the Missisquoi Bay watershed.

3.2.1 Hydrodynamics

Missisquoi Bay is the most northern embayment of Lake Champlain, with relatively straightforward hydrodynamics due to the shallow depth and limited connection with the rest of Lake Champlain through Alburgh Passage. The restricted opening at the southern end of the Missisquoi Bay focuses water flow out of the bay, with 86% of the volume flowing outward through Alburgh Passage and Carry Bay (Marsden and Langdon 2012). The Missisquoi Bay outfall, with a natural width of approximately 1,350 m, features a significant narrowing of two embankments totalling 1,080 m, remnants of the former Alburgh-Swanton Causeway, with a 270 m opening in the centre, or 20% of the original width.

The Bay receives water from three tributaries: the Missisquoi, Pike, and Rock Rivers. The longest of the three is the Missisquoi River, at approximately 142 km. The land use of this tributary comprises 60%, 24%, and 6% of forested, agricultural, and urban coverages, respectively (Vermont DEC 2013). The Missisquoi River accounts for 79% of the discharge to the bay (Limnotech 2012). The Pike River has a similar land use composition with 51%, 34%, and 5% of forested, agricultural, and urban uses, respectively (Vermont DEC 2013). Finally, the Rock River is composed of 40%, 41%, and 5% forested, agricultural and urban uses, with an additional 7% of the land coverage identified as wetlands. The Pike and Rock Rivers contribute 18% and 3% of discharge to the bay, respectively (Limnotech 2012).

The hydrodynamics of Missisquoi Bay are primarily wind-driven (Manley et al. 1999), but also affected by thermal dynamics, solar radiation, and discharge quantity (Isles 2016). There are four identified circulation modes: wintertime sluggish, spring melt, well-mixed summer, and two-layer summer (Manley et al. 2018).

There are 25 dams throughout the Missisquoi Sub-Basin, with varying uses and statuses, altering flow and affecting water quality and sediment transport (Vermont DEC 2013). Tile drainage also alters the hydrology of the sub-basin, increasing total water output from field, but reducing the quantity of surface water (Moore 2016). Approximately 75% of the Missisquoi basin stream channels and water bodies have changed courses due to modifications to land cover and hydrology, as well as anthropogenic channel re-alignments (Potter et al. 2008).

3.2.2 Nutrient enrichment

Dynamics, sources, and causes

Water in Missisquoi Bay consistently exceeds its Vermont and Québec phosphorus criteria of 0.025 mg/L. During the period of 2001-2010, Vermont sources contributed an average of 136 mt/yr of phosphorus to Missisquoi Bay, 42% of which was from agricultural sources and 29% from streams, primarily streambank erosion (U.S. EPA 2016). Mean phosphorus loading rates have also been analyzed for sub-watersheds within the Missisquoi Bay sub-basin: sub-watersheds determined to have the highest mean phosphorus loading rates were the Lower Missisquoi, Pike, Missisquoi Nord, and Upper Missisquoi (Smeltzer and Simoneau 2008). The phosphorus loads from developed, forested, and agricultural lands are some of the highest amongst all the Lake Champlain sub-watersheds (U.S. EPA 2016). Figure 5 shows the distribution of phosphorus sources by land use in the Vermont portion of the sub-watershed.

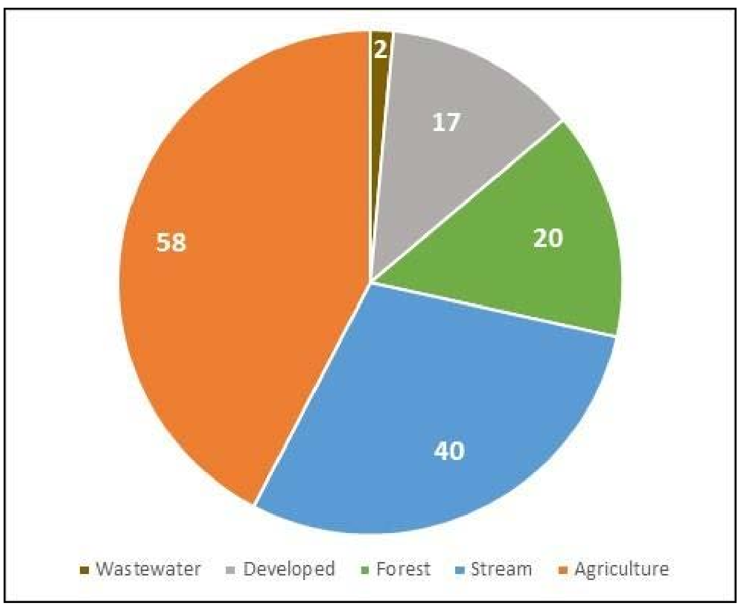

Figure 5. Phosphorus loading (mt/yr) by land use to Missisquoi Bay from the Vermont portion of the sub-basin, 2001-2010 (US EPA 2016)

Point sources are found throughout the sub-basin. Vermont has seven municipal and one industrial wastewater treatment facilities, while Québec has eight municipal wastewater discharges (Missisquoi Bay Phosphorus Reduction Task Force 2000). However, wastewater discharges have been found to be a relatively small source of phosphorus loading to Missisquoi Bay. During 2002-2005 they represented only 2% of the total phosphorus load from Vermont, and 3% of the total load from Québec (Smeltzer and Simoneau 2008). Other urban or developed land uses have average phosphorus loading rates compared to other land-use classifications, but with developed land accounting for only 6% of the land area in the Missisquoi Bay Sub-Basin, the associated phosphorus loading is small (Winchell et al. 2011).

Streambank erosion is a major source of nutrients, contributing approximately 29%-40% of phosphorus and approximately 29-42% of total suspended solids to the bay every year (Morrissey and Rizzo 2010; Winchell et al., 2011; Langendoen et al. 2012; U.S. EPA 2016). Phosphorus mass-balance mixing studies have found that deposited sediments play a significant role in the bay's phosphorus cycle, with legacy sediment acting as both a source and sink of phosphorus (Limnotech 2012). Sediment fluxes are responsible for 20% and 43% of total phosphorus inputs during the whole year and summer, respectively (Limnotech 2012). In addition to streambank sources, erosion from agricultural or forestry practices can also play a role in nutrient deposition. The annual tillage of corn fields, as well as bank instability due to animal traffic can also contribute to erosion and, thereby, sediment and phosphorus contributions to streams and Missisquoi Bay (Potter et al. 2008).

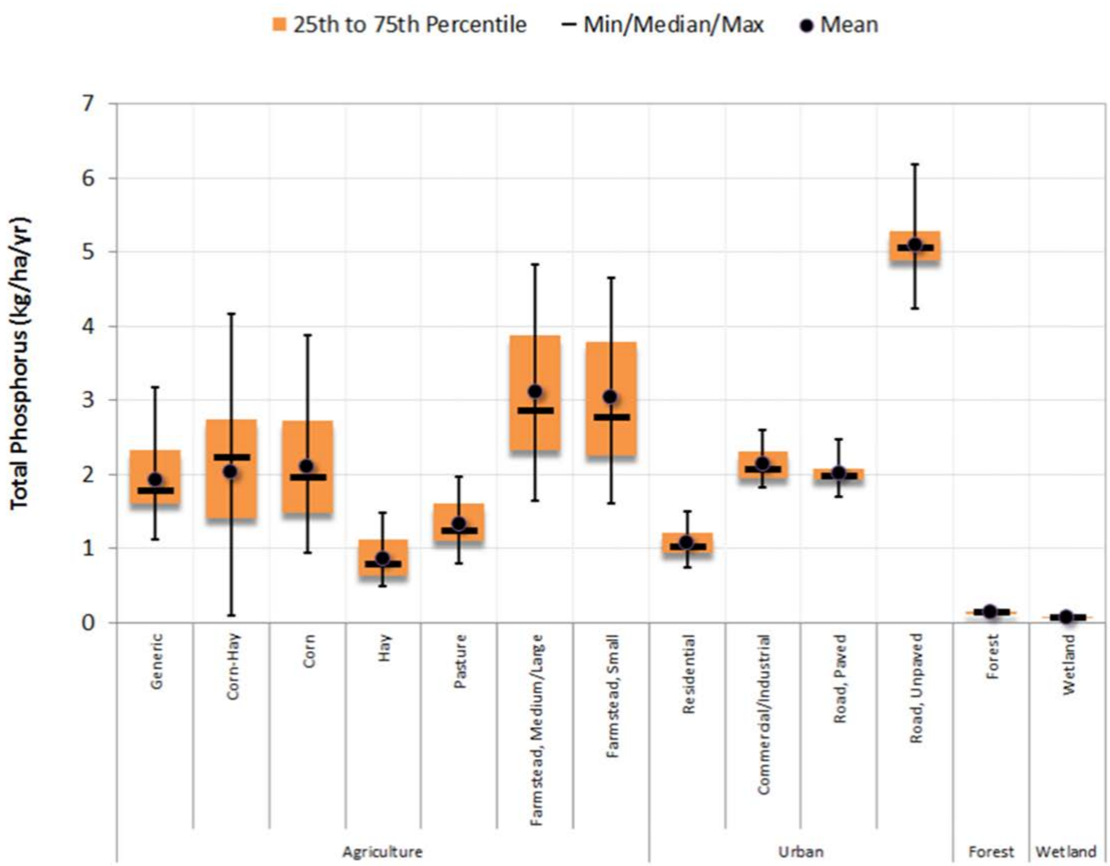

Figure 6. Total P loading rate and load to area ratio for major land uses in the Vermont-portion of the Missisquoi Bay Basin (CSA assessment area) Source: TetraTech, Inc.

Nutrients from agricultural sources within the Missisquoi Watershed have been identified as the leading causes of impairment (Smeltzer and Simoneau 2008; U.S. EPA 2016). There are 290 dairy farms in the Vermont portion of the watershed, with an additional 100 animal-related farms (Vermont DEC 2013).

In the Québec portion of the Missisquoi Bay watershed, according to MAPAQ data from the 2019 farm registration records, there are 490 farms with a primary operating site located in the watershed (MAPAQ, 2019). Farms producing field crops (265) and dairy farms (99) are the most common, followed by horticultural production (99), field vegetable (33), beef cattle (65), hogs (37) and poultry (36). The Pike River's sub-basin has by far the largest number of farms at 359, followed by the Missisquoi River (70). The watersheds of the Rock River (34) and direct drainage to the bay (27) have a smaller number. In 2005, the Missisquoi Bay watershed (Québec and Vermont) was the Lake Champlain sub-basin that had the most farms and animal units per hectare (Watzin, 2005).

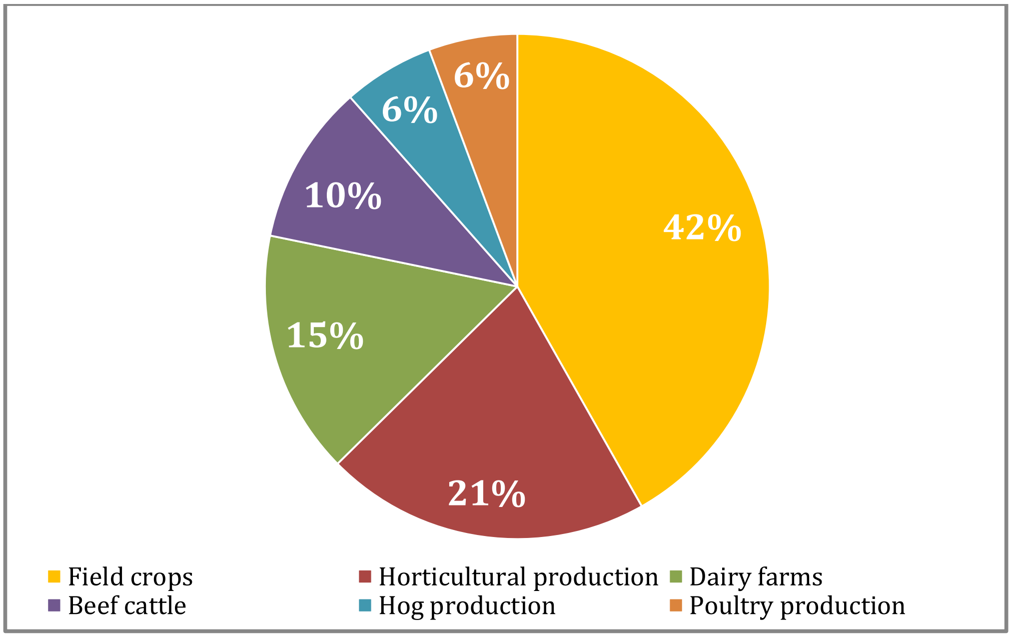

Figure 7. Farms by category in Québec's Missisquoi Bay Watershed Source: MAPAQ, 2019

The 490 farms located in the Québec portion of the watershed are using 52,375 ha of agricultural land in 2019. Of this total, 20,357 ha (39%) are used for field crops (mainly grain corn, soybeans and straw cereals), 10,154 ha for grasslands and pastures (19%), 1,135 ha for silage corn (2%) and 1,134 ha for fruit, vegetable and horticultural production (2%). Forest areas (including maple syrup operations) account for 16,744 ha (32%) and other uncultivated areas (including fallows and brownfields) for 2,500 ha (5%) (MAPAQ 2019)

There are approximately 248 livestock farms in the Québec portion of the watershed, for a total of 30,131 animal units broken down as follows: 41% pork production; 33% dairy cattle production; 15% poultry production; and 11% beef cattle production (MAPAQ, 2019).

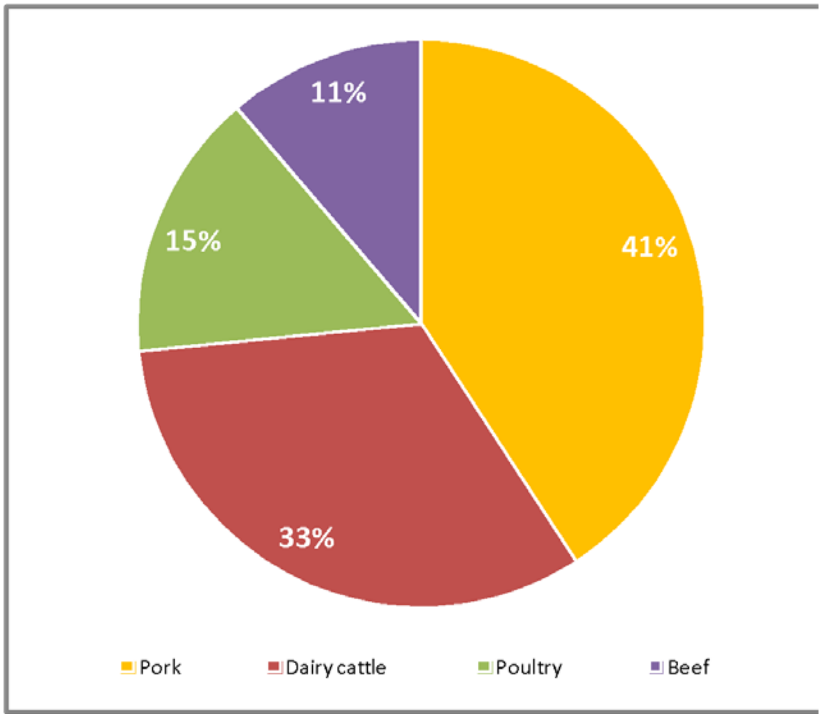

Figure 8. Animal units by category in Québec Missisquoi Bay Watershed Source: MAPAQ, 2019

Livestock numbers have decreased over time: there were 42,060 animal units in the watershed in 2006, according to the census that year (STC 2006). The Pike River Basin has the vast majority (70%) of livestock farms and the highest animal density with 1.4 animal units/hectare (STC 2006). As previously demonstrated, agricultural land is the main source of phosphorus in the Québec portion of the watershed, generating around 75-80% of the loading to Missisquoi Bay. The eutrophication of Missisquoi Bay is closely correlated with the intensification of agriculture in its watershed (Levine et al., 2012). Despite remedial actions and improvements in agricultural practices, the main determinant of median phosphorus concentrations remains land use and more specifically, the proportion of annual crops grown in watersheds (Simoneau, 2018).

Based on MELCC modelling of 25 watersheds in Québec, the proportion of annual crops in a watershed explains 65% of the variance observed in the median phosphorus concentrations measured at monitoring stations and 85% of the nitrogen. Cattle (number of animal units), account for 14% of the observed phosphorus variance (4% for nitrogen) and loads from wastewater account for only 2% of the total phosphorus (Hébert & Blais, 2017). In addition, according to a study by the Research and Development Institute for the Agri-environment (IRDA), overall, about 35% of soil analyses collected in municipalities in the Pike River watershed had phosphorus saturation levels above the vulnerability threshold of 10% P (Deslandes et al., 2004; Michaud et al., 2004; Deslandes et al., 2006). According to the report, the main source of diffuse phosphorus in agricultural land in the Québec portion of the bay is not mineral phosphorus; it comes from animal manure (Michaud et al., 2006). Therefore, manure management is a priority issue.

The type of vegetation cover and the surface application of chemical or organic fertilizers also account for the highest proportion of dissolved phosphorus that has been measured in perennial crops and direct seeding (Stamm et al., 1998; Weighting, 1987; Messiga et al., 2009). An IRDA study on the effect of soil types, crop types and manure application on phosphorus export showed that the soil type is responsible for 70% of the bioavailability of particulate phosphorus, while manure application alone accounts for 35% of the variability in dissolved reactive phosphorus (Michaud et al, 2004). The study of the links between phosphorus concentration and agricultural activities showed that the correlation is stronger with long-spaced crops because the soil is barer and more prone to erosion between rows than for narrow-spaced crops.

There is a correlation with perennial crops, while there is an inverse correlation with forests (Gangbazo, Roy and Le Page, 2005). Soil P levels and supply P balances are significantly correlated in the watershed and contribute to explaining more than 85% of the spatial variability in phosphorus flows in the Pike River's subwatershed (Deslandes et al. 2006,Michaud et al., 2007). At the field scale, similar results were reported by Poirer et al. (2012) with the Pike River watershed, where 80% of particulate P levels in tile and surface runoff were explained by the soil P level alone.

Studies have been conducted, particularly in the Pike River sub-watershed, to assess the mobility of phosphorus in agricultural underground drainage. It was observed that groundwater was the main outlet with about 80% of total water exports and that up to 40% of the phosphorus was exported through tile drains. Losses of dissolved and particulate phosphorus and nitrogen are particularly high in clay soils through preferential channels. However, according to this study, surface runoff contributed to the majority (60%) of phosphorus losses, as phosphorus was, on average, 10 times more concentrated in surface runoff than in drains (Jamieson et al., 2003; Enright and Madramootoo, 2004).

Nitrogen and nitrates are highly soluble and therefore very mobile, particularly in groundwater (Thériault, 2013). A study published in 2002 concluded that 90% of annual nitrate losses occurred through agricultural drains, with measured concentrations ranging from 1 to 40 mg/L (Giroux et al., 2002). Only 10-15% of nitrate losses are from surface runoff.

3.2.3 Cyanobacteria blooms

3.2.3.1 Cyanobacteria and cyanotoxins

Globally, there are 2,698 defined species of cyanobacteria, with some estimates suggesting that the true number could in fact be near 8,000 (Nabout et al. 2013). The most common cyanobacteria genera that occur in Missisquoi Bay are *Microcystis*, *Anabaena*, and *Aphanizomenon* (Davis et al. 2009; Isles et al. 2015; Pearce et al. 2013). Several studies have shown that there is great inter-annual variation in the presence and dominance of different cyanobacteria species (Isles et al. 2017; Bowling, Blais, and Sinotte 2015). The complexity of Missisquoi Bay's nutrient dynamics is largely responsible for the community's heterogeneity. In fact, one study showed that on any given day different taxa could be the dominant species at different sampling sites (Bowling, Blais, and Sinotte 2015).

Coincident with an increase in nonpoint source nutrient inputs to Missisquoi Bay, the cyanobacteria problem has been a growing one since the latter half of the 1900s. Smeltzer, Shambaugh, and Stangel (2012) describe an increasing dominance of cyanobacteria in Missisquoi Bay in the past fifty years. There was little awareness and limited uniform monitoring for blooms in the region prior to the 2000s (Shambaugh 2016). At the turn of the century several dog deaths were associated with severe blooms in the main lake areas of Lake Champlain, which brought public scrutiny and concern about the presence of cyanobacteria (Boyer et al. 2004). Data stations monitoring water quality since 2003 show the severity of some conditions diminishing and, in some locations, a decrease in the frequency of blooms (Shambaugh 2016).

Cyanobacteria blooms in Missisquoi Bay are considered more severe in Québec because blooms are concentrated in the Québec sector of the bay (Blais, 2002). Between 2000 and 2008, the area most heavily affected by cyanobacteria was the eastern portion of Missisquoi Bay, the *Grande Baie* sector, which extends from Pointe Jameson to Saint-Armand, and the Philipsburg sector. The bay of Venise sector is in second place, while the Missisquoi Bay's central sector is the least affected (Blais, 2014). Cyanobacteria blooms are typically observed from the second half of June to mid-October and are more prevalent beginning in the second half of July. The prevailing winds from the southwest encourage cyanobacteria blooms predominantly towards the eastern portions of the bay, as well as towards the bay of Venise (Blais, 2014).

Scientists are working to better understand the relationship between cyanobacteria and cyanotoxins. This connection is complicated by the fact that, even within a genus, some taxa may be incapable of producing toxins while others are capable of toxin production but may not express the toxin-producing gene (Shambaugh 2016). Cyanobacteria can produce a wide variety of toxins with different chemical structures and human health impacts. For instance, while there is only one known analog of anatoxin-a, there are over 80 known microcystin variants with a wide range of toxicities (Boyer et al. 2004).

The ability to better understand when and where a bloom may occur and when it might be toxic is important to managing health, beach, and drinking water advisories. A variety of environmental and water quality factors have been utilized, with various accuracy, in efforts to predict bloom toxicity. These include testing for nutrients, pigments such as phycocyanin and chlorophyll, and newer methods such as molecular testing for toxin-producing cyanobacteria genes. New molecular methods to detect the *mcyE* gene hold promise for more clearly understanding and accurately detecting microcystin-producing cyanobacteria (Francy et al. 2015).

The most commonly found cyanotoxins found in Missisquoi Bay are microcystin and anatoxin-a (Shambaugh 2016; Boyer et al. 2004). There is no way to identify toxicity by sight alone. Therefore, in unmonitored waterbodies it has been the occurrence of animal and human health effects that have indicated hazardous levels of cyanotoxins (Shambaugh 2016; Rosen et al. 2001). Of the common cyanotoxins, microcystins have generally been the most common in Lake Champlain and Missisquoi Bay (Boyer et al. 2004). As with anatoxin-a, microcystin is often found in low concentrations. Of the 80 known variants of microcystin, the most common and toxic being microcystin-LR (Graham et al., 2010). Cyanobacteria likely produce microcystins as a response to conditions of oxidative stress that arise at the surface during blooms (Zilliges et al. 2011).

Cyanotoxins are not typically found in high concentrations in Missisquoi Bay. However, that does not mean that their potential effects can be disregarded. While studies have found that levels of anatoxin-a in Missisquoi Bay tend to be very low, anatoxin-a can negatively affect human health even at low concentrations because it has a higher toxicity at low concentrations (Osswald et al. 2007).

Lake Champlain serves as a drinking water source for approximately 20% of the basin's population. Several public water supplies withdraw and treat lake water for their customers, and there are also private homes along the lake which withdraw water and conduct minimal, if any, treatment prior to consumption (Lake Champlain Basin Program 2018). A short-term study which sampled 16 locations along the lake, as well as both raw and treated water from five water treatment plant intakes, found cyanotoxins at low levels in about half the samples collected. Low levels were detected in a few of the raw and treated drinking water samples, but all below the current Vermont Drinking Water Health Advisory levels (Vermont Department of Health 2018). Microcystin was the predominant cyanotoxin detected, and higher concentrations of this toxin were found in the more northerly portions of the lake, such as Missisquoi Bay. Water collected from shallower water treatment plant intakes showed higher concentrations than those drawn from deeper in the lake (Boyer et al. 2004).

An example of a cyanobacteria bloom in Lake Champlain. Photo: VT DEC.

Public concern about potentially toxic cyanobacteria blooms in the lake has led the state of Vermont to provide microcystin and cylindrospermopsin testing for public water supplies that draw drinking water from Lake Champlain. Since the summer of 2014, the Vermont Department of Environmental Conservation Drinking Water Program, in collaboration with the Vermont Department of Health, has implemented a voluntary, no-cost monitoring program of 22 public water utilities that use Lake Champlain for drinking water. Microcystin and cylindrospermopsin levels are tested weekly in raw and treated water at these utilities during the 12 summer weeks (2015-2018 Cyanobacteria Monitoring Reports, VT DEC).

The city of Bedford's drinking water intake (which also supplies the Philipsburg sector in Saint-Armand) is in Missisquoi Bay at an average depth of 3.5 m (2.5 m in low water periods and 4.5 m in high water periods, Blais, 2014). In Missisquoi Bay in 2001, the criterion of 1.5 µg/L for microcystin in drinking water was surpassed in 31% of samples taken from the bay, with a maximum concentration of 2,204 µg/L (Blais, 2002). In 2002, a cyanobacteria bloom was found inside the plant's treatment system. The existing treatment system was no longer able to ensure the safety of the water supply; as a result, a drinking water avoidance advisory was issued on August 13, and lifted on September 6, 2002.

The challenges posed by cyanobacteria in the intake required significant investments to properly treat drinking water. Activated carbon processing had to be added and follow-up ensured. The costs of drinking water treatment have increased significantly with the advent of cyanobacteria. The bill for chlorine and activated coal has increased exponentially in Bedford since 1994, as operating expenses for the water system have gone from $200,000 to $600,000 per year in a decade (Hébert, 2018). From 2001 to 2006, a raw and treated water monitoring survey of six drinking water treatment plants, including Bedford, sourced from aquatic environments where cyanobacteria proliferate, was implemented by the MELCC as part of its drinking water quality monitoring program. According to the study, despite the high presence of cyanobacteria and cyanotoxins in source samples, the maximum concentrations of microcystin-LR and anatoxin-a measured in treated water were 30 to 50 times lower than the INSPQ recommended guidelines (Robert et al., 2004; Robert, 2008).

Drinking water treatment for cyanobacteria and cyanotoxins may not be part of the operation and design considerations of many existing drinking water treatment plants. Cyanobacteria cells may be removed by certain clarification and filtration processes, but these processes can be complicated by the breakthrough of cyanobacterial cells and may result in treatment disruption leading to compromise of plant operations. Additionally, treatment processes, such as chlorination, may lyse cyanobacteria cells, releasing toxins. It is important to consider appropriate treatment techniques where eutrophic surface water is used as a source of drinking water (Sklenar, Westrick, and Szlag 2016).

Starting in 2018 through 2020, the United States Federal Safe Drinking Water Act will require extensive testing for cyanotoxins. Public water systems serving more than 10,000 customers, a representative sample of smaller public water systems, and all systems using surface water (or ground water under the direct influence of surface water) will be required to sample for nine cyanotoxins and one cyanotoxin group (total microcystins) (U.S. EPA 2016). This testing may identify further drinking water cyanotoxins issues in Lake Champlain and help identify drinking water systems at risk. However, this testing will not apply to the private homes that draw their water directly from the lake.

3.2.3.2 Sources and causes

It is generally accepted that as anthropogenic contribution of nutrients to Lake Champlain increased, so did the frequency and severity of blooms (Isles et al. 2017; Winslow 2016; Boluwade and Madramootoo 2015); this is true of Missisquoi Bay in particular (Levine et al. 2012). Missisquoi Bay specifically has experienced a similar fate as it became eutrophic following the expansion of agricultural production and moderate urbanization in the 1970s, coincident with an increase in the occurrence and magnitude of blooms (Levine et al. 2012).

The proliferation of cyanobacteria is the result of complex interactions between several factors including water temperature, sunlight, pH, nutrient content and currents in the water body in question (Duy et al., 2000). Missisquoi Bay has natural features that make it particularly vulnerable to cyanobacteria blooms. It is shallow bay. This condition promotes greater productivity and can exacerbate the problem of cyanobacteria throughout the water column. The shallow depth of the bay allows for warming of the water column, with a lot of sunlight reaching the sediments. These conditions can stimulate the metabolic activities of cyanobacteria, including the synthesis of gaseous vacuoles (Hyenstand et al*.,* 1998). In addition, the lack of thermal stratification observed in Missisquoi Bay and the abundant light provide cyanobacteria with optimal growing conditions. They can photosynthesize across the water column because light and nutrients are sufficiently abundant.

Cyanobacteria have characteristics that allow them to dominate algal species that make up the phytoplankton of lakes. For example, they can move vertically in the water column through gaseous vacuoles. They can also accumulate phosphorus reserves near sediments and rise to the surface near light to photosynthesize (EXXEP, 2004).

Like the complex interface of the many factors affecting nutrient dynamics in the Bay, cyanobacteria dynamics vary readily within and between years (Isles et al. 2017; Bowling, Blais, and Sinotte 2015). Understanding bloom variability on an inter-annual timescale is important to evaluating options for mitigation. The interaction of various meteorological and hydrodynamic factors further exacerbates the complexity of understanding the causes of blooms.

The Missisquoi Bay bloom season is often split into four distinct time periods: pre-bloom/post ice-out, bloom initiation, peak bloom, and post bloom. The pre-bloom period is often associated with cold air and water temperatures and lower cell counts of cyanobacteria. Bloom initiation is when temperatures start to warm and the nutrients in the lake reach a point where cyanobacteria can become dominant. Peak bloom corresponds to the densest growth of cyanobacteria, often attributed to late summer months when the water temperature reaches 20°C, coinciding with most blooms in Missisquoi Bay occurring in late summer/early fall (Davis et al. 2009; Hart et al. 2013). Generally, post bloom periods indicate a reduction in cyanobacteria as temperatures decrease (Giles et al. 2016).

Nutrient dynamics strongly affect bloom forming conditions. Phosphorus tends to be the driver of cyanobacteria growth, while nitrogen may affect the density and toxicity of some blooms (Gobler et al., 2016, Davis et al., 2009). While it is generally accepted that phosphorus is the limiting nutrient in freshwater systems, there is debate on the importance and role of nitrogen. Human and environmental factors may cause fluctuations in limiting nutrient over months and years, as the quantity of both nitrogen and phosphorus can affect each other and the system as a whole (Doering et al. 1995; Gobler 2016

When the TN:TP ratio is low, as it tends to be in Missisquoi Bay, it is likely that blooms of cyanobacteria will occur as they thrive and hold an advantage over phytoplankton in low-N environments (Davis et al. 2009; Pearce et al. 2013). Missisquoi

Bay has had years in which the TN:TP ratio never rose above 16 (Hart et al., 2013), and some cases where late summer samples showed a TN:TP ratio less than 10 (Fortin et al. 2013). According to the Redfield ratio (atomic ratio of carbon, nitrogen, and phosphorus found in phytoplankton) 16 is the average for TN:TP, and any counts under 10 show clear nitrogen limitation, and any counts above 30 show clear phosphorus limitations. It is not unheard of for a freshwater system to see a switch in the limiting nutrient, either year to year, or even over the course of one summer (Gobler et al. 2016). For example, there are instances where parts of western Lake Erie have been N-limiting in the late summer months (Thorne and Schlesinger 2017).

Key to the argument for phosphorus-limitation is the idea that nitrogen fixation helps cyanobacteria make up for the lack of nitrogen in the system. Nitrogen fixation is the process of turning atmospheric nitrogen into ammonia, which cyanobacteria use to grow and multiply. In Missisquoi Bay, *Anabaena* and *Aphanizomenon* utilize nitrogen-fixation (Davis et al. 2009; Hart et al. 2013; McCarthy et al., 2016; Boyer et al., 2004) and are typically more prominent by count earlier in the typical bloom season (late spring and early summer). This implicates phosphorus as the limiting nutrient for these two species. Contrarily, the growth rates of *Microcystis*, being non-nitrogen-fixing, was significantly increased for both toxic and non-toxic strains with increased concentrations of nitrogen (Davis et al. 2009). Increased phosphorus loads have also led to higher counts of *Microcystis* (Davis et al., 2009), showing the importance of both phosphorus and nitrogen as nutrients. This was showcased in July 2009 when hypoxic conditions at the sediment-water interface lowered denitrification rates and consequently increased the bioavailable nitrogen, possibly triggering a *Microcystis* bloom five days later (McCarthy et al. 2016).

3.2.4 Health risks and recreational impacts

Missisquoi Bay and the water bodies within the Missisquoi Bay Sub-Basin support drinking, swimming, boating, fishing, and other recreational water uses. Missisquoi Bay and the streams, rivers, lakes, ponds and wetlands in its sub-basin contribute much to the economy of the region. While fishing activity may not be restricted during cyanobacteria blooms, public health agencies often advise precautions prior to consuming any fish from compromised areas. Recent work by the Darrin Fresh Water Institute found that fish exposed to microcystin during cyanobacteria blooms did not assimilate the microcystin toxin into their tissues (Swinton and Nierzwicki-Bauer, 2018).

Cyanobacteria blooms in Missisquoi Bay may create low oxygen conditions in the water column, which can lead to multiple health and recreational issues. The Missisquoi Bay segment of the lake has received a “poor” score for cyanobacteria blooms (Lake Champlain Basin Program 2018). In August 2012, during a large cyanobacteria bloom and period of hot weather, thousands of dead fish washed up on the Missisquoi Bay shoreline. The Philipsburg, Québec water supply issued a notice to all its customers warning them to not consume their drinking water unless it was adequately boiled prior to consumption (Schuett 2012), although cyanotoxins are resistant to boiling, so this may not be an effective recourse during cyanobacteria blooms in the proximity of drinking water supply intakes (Falconer and Humpage 2005).

Cyanotoxin-tainted water may cause health issues via recreational contact and consumption of the water. Residents living near Missisquoi Bay participated in a research study and kept a daily journal of symptoms and record of their contact with the bay water, and corresponding samples were collected to document cyanobacteria and microcystin concentrations during the study period. Residents’ gastrointestinal symptoms were correlated with their recreational contact, and residents’ consumption of drinking water was correlated with increased muscle pain and ear symptoms (Lévesque et al. 2014). However, study participants did not report more serious health issues beyond these ailments.

In Canada, the Algal Blooms project, Treatment, Risk Assessment, Prediction and Prevention through Genomics (ATRAPP) is a major international study initiated in 2016 that includes Missisquoi Bay. One of the components of the study aims to predict toxic blooms in order to transmit this information to the Health Agency and municipalities for their drinking water systems. Two regional plants are included in the study, including Bedford. The National Research Council Canada, which is also involved in this large project, is also participating in Genomics Research and Development Initiative, a multidisciplinary program involving several federal government departments to study the impact of eutrophication on

Canadian water bodies, including Missisquoi Bay. As part of the ATRAPP project, a team of researchers with the Université du Québec are developing geomatics models to evaluate certain scenarios for implementing practices and developments aimed at reducing phosphorus loads, particularly in agricultural in the watershed of Missisquoi Bay, in order to evaluate the best costs/benefits. The results are not yet available.

In Vermont, public beaches are usually closed when there is a visible cyanobacteria bloom, and beach closures are generally followed by testing for cyanotoxins. To date, there have been no known human deaths or serious human illnesses associated with cyanobacteria blooms in Lake Champlain, although there have been multiple unconfirmed reports of human illness after swimming in natural waters ranging from skin irritations to respiratory issues and severe gastrointestinal illness (Vermont Department of Health 2015). While rare, there have been human deaths associated with cyanobacteria blooms reported elsewhere in the world (US EPA 2019).

In the past decades there has been extensive education of the public and resource managers on the proper identification of cyanobacteria blooms for the purpose of visually monitoring Lake Champlain's beaches (Vermont Department of Health 2015). Additionally, the development of easier, cheaper testing methods for cyanobacteria and toxins has allowed for more frequent testing for cyanobacteria and cyanotoxins throughout Lake Champlain. This has allowed for more rapid and accurate data informing public beach closures (Shambaugh 2016).

In 2007 the Vermont Department of Health and the Vermont Department of Environmental Conservation (DEC) initiated a program with the public water suppliers to establish best practices to respond to cyanobacteria detections, later expanded to include a free voluntary summer cyanotoxin monitoring program for public water suppliers drawing water from Lake Champlain. Additionally, 140 recreational locations around the state are monitored for cyanobacteria and monitored for cyanotoxins if blooms are found. These programs have allowed for the compilation of regular data available to resource managers responsible for advising health and recreational uses of the bay, as well as to the public. Reports are displayed on an online cyanobacteria tracker map, which is updated weekly: http://www.healthvermont.gov/tracking/cyanobacteria-tracker.

Monitoring data from these programs show that Missisquoi Bay is a relative "hotspot" for both cyanobacteria and microcystin in Lake Champlain (Fig. 9A), with shoreline and downwind Bay locations particularly vulnerable and health guidelines occasionally exceeded at locations in the bay (Shambaugh 2016). A compilation of data on public beach closures across the lake between Memorial Day and Labor Day (2015- 2017) shows a number of sites along the north end of the lake where closures were due to cyanobacteria blooms (Fig. 9B) (Lake Champlain Basin Program 2018).

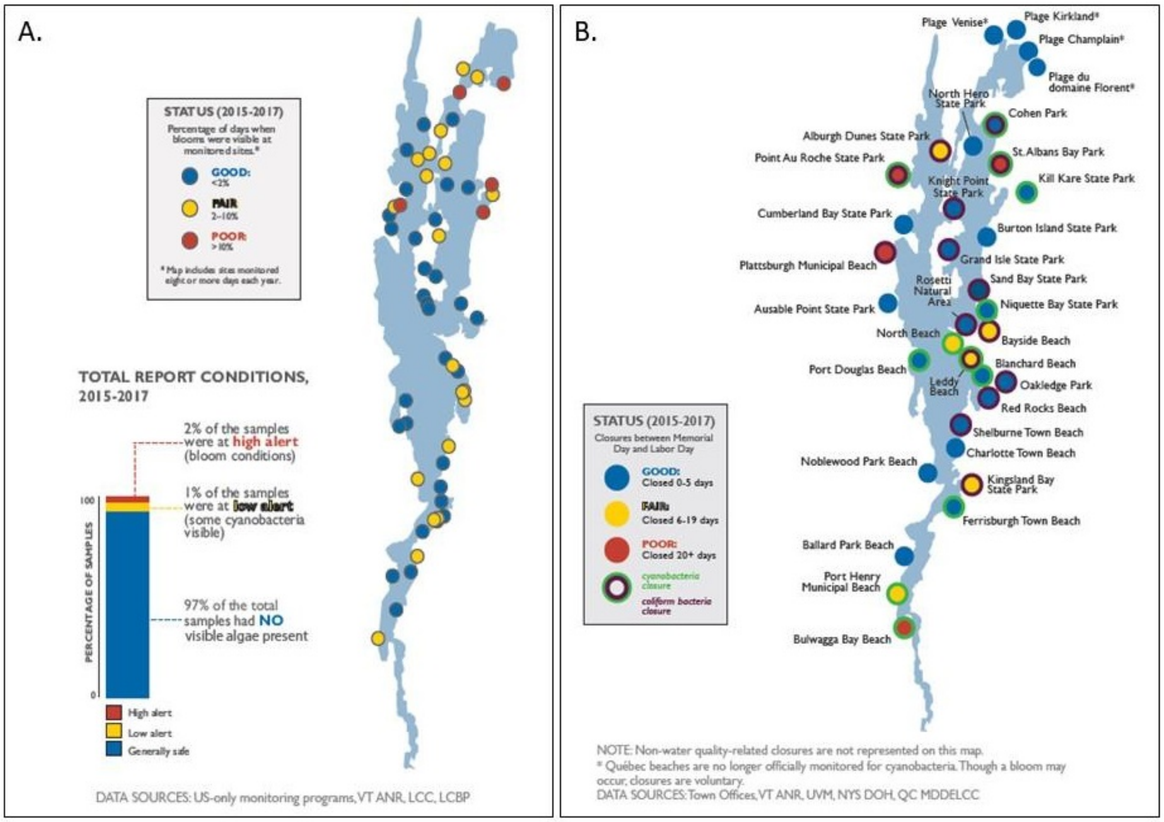

Figure 9. Cyanobacteria alerts (A) and beach closures (B) on Lake Champlain from 2015-2017. *Note that the monitoring stations in Missisquoi Bay are characterized as "Fair" or "Poor". Beaches on the northern banks of Lake Champlain are characterized as "Good," meaning that they were closed less than 5 days during the monitoring period. However, those numbers may be inaccurate, as Québec beaches are not monitored for cyanobacteria and closures are voluntary. Both graphics from Lake Champlain Basin Program (2018).*

3.2.5 Economic impacts

Quantifying the economic impact of eutrophication of our lakes is beset with complexities and data gaps. A national study of fourteen level III ecoregions (Omernik 1987), where median total nitrogen and total phosphorus values for rivers and lakes exceed reference median values, calculated the potential annual value of losses in recreational water usage, waterfront real estate, spending on recovery of endangered species, and drinking water. The combined economic losses in these twelve ecoregions were calculated at approximately $2.2 billion annually, with the greatest economic losses attributed to lakefront property values and recreational use. The authors stated that their evaluation likely underestimated these economic losses, and that gaps in current records (e.g., accounting for frequency of algal blooms) suggest further research is necessary. (Dodds et al. 2009).

Limited information is available on the economic impact of eutrophication of Lake Champlain. A 2015 study utilized scenario analysis to determine how increasing phosphorus concentrations and climate change may affect values of properties near Lake Champlain. The study used lake water clarity as a visible and strongly correlated indicator of phosphorus concentrations. The study found that for the four counties in Vermont abutting the lake, a one-meter decrease in water clarity in the months of July and August would lead to a loss of approximately 195 full-time equivalent jobs, a $12.6 million reduction in tourism expenditures, and a total economic reduction of nearly $16.8 million (Voigt, Lees, and Erickson 2015).

Such costly economic impacts may provide impetus for environmental programs and policies which can also be costly. Studies have analyzed the willingness to pay for programs and regulations to address Lake Champlain's water quality issues. Surveys of Vermonters show that greater education and outreach on water quality issues throughout Vermont (not just in the Lake Champlain Basin) are likely to increase voter support for regulations and programs to address water quality (Scheinert et al. 2014; Koliba et al. 2016).

In Québec, recreational tourism development is very important for the municipalities along the bay, including Venise-en-Québec, Saint-Georges-de-Clarenceville and Saint-Armand. This tourism is mainly water-focused: primarily camping, navigation, recreational fishing, and swimming. Therefore, when beaches are closed due to cyanobacteria and cyanotoxins in the bay's water, businesses and the entire immediate region incur significant economic losses estimated at more than $2 million per year, according to the Regroupement des gens d'affaires de la région du lac Champlain (EXXEP, 2004).

In 2004, just over 100 questionnaires were compiled by the OBVBM, including 60 from residents and 40 from visitors to Missisquoi Bay. The condition of the bay influenced the activities of residents for 65% of respondents, mainly by restricting swimming and fishing, selling of recreational watercrafts, changing the area of the bay used for activities, and decreasing the frequency of aquatic activities (OBVBM, 2004a). Philipsburg residents reported the presence of unpleasant odors in the summer that would sometimes force them to close their windows due to the intensity (OBVBM, 2004a). Some economic impacts were reported during interviews. For example, renting cottages was more difficult, and rental durations were shorter than before, lasting until about mid-August instead of mid-September (Jacques Landry, Mayor of Venise-en-Québec, OBVBM interview, 2019).

Established economic policies and mechanisms such as tax exemptions, loans, grants, subsidies and free technical assistance can encourage more sustainable environmental practices and help shape the environmental future of the Missisquoi Bay sub-basin. Additionally, newer market mechanisms such as phosphorus taxes, nutrient cap and trade policies, and incentives to implement sound ecological farming, stormwater, and development best management practices, may provide viable future options to help address water quality issues in Missisquoi Bay (Koliba et al. 2016).

3.2.6 Wildlife impacts

Cyanobacteria blooms can have powerful negative impacts to wildlife. The blooms have caused at least one fish kill along with die-offs of native mussels in Missisquoi Bay in recent years (Ken Sturm, Missisquoi National Wildlife Refuge, and Angela Shambaugh, VT DEC, personal communication). Other parts of the US and the world have experienced more severe wildlife impacts due to cyanobacteria blooms (Hilborn and Beasley 2015). Exposure to cyanobacterial toxins in combination with other environmental stressors or disease may result in increased mortality of waterfowl (Pikula et al 2010; Wurtsbaugh 2011). Given the current trajectory of warming waters, extended summer weather and longer and more severe cyanobacteria blooms, there is concern that in the future we may begin to see additional wildlife impacts around Missisquoi Bay.

4 Overview of potential in-lake restoration measures and technologies

4.1 International overview of restoration efforts and results

In general, nutrient loads to lakes come from watershed and atmospheric sources (external loading), and from re-suspension and reductive dissolution of lakebed sediments (internal loading). In-lake treatments may be a useful tool to reduce internal nutrient loading in eutrophic lakes where external nutrient loads have been reduced to target levels (Lewtas et al. 2015; Cooke 2005; NALMS, 1990). Common sense dictates that in-lake restoration measures are best implemented after land-based controls are in place, or at least coincident with land-based control measures

4.1.1 Canada

In 2004, the OBVBM commissioned an extensive study (*Solutions phosphore baie Missisquoi*, EXXEP, 2004) to assess *in situ* measures to reduce phosphorus problems in Missisquoi Bay. In addition, as part of the *Plan d'intervention détaillé sur les algues bleu-vert 2007-2017*, the MELCC issued a call for proposals in 2008 to fund four pilot projects on Brome, Waterloo, Saint-Augustin and l'Anguille lakes to evaluate the effectiveness of eutrophic lake restoration techniques (MDDEP, 2009). Several other restoration projects were also monitored by MELCC (Fallu and Roy, 2015).

The study by EXXEP showed that restoration solutions applied directly to the bay are costly and not effective in the long term without a reduction of phosphorus in the watershed and sediment inputs into the bay (EXXEP, 2004). The results of this study suggested that the best long-term solution is to reduce phosphorus inputs from the watershed (EXXEP, 2004).

The main finding of the MELCC pilot projects is that results of in-lake restoration techniques are mixed, but that no effective and affordable "quick fix" was found. The MELCC also recommends prioritizing source phosphorus management throughout the watershed of eutrophic lakes (Boudreau et al, 2017). In addition, several concerns were raised regarding the costs associated with such projects, their actual effectiveness, impacts on the ecosystem, interference with other uses, ability to withstand harsh weather conditions such as flooding and high winds, as well as necessary maintenance (Boudreau et al., 2017). Assessing enclosed pilot projects that take place in conditions different from those of an open lake makes it difficult to interpret results on a larger scale (Boudreau et al, 2017); however, it would be difficult to implement projects in larger areas like Missisquoi Bay because the bay is an open environment with water interchange with other Lake Champlain segments.

In situ restoration techniques all have significant limitations, particularly in the duration of their effectiveness. The chemical content of a lake is usually a reflection of what flows into it. If external inputs of nutrients remain excessive, any one-time *in situ* restoration effort is likely to have a limited duration. In specific cases where the main source of nutrients is lake sediments, it may be useful to apply substances that can immobilize phosphorus (e.g., Phoslock).

Given that Missisquoi Bay has an area of 78 km^2, as well as strong winds and waves, no technique seems suitable for this type of condition unless substantial funding is available. Even with massive financial investment to "treat" the water, the bay will continue to receive large loads of sediment and phosphorus from its tributaries, likely negating the effectiveness any of such *in situ* restoration techniques. Controlling nutrient and sediment inputs remains a critical step before undertaking any *in situ* approach, such as the removal or inactivation of phosphorus in sediment.

It is also important to note that these treatment methods would require authorizations and pre-studies from MELCC, Ministère de la Faune, Forêts et des Parcs (MFFP) and sometimes from Fisheries and Oceans Canada. Before granting approval for *in situ* treatment, MELCC must first consider whether nutrient sources from the watershed are controlled, so that the response does not become a recurring approach to problem management. *In situ* treatments should be viewed as a last resort (Boudreau, 2017).

4.1.2 U.S.

4.1.2.1 Commonly used in-lake restoration techniques

This section will focus on four techniques that have been commonly used in the Northeast to reduce and control internal nutrient loading: hypolimnetic aeration and oxygenation, artificial circulation, phosphorus inactivation and capping, and hypolimnetic withdrawal.

This section does not include details on other techniques sometimes used in the Northeast, such as dredging or algicide treatments, as these are not likely appropriate solutions for Missisquoi Bay. Additionally, this chapter does not address techniques that do not have a record of use in the Northeast, including: floating treatment wetlands, dilution and flushing, biomanipulation, and removal of macrophytes (Lewtas et al. 2015). Table 3 summarizes and compares the above techniques used to control cyanobacteria. This table is extracted from and based upon the consensus of a panel of lake and reservoir restoration experts (NALMS, 1990).

Table 3. Comparison of lake restoration and management techniques for control of nuisance algae.

Treatment (one application)	Short-Term Effect	Long-Term Effect	Cost	Chance of Negative Effects
Phosphorus Inactivation	E	E	G	L
Artificial Circulation	G	Unknown	G	F
Hypolimnetic Aeration	F	Unknown	G	F
Hypolimnetic Withdrawal	G	G	G	F

E = Excellent F = Fair

G = Good P = Poor

H = High L = Low

Excerpted from "The Lake and Reservoir Restoration Guidance Manual, Second Edition," North American Lake Management Society, 1990.

4.1.2.2 Regional Lake Restoration Efforts

Although in-lake restoration efforts are utilized throughout the world, this review focused on the most commonly utilized technologies implemented in the northeastern United States. Table 4 profiles nine representative regional water bodies that have actively addressed nutrient enrichment issues and cyanobacteria blooms in Vermont; Table 5 presents parallel information from Québec. Treatment cost information is provided if available.

Table 4. Representative in-lake restoration efforts completed in Northeast US lakes. Lake vital statistics are included to facilitate comparison to Missisquoi Bay, which has a surface area of 7,800 ha, watershed area of 310,800 ha, and maximum depth of 4.6 m (Vermont DEC, 2013). It must be pointed out that none of the examples have a comparable scale. The largest lake here are still 10x smaller than Missisquoi Bay. All the efforts profiled here were conducted with the intent to reduce in-lake phosphorus loading from sediments. Some of these data are of unknown quality and are presented here for illustrative purposes only. No inferences regarding the impacts of nutrient loading and cyanobacteria blooms on water quality in the Lake Champlain Basin should be made based on these data until their quality can be determined.

Water Body	Area (ha)	Watershed Area (ha)	Max Depth (m)	Treatment Type and Year	Result	Cost
Lake Carmi[1]	567	3120	10	Hypolimnetic Oxygenation To begin in 2019	Model simulations of planned treatment show improvements in hypolimnetic dissolved oxygen	Approx. $1.5 M/year including O&M
Lake Morey[2]	220	1900	13	Aluminum Sulfate/Aluminate 1986	Substantial decrease in P and increases in clarity for 3 + years after treatment	Approx. $177,000/133 ha treatment (1986) with alum donated
Morses Pond[3,4]	40.5	2145	7	Aluminum Sulfate/Aluminate, Polyaluminum Chloride 2009-2018 Plant Harvesting: 2007-2018	Substantial decrease in P, increases in clarity, decreases in blooms	P inactivation only: $312,000/5 years
Kezar Lake[5]	73.5	2770	8.2	Aluminum Sulfate: 1984 Upstream Wetland Manipulation	Decrease in total P and P variance for 3+ years, increased clarity, poor wetland attenuation	$1,367/ha (1984)
Lake Waramaug[6,7,8,9,10,11]	275	3723	12.2	Hypolimnetic Withdrawal: 1983-2015 Aeration Ongoing Since 1989	Decrease in P (epilimnetic P concentrations were below 18 mg/m^3 in 1993) and increases in water clarity	$500,000 for original pumping system (1983) 2015 installation of two aerators – initial cost of $140,000

Water Body	Area (ha)	Watershed Area (ha)	Max Depth (m)	Treatment Type and Year	Result	Cost
Cochnewagon Lake[5,12,16,17]	159	727	8.5	Aluminum Sulfate/Aluminate 1986	Increased clarity for nearly 20 years, recent blooms	Chemicals, Labor, & Equipment = $81,840; Personday/ha = 0.41; Cost/ha=$844
Annabessacook Lake[5,12,13,14]	572.6	4294	15	Copper Sulfate Algicide Treatments: 1964-1971	Algicides had short term impact, but lost efficacy with emergence of resistant algae species	Aluminum salts treatment: Chemicals, Labor, & Equipment = $234,000; Personday/ha = 1.12; Cost/ha = $1,934
				Hypolimnetic Aerators: 1972 & 1974	Aerators were ineffective. They did not mix waters more than 50 meters beyond the units and may have disturbed sediments increasing the internal phosphorus loading of the lake	
				Aluminum Sulfate/Sodium Aluminate: 1978	Aluminum salt treatment led to dramatic decrease in internal loading of P, with calculated longevity of reduced P at 13 yrs	
Threemile Pond[5,12,14]	475.1	2414	11	Aluminum Sulfate/Sodium Aluminate: 1988	Calculated longevity of decrease in P of 4 years	Chemicals, Labor, & Equipment = $170,240; Personday/ha = 0.06; Cost/ha = $640
Chickawaukie Lake[12,14,15]	143	670	10	Aluminum Sulfate/Sodium Aluminate: 1992	Calculated longevity of decrease in P of 39 years	
Ticklenaked Pond[18,19]	21.9	584.4	14.5	Alum Treatment May 2014	3 months post-treatment: water clarity improved from 1.7 to 7.2 m total and dissolved phosphorus decreased, especially at surface	$95,990 Grant Received

Water Body	Area (ha)	Watershed Area (ha)	Max Depth (m)	Treatment Type and Year	Result	Cost
Nutting Lake[20]	31.6	292.7	2.1	Dredging of ~275,000 m^3 of sediment 1978-1981		~$688,000
Lake Waccabuc [21, 22, 23]	52.0	317	14	Hypolimnetic Aeration Two aerators installed in 1972	decrease in the in-lake nutrient concentrations and improvement in water quality conditions through decreased hydrogen sulfide, iron, manganese levels	as of 2004- annual operation of aerators is $9000
Lake Wononscopomuc [24]	24	599	15.2	Hypolimnetic Withdrawal 1981	TP decreased during summer stratification (25 to 12 ppb) and maximum hypolimnetic (473 to 89 ppb)	
Sebasticook Lake[25]	1735	21995	15	Lake Drawdown 1982- 2001 (confirmed)	Internal load of TP reduced by 50% (4,000 to 2,000 kg)	
Irondequoit Bay, Lake Ontario[26,27]	694	43583	25	Alum Treatment 1986	60-75% reduction in hypolimnetic P	
				Hypolimnetic Aeration 1993- Present	Epilimnion TP maintained (approximately 20 ppb) in target range during the summer sampling seasons	

Table Data Sources: 1: (Reservoir Environmental Management, 2018); 2: (Smeltzer, 1990); 3: (Water Resources Services, Inc, 2018); 4: (Way and Box, 2005); 5: (Connor and Martin, 1989); 6: (Healy and Kulp, 1995); 7: (Lake Waramaug Task Force); 8: (Kortmann, 2010); 9: (Verhovek, 1988); 10: (Lake Waramaug Association); 11: (CT Institute of Water Resources, 2008); 12: (Vaux, 2015); 13: (EPA, 1980); 14: (Huser et al., 2016); 15: (City of Rockland, ME, 2002); 16:(Charles Eichacker, 2016); 17: (Maine DEP, 2011); 18: (Vermont ANR, 2009); 19: (Meringolo, 2016); 20: (Purcell & Taylor, P.C., 1981); 21: (NYSDEC, 2017b); 22: (Fast et al., 1975); 23: (NYSFOLA, 2009); 24: (Nürnberg, 2007); 25 : (Maine DEP, 2001); 26 : (Sansone, 2016); 27 : (Sansone, 2018).

Table 5: In-Lake Restauration Pilot Projects in Québec

Water Body	Area (ha)	Watershed Area (ha)	Max Depth (m)	Treatment Type	Year	Result	Cost

Lake Heney (Gracefield) Outaouais	1233	5248	32,5	Immobilization of phosphorus with iron chloride (217 t, once). Test on the entire surface of the lake (preliminary tests on the bay). The largest attempted lake restoration project in Québec	2007	Total phosphorus concentrations in the water column have changed from 0.024 mg/l to approximately 0.015 mg/l during the 2008-2013 monitoring period. Chlorophyll-a also decreased by 50%.	NA
Three Lake (Asbestos)	240	51000	8	Amphibious dredging with pump bucket (Amphibex) over 51,000 m2 (31% of lake)	2011 2014	Perception of increased water circulation in dredged areas, low rates of seagrass recovery measured over a short-term period (1-3 years), Decreased thickness of sediment deposition	$3,04 M
Lake Tomcod (Saint-François-Xavier-de-Brompton)	180	1850	2	Several solutions to reduce inputs upstream of the lake, including the use of steel slag. Algal Growth Control by Ultrasound (Quatro-DB Device from AlgaeControl Company)	2017 2018	Bloom in August 2017. Presence of cyanobacteria constant at different stages between May and September 2018. Since 2009, annual average chlorophyll a was 71.6 ug/l. In 2018, it stands at 106.2 ug/l	NA
Lake Bromont (Bromont)	46	2380	7,6	Immobilization of phosphorus by the application of Phoslock. 174 tonnes of this lanthanum enriched clay (bentonite) was dispersed throughout the lake to capture 1738 kg of phosphorus	2017	The total phosphorus concentrations measured at depth (6.2m) in June 2019 are 70% lower than in June 2017. However, cyanobacterial bloom were still observed in 2018 and 2019, forcing the closure of the beach.	$650 000
Lake Pierre-Paul (Mauricie)	61	440	7,9	Precipitation/inactivation of phosphorus. Liming	1996 2016	Total phosphorus in sediments decreased from 2274 mg / kg in 1996 to 1233 mg / kg in 2007, a reduction of approximately 54%. However, cyanobacterial blooms have been recorded 6 years since 2007.Treatment effectiveness outcomes assessed by the MELCC were inconclusive as an effective medium and long-term restoration solution	NA
Lake Saint-Augustin (Québec)	62	750	6,1	Immobilization of phosphorus in sediments by adding alum for coagulation / flocculation and calcite for active recovery. Pens have been installed to test the different compounds (alum, calcite, alum + calcite, control)	2009	The treatment alum + calcite compound achieved the best reduction of phosphorus dissolved in the water column. Alum alone would have obtained a reduction at the beginning which would have subsequently increased. The authors of the study recommend recovery by calcite alone in deeper areas. The MELCC recommends an intermediate in situ calcite-alum recovery test in an isolated area of the lake with a longer follow-up period to verify stability	NA

Lake Saint-Augustin (Québec)	62	750	6,1	Hydraulic and mechanical dredging of the superficial layer of sediments. Several pens have been installed to compare techniques (hydraulic dredging, mechanical, control)	2011	A significant decrease in dissolved phosphorus was measured in the hydraulic dredging pen after two weeks. As for mechanical dredging, a downward trend following treatment was reversed after one week to become an increase in phosphorus concentration that remained during the follow-up period	NA
Lake Waterloo (Montérégie)	136	3040	5,3	Aerators/Circulators	2004	Cyanobacterial water blooms were observed and persisted, this technique did not seem efficient or poorly adapted	NA
Lake Waterloo (Montérégie)	136	3040	5,3	Removal of sediment. Hydraulic dredging of the surface layer of phosphorus-laden sediments	2009	No trend in phosphorus concentration in the water column was observed following pumping. Tested on reduced surface	$37 M estimated for the full lake
Lake Waterloo (Montérégie)	136	3040	5,3	Floating beds of duckweed (with and without sediment mixing)	2009	Difficulties encountered: development of variable lenses, optimal density of water lenses difficult to maintain, distribution of lenses difficult to control with the wind, etc. Conclusion: not applicable at the scale of a lake	NA
Lake Carré (Laurentides)	14	197	8,4	Aerators/Circulators (*Speece Cone)*	2002 2010	No improvement in oxygenation of the hypolimnion observed. In 2010 and 2011, Lake Carré still had an anoxic hypolimnion	NA
Lake Selby (Montérégie)	117	1852	10,3	Wind turbines serving as water aerators	2015	No significant changes have been reported. These wind turbines have been removed.	NA
Bay Charrette (Saint-Donat)				Removal of more than 50,000 m3 of sediment	2011 2012	The depth of the water column increased from 0.3-0.5 m to 1.5-2.5 m	NA
Lake Anguille	98		12	Floating plant island of 20 m2 including 400 plants of 8 species. The most effective species were: Typha latifolia, Iris pseudocarus, Spartinapectinata and Glyceriacanadensis	2008 2012	The results indicate a withdrawal rate of 1000 mgP / m2. The number of floating islands needed to treat a large area is very important. For example, 1650 blocks covering 3.5% of the lake area would be required to reduce phosphorus by 50%	$45 000\ 0,1 ha
Lake Saint-Louis (La Tuque, Mauricie)	Small lake		9,8	Ultrasonic irradiation	2008	The City has reported a decrease in cyanobacteria but there is insufficient data to draw conclusions	NA
Petit lac de l'Aqueduc (Saguenay)	Small lake			Ultrasonic irradiation	2012	decrease in chlorophyll was observed but a proliferation of macrophytes (aquatic plants) also	NA

Missisquoi Bay (Venise-en-Québec)	7800	312 200	4,5	Collection and cutting of macrophytes. Project to collect and compost aquatic plants on 365 m3	2003	According to samples taken in 2003 at Missisquoi Bay and analyzed by MELCC, aquatic plants contain an average of 400 mg P/kg of dry matter and 2200 mg of nitrogen per kg of dry matter. We multiply by a factor of 5 for the wet matter which gives us for a crop of one square meter of aquatic plants the equivalent of about 734 mg of phosphorus and 4035 mg of nitrogen would collect approximately 734 kg of phosphorus per hectare/year in the bay (about 1-2%).	$20 000 to 30 000/year

Sources : Boudreau, 2017; Boudreau *et al.*, 2013; MDDEFP, 2013; Carignan, 2009; Denis Brouard et Associés inc., 2007; EXXEP, 2004; MDDELCC, 2018f; Roy, 2015; Galvez-Cloutier et al., 2012; Dessau, 2008; Richer-Bond, 2013; Bolduc et Kedney, 2005; Questionnaire OBVBM-MELCC, 2019; OBVBM, 2011; ACBVLB, 2019; Paulin, 2017 et 2018; Roy, 2016; Thibault, 2016.

4.2 Effectiveness results and analysis, estimated cost-benefit, and adaptability to Missisquoi Bay

The effectiveness and cost/benefit of in-lake restoration efforts in Missisquoi Bay should be determined by further studies and pilots that test selected technologies, similar to the process undertaken at Lake Carmi in Vermont and Lake Bromont in Québec. One confounding factor here is that many of the in-lake restoration technologies addressed in this chapter may not be adaptable to a water body as large as Missisquoi Bay, or may become cost-prohibitive when scaled up to Bay size.

An upcoming study on Missisquoi Bay will conduct an internal loading assessment and make use of updated modeling tools to better characterize internal phosphorus loading. This study will be funded with fiscal year 19 EPA funds and overseen by the Lake Champlain Basin Program. Results of this study may help to inform a plan of action for Missisquoi Bay, including the viability of in-lake restoration efforts.

5 Programs and policies influencing key issues and their effectiveness

5.1 History of phosphorus management in the Lake Champlain Basin

The late 1980s and 1990s saw an increase in policy focus on Lake Champlain from state, provincial, and federal governments, laying the groundwork for clean water policy in the decades to come. In 1988, the three jurisdictions signed the *Vermont, New York, and Québec Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain (MOU)*, and in 1990 the Lake Champlain Management Conference provided an opportunity to discuss in-lake phosphorus concentration targets for each Lake segment. In the 1993 Water Quality Agreement, the three jurisdictions agreed to phosphorus reduction goals. This MOU led to the creation of:

- The Lake Champlain Basin Program in 1990;
- The Steering Committee for the Coordination and Implementation of the MOU;
- The Québec – Vermont Phosphorus Reduction Task Force in 1996.

LCBP is a key part of Lake Champlain's water management and is the forum for cooperation among the governments concerned. The Lake Champlain Basin Program has led to the creation of several committees to implement the MOU.

The first action plan, *Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin*, was approved for the period 1996-2016. The main priority of this plan was the reduction of phosphorus loads into Lake Champlain. The concentration of 0.025 mg/L adopted in 1993 for the Missisquoi Bay was considered achievable by the 2016 deadline, based on a median concentration of 0.037 mg/L in 1992. When *Opportunities for Action* was renewed in 2003, Québec formally agreed to join the plan and made a commitment to meet its objectives. The plan was renewed again in 2017 and accompanied by a message from the premier of Québec in support of its signatories. Phosphorus reduction remains the plan's top priority, but it does not identify everything that can be done to achieve the goals for Missisquoi Bay (LCBP, 2017).

5.1.1 Agreement on the Reduction of Phosphorus levels in Missisquoi Bay between the Governments of Québec and of the State of Vermont

The governments of Québec and Vermont signed the Québec-Vermont Phosphorus Reduction Task Force agreement in 1997 to assess phosphorus inputs from the watershed and propose a division of responsibilities. The report, which was tabled in 2000, proposed the development of an agreement between Vermont and Québec on the reduction of phosphorus levels in the Missisquoi Bay. The

Agreement on the Reduction of Phosphorus levels in Missisquoi Bay between the Governments of Québec and of the State of Vermont (Québec-Vermont Agreement) was subsequently signed on August 26, 2002 (Gouv. Du Québec, 2002a). This agreement stipulated that in order to meet the target concentration of 0.025 mg/L, the reduction of phosphorus loads in the Missisquoi Bay watershed was to reach a target of 97.2 metric tonnes per year by 2016.

The Québec-Vermont Agreement represented a historic step in efforts to reduce phosphorus levels in Missisquoi Bay. It defined for the first time a shared responsibility for a total phosphorus target load from the Missisquoi Bay watershed of 38.9 t/yr (40%) for Québec (a reduction of 27.3 mt/yr) and 58.3 mt/yr (60%) for Vermont (a reduction of 42.8 mt/yr; CICBM, 2003). The MELCC is responsible for implementing and renewing this agreement. This agreement expired on December 31, 2016, and, despite efforts, the average phosphorus concentration in Missisquoi Bay is still 0.050 mg/L as of 2018.

However, this agreement has resulted in several nutrient reduction implementation projects, funding for research studies, and advancing knowledge about phosphorus levels in the Missisquoi Bay watershed. Its renewal by the Government of Québec and the State of Vermont was of utmost importance for many participants interviewed in Québec (OBVBM Interviews, 2018-2019).

An inter-agency committee for cooperation on Missisquoi Bay-Estrie and Montérégie regions was created to coordinate the actions of the Québec government and ensure alignment among the various agencies under the Agreement for the reduction of phosphorus in Missisquoi Bay. The Inter-Agency Committee, coordinated by the MELCC, consists of representatives from the agriculture, municipal, wildlife, transport, health and security agencies (MAPAQ, MAMH, MFFP, MTQ, MSSS, and MSP), which are the agency partners essential to the implementation of projects that support the achievement of objectives.

An initial Action Plan 2003-2009 on the reduction of phosphorus in Missisquoi Bay was developed in consultation with the main offices of the MELCC, MAPAQ and MAMH. The actions listed in these response plans are also included in the LCBP's *Opportunities for Action* plan. From 2003 to 2009, the Québec government and its partners invested more than $25 million in various measures to reduce phosphorus supplies from the Missisquoi Bay watershed, including $14 million from MAMH (wastewater), $4 million from MAPAQ (Ag BMPs), and $3.5 million for research projects in the watershed. This is in addition to the significant amounts invested prior to 2003 for urban and agricultural sanitation: approximately $24 million for wastewater treatment plants and $3 million for manure storage, for a total of over $52 million (Mimeault and Simoneau, 2010).

An initial report on the agreement concluded that, "although phosphorus concentrations have not decreased in Missisquoi Bay, it is encouraging to see a downward trend in phosphorus concentrations and loadings in the Pike River as a result of the full implementation of the Action Plan 2003-2009. In 2009, the Inter-Agency Committee renewed the initial plan and adopted the Action Plan 2019-2016. This plan was in line with the first one, but intensified actions in identified priority sub-basins" (Mimeault and Simoneau, 2010). A few examples of Québec's actions have been partially incorporated in the State of the Lake 2015 and LCBP's Opportunities for Action document. Since 2015, the OBVBM Water Master Plan (PDE) approved by the MELCC groups together the actions of the various ministries and the actions listed in the Inter-Agency Committee Action Plan (OBVBM, 2015).

5.2 Total Maximum Daily Load

In 2002, the states of Vermont and New York developed a Total Maximum Daily Load (TMDL) for phosphorus in Lake Champlain; in 2011, the EPA disapproved the Vermont portion of this TMDL for two major reasons: the 2002 plan did not adequately address a margin of safety to account for uncertainty in the original analysis, and did not provide sufficient assurance that nonpoint source reductions would occur (U.S. EPA, 2016).

This disapproval of the Vermont portion of the 2002 TMDL and subsequent reissuance of the 2016 TMDL was triggered as a result of a lawsuit from the Conservation Law Foundation (CLF) (Chapman and Duggan 2015; *Conservation Law Foundation v. Environmental Protection Agency* 2008). In 2008, CLF filed a federal lawsuit appealing the EPA's approval of the Lake Champlain TMDL, citing the reasons above and two additional factors: failure to accurately consider point sources of phosphorus, and a lack of consideration for the long-term effects of climate change in the basin (*Conservation Law Foundation v. Environmental Protection Agency* 2008). The EPA and CLF signed a settlement agreement in 2010 to allow EPA Region 1 to reconsider whether the 2002 TMDL was consistent with Section 303(d) of the Clean Water Act (U.S. EPA, 2016). The 2011 disapproval of the 2002 VT Lake Champlain TMDL compelled EPA Region 1 (New England) to reestablish a new phosphorus TMDL in order to conform with section 303(d)(2) of the Clean Water Act (*Federal Water Pollution Control Act* 1978).

As discussed in section 2.1 and 2.2.2, the 2002 and 2016 TMDLs set phosphorus loading targets for individual segments of Lake Champlain. Twelve out of thirteen of these segments, all except Cumberland Bay, are directly affected by Vermont sources of phosphorus; five segments are entirely within Vermont's borders, and the rest are shared with New York and/or Québec. These discrete targets are based on the amount of phosphorus already present in the segment's waters and the amount of phosphorus entering the segment from the surrounding basin, and take into account the movement of phosphorus from adjoining segments (U.S. EPA, 2016).

5.3 Vermont

5.3.1 Clean and Clear Action Plan

In 2003, Vermont Governor James Douglas released the Clean and Clear Action Plan, a water quality initiative designed to accelerate the phosphorus reduction efforts laid out in LCBP's 2003 release of *Opportunities for Action* (Douglas 2003, 2004). Fittingly, Governor Douglas announced this new effort on the shores of Missisquoi Bay, with the support of Québec Premier Jean Charest and New York Governor George Pataki (Douglas 2003).

Douglas's six-year Clean and Clear Action Plan called for $150 million in increased funding for clean water work, including working with Lake Champlain's congressional delegation to pursue increased federal appropriations and a request to the Vermont Legislature to issue Citizen Environmental Bonds. In 2007, the Vermont State Treasurer's Office sold approximately $5 million in these Series C Citizen Environmental Bonds (Vermont State Treasurer's Office 2007, 2015a); later, they were replaced by more general Green Bonds, designed to target a broader selection of environmental issues including water quality and wastewater (Vermont State Treasurer's Office 2015b). Douglas's Clean and Clear efforts were spurred by recent algal and cyanobacterial blooms in Lake Champlain, and proposed prioritizing restoring riparian wildlife habitat and sediment retention on eroding streambanks, better agricultural management of phosphorus, and capital funding to improve nutrient removal at wastewater treatment facilities (Douglas 2003).

By 2011, the State of Vermont had invested over $57 million in Lake Champlain funding as part of the Clean and Clear program, and had leveraged an added $68 million in federal funding (Vermont State Treasurer's Office 2015b). These funds were focused on a handful of Vermont state programs: wastewater discharges, river management, better backroads, stormwater management, and erosion control at construction sites. However, while substantial progress was made in reducing phosphorus in wastewater, nonpoint runoff had not significantly decreased (Smeltzer, Dunlap, and Simoneau 2009; Lake Champlain Basin Program 2005).

5.3.2 Act 64: Vermont's Clean Water Act

In May 2015, the Vermont General Assembly passed H.35, "An act relating to improving the quality of state waters." H.35, subsequently named Act 64, also known as the Vermont Clean Water Act, was signed into law by Governor Peter Shumlin on June 16, 2015 (U.S. EPA, 2016). Governor Shumlin had emphasized the need for comprehensive clean water legislation in his 2015 State of the State Address (Shumlin 2015). Act 64 addressed Lake Champlain's phosphorus TMDL by setting deadlines for many of the EPA-required programs, increased clean water staffing and resources, required tactical basin planning to prioritize subwatersheds of the greatest need and project types necessary to achieve reductions, and created the first public funding source for the Vermont Clean Water Fund. Act 64 created the first public funding source for the Clean Water Fund, relying on a surcharge on all property transfers over $100,000 (Martin 2015).

Among many smaller policy amendments, Act 64 revolutionized water quality policy in Vermont in the following major ways:

- Amended agricultural policy in Vermont by shifting the framework of regulation from "accepted agricultural practices" to "required agricultural practices" (*No. 64. An Act Relating to Improving the Quality of State Waters* 2015). This new designation came with additional staff and funding resources to inspect farms and enforce regulations, rather than relying on the former complaint-based system. It also requires that the Vermont Agency of Agriculture, Food and Markets collaborate with the Agency of Natural Resources in implementing enforcement and new clean water policy (Martin 2015).
- Required updated to the Accepted Management Practices for Logging jobs in Vermont to incorporate new water quality practices.
- Promulgated a permit program aimed at reducing nutrient and sediment from local roads known as the Municipal Roads General Permit Program.
- Promulgated a program aimed at reducing nutrient and sediment from State-managed roads known as the Transportation Sector Separate Storm Sewer Permit Program.
- Promulgated several programs aimed at managing runoff from impervious surfaces and developed lands. These programs included updates to the Vermont Stormwater Management Manual and related stormwater construction and operational permit programs for all new and re-development over one acre in size. The Act also created a new program requiring the retrofit of all stormwater management systems for parcels with three or more acres impervious surface that were authorized prior to 2002. Relatedly, in 2017, Act 64 was amended to lower the threshold for operational stormwater permitting from 1 acre to one-half acre.
- Required an update to the Combined Sewer Overflow rules managed by the State of Vermont.

As of the publication of this report, all of these requirements have been put into place by the State of Vermont.

5.3.3 The Clean Water Service Delivery Act of 2019

In May of 2019, the Vermont Legislature passed Act 76, referred to as Vermont's Clean Service Delivery Act Act 76 sets up a long-term clean water funding source, by designating 6% of Vermont's rooms and meals tax, re-confirming the property transfer tax surcharge listed above, and allocating all escheats from the Vermont Bottle Bill for the state's Clean Water Fund. This perpetuates a total annual public investment of $20M into the Clean Water Fund, which is expected to grow over time. Coupled with additional State funds and Federal expenditures, Vermont is poised to invest over $50M annually for clean water efforts for the foreseeable future.

The Act also provides for the designation of watershed-based clean water service providers to coordinate and implement clean water practices locally and report to the Vermont Agency of Natural Resources annually, and establishes four new water quality grant programs.

5.3.4 Additional Vermont Policy

While the Clean and Clear Action Plan and Act 64 are the most topically and temporally relevant Vermont policies to this report, Vermont has additional acts, programs, and regulations that address water quality.

Effective July 1, 2014, the Vermont Legislature passed the Shoreland Protection Act (Chapter 49A of Title 10, §1441 et seq.), which regulates shoreland development within 250 feet of a lake's mean water level for all lakes greater than 10 acres in size. The intent of the Act is to prevent degradation of water quality in lakes, preserve habitat and natural stability of shorelines, and maintain the economic benefits of lakes and their shorelands. The Act seeks to balance good shoreland management and shoreland development. Any new development, redevelopment, or clearing within 250 feet from mean water level may require a permit or registration.

Act 250, Vermont's land use and development law, was enacted in 1970 to govern new construction in the state through a public review process by the Natural Resources Board (*Act 250: Land Use and Development Law* 1970). This review involves the assessment of nine statutory criteria, including several that may affect Lake Champlain: air and water pollution, water supply, impact on water quality, and erosion and the capacity of soil to hold water (Vermont Natural Resources Board 2019). While these criteria do not explicitly address phosphorus or cyanobacteria, the focus on diligent review of high impact land development has almost certainly impacted Lake Champlain's water quality. Act 250 is now nearly 50 years old, and is currently in the final stages of review by a state commission to address the law's success and ensure that the law adequately addresses emerging challenges like climate change (Dillon 2018).

5.4 New York

As Missisquoi Bay is not a New York segment of Lake Champlain, we have devoted less focus of this chapter to the state's water policy. However, New York does have significant regulatory policy that addresses Lake Champlain's water quality.

Segments of the lake are individually classified based on New York's criteria: the Main Lake and South Lake segments are designated Class A overall, considered appropriate "as a source of water supply for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing" (*Class A Special (A-S) Fresh Surface Waters* 1972). More specifically, the shoreline waters in these segments are Class A, while the deeper open waters are designated the more pristine Class AA. Two exceptions exist: Bulwagga Bay is Class B, and Deep Bay is Class C (New York Department of Environmental Conservation 2018; *Class AA Fresh Surface Waters* 1972; *Class B Fresh Surface Waters* 1972; *Class C Fresh Surface Waters* 1972), meaning that their most appropriate usages are primary and secondary recreation, and fishing, respectively. Phosphorus in each of these class designations should be limited to an amount that will not cause "growths of algae, weeds, and slimes" (*Narrative Water Quality Standards* 1972). Regulatory and permitting authority of New York waterbodies rests with the New York Department of Environmental Conservation (Wroth 2012).

In 2018, New York Governor Andrew Cuomo announced in his State of the State address that the state would appropriate $65 million to aggressively combat harmful algal and cyanobacteria blooms; Lake Champlain was identified as a high priority source of drinking water and site for recreation (Governor's Press Office 2017). In June 2018, following four cyanobacteria stakeholder summits, Governor Cuomo announced the release of a tailored action plan for Lake Champlain (Governor's Press Office 2018).

5.5 Québec

According to the Canadian Constitution, the management of natural resources including water is a provincial jurisdiction. The federal government is responsible for navigable and transboundary waters and the protection of fish habitat (Gouv. Du Québec, 2017).

The MELCC is responsible for coordinating water management in Québec. To ensure the protection of this resource, to manage water in a sustainable development perspective and, in doing so, to better protect public and ecosystem health, in 2002, Québec launched the National Water Policy (PNE).

The PNE approach sought to:

- Implement integrated management of all watersheds to reform water governance,
- Implement this approach of management in the Saint Lawrence while recognizing the special status and importance of this waterway,
- Protect water quality and aquatic ecosystems,
- Continue to clean water and improve water service management, and
- Promote recreational tourism activities related to water.

The PNE led to the recognition of 33 priority watersheds, including the Missisquoi Bay watershed, and to the creation of a network of watershed organizations (OBVs) responsible for their integrated and collaborative management. In Missisquoi Bay, this resulted in official recognition of the Corporation de basin versant de la baie Missisquoi, which would become the Organisme de basin versant de la baie Missisquoi in 2009. In addition, the PNE mandated these watershed agencies to complete the first Water Master Plans (PDE) and suggested their implementation through basin agreements among various watershed stakeholders.

In 2009, the Act Affirming the Collective Nature of Water Resources was adopted. This act aimed to strengthen water resource protection by confirming the legal status of water resources as part of the heritage of the community, and clarified the responsibilities incumbent to the state as custodian of the resource. This act has clarified the mission of the watershed organizations, now numbering 40, that is, "to develop and update a water master plan, to promote and monitor its implementation ensuring a balanced representation of the users and the various interested parties, including the governmental, aboriginal, municipal, economic, environmental, agricultural and community milieu, in the composition of this body" (Article 14). This law was amended in 2017 and is now called the Act Affirming the Collective Nature of Water Resources and Promoting Better Governance of Water and Associated Environments. As part of the implementation of integrated watershed management in Québec, the water master plan helps structure the process and help decision-making. This planning process, carried out in consultation with watershed stakeholders, is intended to be adaptive, iterative, and prospective.

Finally, in 2018, the Government of Québec unveiled the Québec Water Strategy 2018-2030 (Water Strategy), which takes over from the 2002 National Water Policy (Gov. Du Québec, 2018).

5.5.1 Agricultural Regulatory Framework

Québec's first environmental framework for agricultural activities was created in 1981 with the adoption of the Regulation Respecting the Prevention of Water Pollution in Livestock Operations (RPPEEA), which aimed to protect water by making manure storage structures impermeable. It also required consideration of nitrogen concentration of manure (CAAAQ, 2008). In 1996, the concept of municipalities with a surplus was introduced into the RPPEEA. In 1997, the Regulation Respecting the Reduction of Pollution from Agricultural Sources (RRPOA) introduced Agro-environmental Fertilization Plans (PAEF), a phosphorus standard that included standard manure spreading practices. The development of agro-environmental farm plans has led to a significant reduction in mineral fertilizer discharge across Québec; it also increased recognition of the importance of manure as a fertilizer, to be seen more as a valuable resource and less as waste to be disposed of (CAAAQ, 2008).

The concept of animal units has also been abandoned due to wide disparities in animal feed, making it difficult to use averages to assess phosphorus concentrations in manure (CAAAQ, 2008). Calculations to assess application requirements are now based on the degree of phosphorus saturation in the soil rather than total concentration, allowing for consideration of differences among soil types or among soils in the same category under different conditions. To this end, mathematical relationships to determine maximum phosphorus deposits per hectare have been developed to replace calculations based on animal units per hectare, and because this approach is considered more effective in preventing eutrophication of waterways (CAAAQ, 2008).

In 2002, as part of the launch of the National Water Policy, the RRPOA was replaced by the Agricultural Operations Regulation (REA), which introduced requirements for phosphorus saturation thresholds for agricultural soils, restrictions on animal access to waterways beginning in 2005, mandatory ban of increasing crop areas in watersheds that are overly saturated with phosphorus, requirements to spread manure using a low ramp, and the recovery of waste water from dairy farms (Gouvernement du Québec, 2004).

Managing soil phosphorus concentrations

The problem of phosphorus oversaturation in agricultural soils was addressed through implementation of the REA, which governs the management, method and quantity of fertilizers applied to fields. Since 2010, the REA has required farmers to present a yearly phosphorus report to govern fertilizer application. The phosphorus report is an inventory of phosphorus loadings, produced or imported, and the ability of soils to receive these loadings in accordance with maximum annual phosphorus deposits provided by the REA. It checks the balance between phosphorus inputs and maximum depositional capacity, to prevent surplus water from entering waterways and altering their quality, notably by abetting the proliferation of cyanobacteria (MELCC, 2019b). The REA always requires the yearly presentation of a report on the equilibrium of phosphorus and the maintenance of that equilibrium. Therefore, the operator must have enough acreage to manage the fertilizing materials according to the guidelines set out in Appendix I of the REA.

Agri-Environmental Fertilization Plans (PAEF) have also been developed to help restore the soil's equilibrium and ensure that the quantities of fertilizers applied do not exceed plant needs. It is important to note that the mathematical relationships, more or less consider the plant's needs. They allow significant inputs into poor soils to enrich them and lower inputs in rich or saturated soils to reduce P content.

PAEF determine, for each parcel in an agricultural operation and each annual growing season (for a period up to 5 years), the crop grown and the spreading limits for fertilizers (MDDELCC, 2017). If the soil of a cultivated parcel exceeds one of the saturation thresholds listed in Appendix I of the REA, the fertilization recommendations listed in the PAEF for a livestock or manure spreading site stipulate that the concentration must be lowered and maintained below the prescribed thresholds**.**

The PAEF and phosphorus reports are prepared by agronomists hired by the agricultural producers concerned. Compliance with these provisions is monitored by the MELCC's regional branches. Data on the phosphorus reports released in 2016, as well as data on water quality in the bay watershed's agricultural zones, indicate that more work remains to be done to reduce phosphorus saturation rates in soils and ultimately the amount of phosphorus that is released into streams and Missisquoi Bay. Despite farmer compliance, the support capacity has been significantly exceeded.

Phosphorus (P) mass balances and dynamic simulation of P inputs, storage and exports have been the subject of several studies in Vermont (Cassell et al., 1998, 2001, 2002; Meals et al., 2008a, 2008b). A clear finding of these studies was that the long-term goal of reducing phosphorus loads into Missisquoi Bay can only be achieved by addressing the imbalance between imports and exports in the agricultural sector and, where appropriate, in the urban environment as well (Jokela et al., 2002). At the dairy farm level, for example, mass balances established by Vermont researchers have shown that between 20% and 40% of the phosphorus imported (fertilizers, feed, etc.) leaves the farm in the form of milk, meat or other products (Anderson and Magdoff, 2000). Over time, the concentration of P increases in soils and deposition zones in water bodies, generating increasing P flows. For example, in the Québec portion of the Pike River's watershed, soil richness and input reports were shown to be significantly correlated, contributing to more than 85% of the spatial variability in phosphorus flows (Deslandes et al., 2002a, 2002b). Already more than 15 years ago, one third of the soils in a sub-basin in the same study area had saturation rates above the 10% vulnerability threshold for phosphorus loss (Michaud et al., 2002a, 2002b).

This finding does not diminish the importance of agricultural practices regarding the conservation and anti-erosive development of lands and waterways. Their benefits have been demonstrated in the Missisquoi Bay watershed, as elsewhere in the northeastern United States. However, in North America, long-term monitoring of the effects of these "traditional" beneficial management practices on control of P runoff, erosion and particulate loads has shown that P trapping sites become long-term sources of soluble phosphorus (Dodd and Sharpley, 2016). Clearly, the main implication of long-term P mass balance studies and the effectiveness of runoff and erosion control on P mobilization is that achieving P target loads in the Missisquoi Bay watershed is compromised without rebalancing the phosphorus mass balance.

Systems for separating solid fractions (90% of P) and manure liquids, for example, are widely used in Europe and have also proven to be effective in Québec hog farms (Godbout et al., 2006). The liquid fraction, relatively low in P but high in nitrogen, can then be applied to the field, while limiting soil enrichment in P and preventing P losses in the waterway. This “low P” manure is particularly beneficial in the organic grain sector, where soil is vulnerable to P over-enrichment due to continued use of farm fertilizers. With respect to the recoverable solid fraction (90% P; Godbout et al., 2006), high nutrient richness and low humidity make it easier to apply on more distant fields, or off-farm, after it has been dried, composted or granulated.

Supporting larger livestock operations, for example, in separate management of the solid and liquid phases of manure, is a two-pronged approach in preventing the long-term eutrophication of Missisquoi Bay. On the one hand, the availability of P-depleted manure will contribute to limiting long-term phosphorus enrichment in the watershed. As well, the cleaned-up solid fractions could replace phosphate mineral fertilizer inputs, lowering the overall P supply in the watershed.

Managing phosphorus levels in organic fertilizers at the source also involves reducing mineral phosphorus added to feeds by using enzymes in some livestock production to better assimilate phosphorus in cereals (e.g., phytase). Feed assessments would confirm whether the nutrition of livestock located in this watershed is benefiting from this option

The MRC Brome-Missisquoi in Québec has mandated the Institut de recherche et de développement en agroenvironnement (IRDA) to adapt the Phosphorus Exports Diagnostic Tool to the needs of the MRC in terms of management and control of runoff water on its territory. This spatial reference tool makes it possible to estimate and visualize surface runoff, erosion and phosphorus transfer rates by surface area. The main risk areas were thus located for the entire Brome-Missisquoi RCM.

Also, the OBVBM commissioned IRDA to carry out in the basin of Rock River a scenario analysis aimed at reducing phosphorus loads by 40% using the *GEODEP* tool (Michaud et al., 2019). The results of the analysis will be used to prioritize the interventions according to the gains and to make representations to the governmental authorities for the implementation of the actions. IRDA analyzed the entire watershed of Rock River for scenario modeling. However, the benefits/costs component was only implemented for the Québec portion of the watershed.

Four objectives guided the selection of alternative management practices modeled for the Québec portion of the watershed:

1. Reduction of erosion rates in corn and soybean crops through residue cultivation and cover crops
2. The superficial incorporation of farm manure in the application
3. Development of riparian zones to watercourses
4. Protecting areas that are flooded or excessively vulnerable to erosion

The project was funded by the LCBP under the Support to Pollution Prevention and Habitat Preservation component.

5.5.2 Farm Support Programs

The main support programs for agricultural producers in Québec are the Canadian Agricultural Income Stabilization (PCSRA) Program, the Farm Income Stabilization Insurance Program (ASRA), the Crop Insurance Program, used to address natural risks and the Farm Property Tax Credit Program. These programs are managed by the Fédération Agricole du Québec (FADQ). Spending on these programs ranges from $500 million to $1 billion annually, and has increased by almost 250% between the early 1980s and 2008 in response to various factors, e.g., property tax increases, climate events, etc. The ASRA is by far the Québec government's largest financial assistance program. Supply-managed productions, which already enjoy special protection from foreign competition, are not eligible for this program. Four non-supply-managed commodities (grain corn, feeder veal, pork and piglets) share the majority (about 65%) of the money spent on these various support programs in Québec (CAAAQ, 2008).

Since 2008, compliance or the protection of riparian buffers and the prohibition of increasing cropping areas in certain municipalities targeted by the REA have been implemented under the ASRA and crop insurance programs (Auditor General of Québec, 2012).

Prime-Vert Program

The Prime-Vert Program is managed by the MAPAQ and co-funded by the federal and provincial governments under various agricultural partnerships. Originally designed to support agricultural producers in establishing sealed storage structures, this program has provided funding to producers since 2002 to reduce non-point source pollution by supporting agro-environmental practices (BMPs). For example, farms can get funding to manage animal access to waterways, develop riparian buffer and windbreak, install erosion protection structures in fields or along waterways, and adopt farm practices that conserve soil and water. The Prime-Vert Program is essential for the reduction of non-point source pollution in Québec.

The 2018-2023 version of the Prime-Vert introduces new features such as funding for cover crops and intercropping, which rapidly became very successful with more than 350 applications received by MAPAQ (covering at least 10,000 ha) for the Montérégie in 2018. The new Prime-Vert program also considers the maintenance of riparian plantings that it has funded, which is a benefit and incentive for establishing these works. The amount available to producers has also increased from $30,000 to $40,000 per farm.

The 2018-2023 MAPAQ Prime-Vert program offers three funding streams:

Stream 1: Agro-environmental intervention by a farm, which funds among other things other agro-environmental developments (windbreak hedge, extended riparian strips, etc.) and soil conservation practices and structures (erosion control works, cover crops, etc.)

Stream 2: Regional or inter-regional agro-environmental approach, which supports actions related to agro-environmental issues identified in the Montérégie by MAPAQ and local partners:

- Degradation of soils due to monoculture, inappropriate rotations and poor agricultural practices,
- Intensive use of pesticides that pose a serious risk to the environment and to health in field crops as well as in horticultural production, particularly in southern parts of the Montérégie,
- Stream pollution and degradation of water quality caused, in part, by agricultural inputs and soil loss in intensive cropping areas within watersheds, including the Rock River watershed, and
- Biodiversity loss in intensive agricultural areas including the Missisquoi Bay watershed.

Stream 3: Support for development and transfer of agro-environmental knowledge, which provides assistance to experimental development, technological adaptation and transfer of agro-environmental knowledge, dissemination of agro-environmental information, and individual farm business support for testing implementation of proven BMPs (cover crops, fall cereal planting) on a maximum test area of 5 ha.

A significant decrease in grant applications was noted between the 2009-2013 and 2013-2018 periods, from 64% to 18% of the total farmer participation rate. However, during this 2009-2018 period, an amount of $4.57 million was invested by MAPAQ as part of the Prime-Vert program in the territory of the Missisquoi Bay watershed.

The Prime-Vert Program has made it possible to carry out watershed projects such as removal of animals from waterways, soil conservation works (drains, rainwater inlets, filter trenches, etc.), cover crops, planting of shrub and windbreak hedges, storage infrastructure for manure, and purchase of equipment to reduce pesticide use. Training on the direct seeding method and other soil conservation practices has also been offered to agricultural producers, many of whom have purchased equipment to make the transition to these practices (Mimeault and Simoneau, 2010).

MAPAQ provided technical and financial support for several initiatives in the Missisquoi Bay watershed between 2007 and 2019, totaling more than $1.6 million, including the Lisière Verte program (2007-2010), the Missisquoi Bay ZIPP project (2009-2013), the ruisseau Morpions ZIPP project (2010-2014) and the OBVBM'S Interventions ciblées sur le contrôle des eaux de ruissellement et la conservation des sols dans la MRC Brome-Missisquoi (2016-2019). The latter project was funded by the Prime-Vert (regional approach) program, the MRC Brome-Missisquoi, OBVBM, and Environment and Climate Change Canada's EcoAction program.

As part of this targeted project on stormwater control and soil conservation in the MRC Brome-Missisquoi, OBVBM and the MRC are working together to reduce the impact of runoff from agricultural lands in areas most vulnerable to erosion and in watersheds where stream maintenance work is taking place. Since 2016, targeted agricultural producers have received assistance from OBVBM and MRC agronomists to implement measures to reduce nutrient inputs into waterways. Cover-cropping practices, expanded riparian buffers development, and hydro-agricultural structures are highly recommended.

Several stakeholders interviewed observed significant changes in the "mindset" regarding the environmental protection of agricultural areas. The bay watershed would be "fertile ground" for innovative projects considering some strong interest from agricultural producers and advisors (OBVBM interviews, 2019). Some improvements are noticeable in water quality analyses weighted to the flows. However, loads are still excessive and non-point source management remains a major challenge in the Missisquoi Bay watershed.

5.5.3 Québec Water Strategy 2018-2030

In 2018, the Québec government unveiled the Québec Water Strategy 2018-2030 (Water Strategy), which replaces the 2002 National Water Policy (Gouvernement du Québec, 2018). The Water Strategy will be implemented through three successive action plans with the first Action Plan 2018-2023 representing investments of over $550 million.

The Water Strategy's seven priorities are:

- Ensure public access to quality water,
- Protect and restore aquatic environments,
- Better prevent and manage water-related risks,

- Harness the economic potential of water,
- Promote sustainable water use,
- Acquire and share the best knowledge on water, and
- Ensure and strengthen integrated water resources management.

The priorities and objectives for the Missisquoi Bay issue are Priority 1 with Objectives 3 and 4. With respect to Objective 3, which aims to bring the wastewater infrastructure up to standard, certain measures are aimed at ensuring better control of discharges and promoting the upgrade of residential wastewater treatment facilities. Objective 4, meanwhile, is the continuation of the agro-environmental shift through actions taken in the following areas: controlling sources of contamination of surface water, repairing animal waste storage facilities and improving the efficiency of riparian buffers. As well, Priority 7, which seeks to ensure and strengthen integrated water resources management, includes a measure to support the Québec-Vermont-New York cooperation for the integrated management of Lake Champlain, Lake Memphrémagog and the Richelieu River.

The Water Strategy's Action Plan 2018-2023 includes 63 measures administered by eleven government agencies and organizations whose key actions include: improving water-related risks prevention and management, including for flood events ($53 million); conserving and restoring aquatic environments ($32 million); ensuring access to quality water in adequate quantities, including through the program for the enhanced protection of drinking water sources ($34 million, Gouv. Du Québec, 2018). Monitoring of the Water Strategy is carried out by the MELCC; each year, a progress report must be published, and a mid-term report is in the works. The Water Strategy aims to foster greater coherence in water management responses.

As part of the Québec Water Strategy 2, the Program for Greater Protection of Sources of Drinking Water (PPASEP) supports municipalities implementing the Drinking Water Protection Regulation. The PPASEP is administered by the MELCC and it has two components: The first component will help municipalities that need to perform vulnerability analysis of their drinking water sources, while the second will help municipalities to financially compensate for lost revenues suffered by agricultural producers due to certain restrictions imposed by the Pesticide Management Code (MDDELCC, 2018e). The municipality of Bedford, which has its source of drinking water in Missisquoi Bay, is in the process of conducting the vulnerability analysis.

5.5.4 Additional Québec Policy

Development projects involving the expansion of a sewer system with a total area of more than two hectares (taking into account all the planned phases) must comply with the stormwater requirements, which includes the removal from 60 to 80 % of suspended solids, depending on the sensitivity of the receiving environment. It should be noted that the MELCC may, in the case of environments deemed to be very sensitive (e.g., lakes affected by cyanobacteria blooms or salmonid spawning areas), set more stringent requirements for the removal of suspended solids and phosphorus or, alternatively, require reduction of fecal coliforms through disinfection. For projects less than two hectares, the MELCC could require the implementation of quality control measures if a particular problem justifies their use.

5.6 Recommendations from Experts

5.6.1 Québec

In Québec, the OBVBM consulted more than 65 persons from different agencies, research centers and universities as well as municipal and agricultural stakeholders to gather their views and recommendations. A questionnaire was developed for each person consulted. Some provided written responses, but most were met in interviews from October 2018 to January 2019. Governance, financing programs, current regulations, and interviewee recommendations were discussed. A comprehensive synthesis of the views expressed was completed and the Québec CSAG assessed the most relevant interview sections for the IJC mandate.

The personalized questionnaires approach gave qualitative results and does not make it possible to quantify or present statistics. However, opinions reflecting a certain consensus or raised by several persons served as a basis for the development of the recommendations of the QC SCAG are listed here.

Agriculture and phosphorus limitation

Representatives of the scientific community agree that addressing phosphorus is crucial to reducing eutrophication and cyanobacteria blooms.

As discussed in previous sections, agriculture is the highest contributor of phosphorus to Missisquoi Bay. In order to limit the production of intensive crops in degraded areas, many interviewees suggested financial incentives to promote the transition to cereal and fodder crops. Revised fertilizer requirements have been questioned many times (NMP/P-Balance Sheet) for these control tools to achieve water quality restoration goals. The support and financial support of agricultural producers and the cross-compliance and the compensation for ecological goods and services rendered, should, for many, be the subject of in-depth reflection in order to propose models that would be better suited to the needs of farmers. Market development to support grain and forage production to reduce corn/soybean production was also recommended. Financial support should be provided by several stakeholders to municipalities to upgrade sewage treatment works and reduce their overflows.

Policy, governance, and international cooperation

Most people consulted mentioned the importance of the renewal of the agreement between the Government of Québec and the State of Vermont that came to an end in December 2016 regarding phosphorus reduction at Missisquoi Bay in order to have an official commitment from both governments. To ensure that the objectives of this agreement are achieved, a budget envelope commensurate with the objectives has been strongly recommended, as well as the establishment of a binational agency or a committee of experts dedicated to evaluating and recommending the actions and solutions to be prioritized for the reduction of phosphorus inputs to Missisquoi Bay. In order to follow the progress of the objectives, an annual report should be presented to each of the bodies concerned and to the stakeholders in the field.

From a regional point of view, the delineation of constraint zones in the Regional County Municipality development plans could make it possible to regulate certain uses of the territory in the identified degraded areas. The protection of natural environments and wetlands was also a consensus. In terms of regulation, there have been several enforcement and monitoring shortcomings due to the lack of staff in the departments and the lack of financial resources of the municipalities as is the case with the Shoreline and floodplains Protection Policy that is generally poorly respected.

Cyanobacteria and public health

There is little information available on water bodies affected by cyanobacteria in Québec. The ministry no longer produces an annual report since 2016 and the follow-up is done by volunteers. The beach owners and municipalities do not sufficiently display the information transmitted by the Ministry of Health on follow-up instructions when a water body is affected by cyanobacteria. The fact that the MELCC no longer systematically samples recurrent water bodies, such as Missisquoi Bay, suggests that there are no longer any problems. For many, there is a risk of normalization of the situation. This would have a negative effect on the implementation of action to reduce nutrient inputs. For many stakeholders, the government should require beach owners and municipalities to inform citizens and visitors of the health risks.

In Vermont, as part of the literature review, the LCBP met with watershed professionals to discuss Lake Champlain's water quality and cyanobacteria management. These experts ranged in affiliation from small watershed groups and local municipal officials to regulatory personnel within state and federal governments. These informal, semi-structured interviews were guided by a series of standard questions on water quality and cyanobacteria in the Lake Champlain Basin (Appendix 2). Principally, these conversations focused on programs, factors, and efforts that had been successful and unsuccessful at addressing nutrient loading and cyanobacteria in Lake Champlain, and recommendations for future efforts, given level or increased funding. US Interviews were conducted in December 2018 and January 2019 and were typically around an hour in length. Our initial interviews were with CSAG members; subsequent interviews were solicited with watershed professionals suggested by CSAG members.

5.6.2 United States

Responses from U.S. interviewees were thematically grouped into loose categories: policy, regulation, and the distribution of funds; high-priority phosphorus contributions and potential solutions; and education, outreach, and watershed-scale collaboration. For each of these categories, we listed interviewees' mentions of the following topics: successful programs, projects, and factors; unsuccessful programs, projects, and factors; and overall recommendations. These responses are listed in Table 6 and discussed in more detail below.

Table 6. U.S. Interviewee responses categorized by theme. The number in parentheses after each point represents the number of interviewees who mentioned the topic. Topics with fewer than two mentions are not listed.

	Successful programs, projects, and factors	Unsuccessful programs, projects, and factors	Recommendations
Policy, Regulation, and Distribution of Funds	• Vermont's Act 64 and associated regulatory changes (4), and in particular the new Required Agricultural Practices (4)	• Current system for distributing clean water funding (5) • Vermont's Act 64 and associated regulatory changes (2) • Organization of clean water programs make it difficult for individuals to see their own role (2)	• Keep current funding steady, and evaluate success (4) • Administer a new system for more efficiently distributing funding (4) • Give more power to watershed groups (4) • Decrease administrative and

			reporting requirements for clean water grants (4) • Increase funding for research (3) • Devote some funding to costly pilot projects (3) • Address aging infrastructure (2) • Consider climate change when making policy decisions (2)
High-Priority Phosphorus Contributions and Potential Solutions	*None mentioned*	• Current focus on crisis response rather than on proactive actions (2)	• Focus dollars on highest phosphorus contributors (6) • Address legacy phosphorus in Lake Champlain sediment (5) • Provide more support to farmers (4), possibly by overhauling the milk pricing structure (4) • Implement stormwater BMPs (4) • Prioritize nature-based water quality solutions (3) • Implement a cap-and-trade system for phosphorus (2) • Restore riparian corridors (2)

Education, Outreach, and Watershed-Scale Collaboration	• Existing education and outreach programs (5) • Lake Champlain long-term monitoring program (4) • Concept that water quality improvement is a shared stakeholder responsibility (4) • Collaboration between New York, Vermont, and Québec (4) • Citizen cyanobacteria monitoring (2) • Clean water advocacy groups (2)	• Lack of ownership of water quality problems, and reduced interjurisdictional collaboration (2)	• Encourage more clean water stakeholder "buy-in" (4) • Facilitate more watershed-scale collaboration (4) • More education and outreach, particularly to underserved communities and groups (2)

Respondents were split on the topic of Act 64, Vermont's Clean Water Act. The Required Agricultural Practices (RAPs) set forth by the act were viewed favorably; and the Act more generally received positive mentions from federal and state employees. While some observed that while the Act's 2015 passage may still be too recent to have had measurable positive impacts, it "has the potential to be successful." However, respondents from local governments and watershed nonprofits looked on the Act and related legislation less favorably, noting that while the tactical basin planning process may result in useful information, the process is difficult for stakeholders to understand and engage with, and that Act 64 may put an unfair share of responsibility on municipalities rather than the Vermont Agency of Natural Resources.

Interviewees were asked about where they saw opportunities for policy, research, and implementation improvement. When given a scenario of level funding, several of those interviewed suggested keeping current water quality appropriations steady, and evaluating success. This was true particularly of those state and federal employees who had been involved in crafting Act 64, Vermont's Clean Water Act, who requested that more time be given to determine success of initiatives that have recently gone underway.

Interviewees had fewer responses when asked to list examples of programs and efforts that had been unsuccessful in addressing water quality and cyanobacteria in Lake Champlain. The most major topic, shared by five interviewees, was that the current structure of dispersing water quality funding is inefficient and could be made more effective. However, the specifics of views on this topic varied substantially: several interviewees argued that too great a proportion of total funding goes to administrative support and reporting costs, and that more resources should go to implementation rather than research and monitoring, while others suggested that funds be distributed based on water quality outcomes – that is, pounds of phosphorus reduction.

Several interviewees mentioned the importance of optimizing the distribution of any increased funds. Some suggested that an increase in funding go to the Agency of Natural Resources to be administered; there is already significant challenge in issuing funds in a timely and efficient manner, so up to a third of any increased funds should go to fund staff to facilitate grant projects around the state. However, other interviewees, mostly from municipalities and watershed groups, disagreed, suggesting that the federal and state governments attempt to be more closely aligned with local nonprofits, and stretch funding by removing the barriers that these organizations have to cross, such as the time-consuming process of applying for grants rather than receiving steady funding, and the significant amount of reporting paperwork. Another suggestion was to decentralize state government to better support municipalities: specifically, moving up to 80% of the ANR's Montpelier staff to underserved communities throughout the Vermont. These differing views illustrate the clear division in perceptions of priorities and challenges between state and federal employees who craft and promote the current regulatory framework, and the municipal staff and watershed groups who conduct on-the-ground implementation work in response.

The most common suggestions for the use of increased funding were to target high priority phosphorus sources, and to prioritize education and outreach efforts. Regarding high priority phosphorus areas, responses were varied, but many centered on agriculture. Several mentioned the importance of encouraging the state, municipalities, and watershed groups to buy out farms in critical phosphorus source areas, particularly in the Lake Carmi watershed; while agriculture is seen as a fundamental part of the watershed's landscape, farming is the largest contributor of phosphorus to Lake Champlain and must be addressed. Providing support and incentives to farmers to transition away from high-impact crops like corn and dairy may be a relatively simple way of decreasing agricultural phosphorus. Funds for farmer education, subsidies for equipment purchases and best management practices (BMPs) installation, and easier access to personalized nutrient management plans were mentioned as possible ways to support farmers.

Another suggestion was an overhaul of the federal milk pricing structure. Most milk prices paid to farmers are set monthly, according to Federal Milk Marketing Orders, based on a combination of market-determined dairy prices and estimated production costs, yields, and location (MacDonald, Cessna, and Mosheim 2016). Milk production has shifted to larger farms, and these larger farms can earn much more per unit of milk than smaller operations, giving them a strong incentive to further expand; these farm size increases caused milk production costs to decrease for larger farmers between 1998 and 2012, and as a result milk prices have been reduced (MacDonald, Cessna, and Mosheim 2016). In 2010, the median national dairy herd size was 900 cows, up from 80 in 1987 (MacDonald, Cessna, and Mosheim 2016); in Vermont, the average herd size is 125 cows, an increase from 60 in 1990 (Parsons 2010). These descriptive statistics are not directly comparable, but they suggest that while Vermont's dairy herds have nearly doubled in size, they are still much smaller than the industrial-scale dairy herds nationwide. Vermont's dairy industry has been described as "in crisis" (Heintz, April 2018), and the pressure for farmers to aggregate larger herds on the same farm parcel increases the environmental impact of dairy production. Dramatic surges in volatility of milk prices have negatively impacted farmers (Bolotova 2016), and eliminating or overhauling the federal milk pricing scheme has been a topic of research and discussion for several decades (Manchester and Blayney 1997; McNew 1999).

While addressing the most challenging nutrient and cyanobacteria areas on Lake Champlain is crucial, several interviewees also noted the importance of protecting and conserving intact, well-preserved areas. Protecting and maintaining natural resources maximizes their water quality value, shifting focus to “nature-based” solutions rather than relying entirely on technological innovation to fix ongoing problems.

Technology was a recommendation for several of those interviewed: increased funding would allow for the installation and testing of new, costly systems to remove phosphorus and increase water quality. Some pilot project possibilities included phosphorus treatment train installations; purchase and implementation of enhanced treatment units (ETUs), used in place of traditional septic systems to remove more nitrogen and phosphorus; and addressing of high phosphorus legacy sediments in the lake. In particular, respondents suggested implementing pilot projects to highlight the value of ecosystem services and considering applying successful pilot projects on a larger scale – for example, implementing the treatment train project on a larger scale, perhaps at the mouth of the Rock River.

5.6.3 Education, Outreach, and Basin-Scale Collaboration

A major theme throughout the interviews was the importance of basin-scale collaboration in the Lake Champlain Basin. Several of those interviewed noted the value of collaboration between the United States and Canada, and suggested that successful regulations – be they from Vermont, New York, or Québec – be implemented in other jurisdictions as well. Respondents emphasized the need for communication and collaboration with Québec, and suggested a common informatics and planning process for the basin, and that New York and Québec might consider adopting Vermont’s Municipal Roads General Permit system.

Most interviewees noted their recognition of the importance of data collection and research. Many listed the Lake Champlain Monitoring Program as an example of a program that has been successful in addressing water quality and cyanobacteria. This bi-state program, begun in 1990, provides long term data on many of Lake Champlain’s water quality parameters, including total and dissolved phosphorus. It has provided scientific basis for several regulatory and policy actions in the basin. Respondents noted that in addition to the strength of the data collected by the long-term monitoring program, the citizen cyanobacteria monitoring program coordinated by VTDEC, VT DOH, and the Lake Champlain Committee has given stakeholders an opportunity to learn more about water quality and get involved in research on the lake.

Education and outreach were topics with significant support from interviewees. Activities that encourage stakeholder engagement and public participation were particularly well-regarded, including LCBP’s teacher trainer program (Champlain Basin Education Initiative) and Boat Launch Steward program (while these stewards are principally intended to focus on invasive species prevention, they have interactions with many users of high-traffic boat launches on the lake, and often discuss phosphorus and cyanobacteria with concerned stakeholders). Several respondents mentioned the importance and challenge of reaching new audiences; television, radio, and new social media avenues like Facebook and Twitter were raised as opportunities. Thinking generationally – involving younger stakeholders in the lake’s management – was a topic of major discussion as well.

One final commonality between interviews was the importance of personal responsibility and long-range thinking. The state of Lake Champlain and, more specifically, Missisquoi Bay, is the result of hundreds of years of human land use, and several respondents noted that the TMDL’s 20-year timeframe will likely not be adequate to complete clean-up effort. Stakeholders in the basin need to better understand the timescale required for major changes in water quality.

Overall, most of those interviewed observed that while the management of phosphorus and cyanobacteria is substantial challenge, stakeholders in the Lake Champlain basin particularly need to be educated on their personal impacts and responsibilities. In a complex, diverse, multi-jurisdictional system like Lake Champlain, progress is being made in several sectors. The importance of prioritizing high-impact phosphorus sources, continuing to collect high quality data to inform policy, and providing education, outreach, and support to stakeholders is clear.

6 Recommendations for Reduction of Nutrient Loading and Cyanobacteria Blooms in Missisquoi Bay

Missisquoi Bay has long been degraded by excessive phosphorus inputs from the Bay watershed, and has one of the highest in-lake phosphorus concentrations of any segment of Lake Champlain (Lake Champlain Basin Program 2018). While the drainage area to Missisquoi Bay makes up only 15% of the lake's total watershed, it contributes about 23% of the total phosphorus load to the lake. The effects of this disproportionately high phosphorus loading from the Bay watershed are compounded by the Bay's shallowness and limited connectivity to the rest of the lake. The resulting excessive phosphorus levels threaten Missisquoi Bay's ecosystem, public drinking water supply, and recreational opportunities.

Despite progress made by the governments of Québec and the State of Vermont (the Parties) in the Missisquoi Bay watershed through the implementation of urban and agricultural remediation measures, the phosphorus concentration target of 0.025 mg/L was not reached by December 30, 2016, when the Agreement between the Parties concerning phosphorus reduction in Missisquoi Bay expired.

As noted in numerous sections of this report, climate change poses a significant ongoing stressor upon the quality of Missisquoi Bay waters. While the recommendations presented below address water quality specifically, an overriding recommendation is that the Governments of Canada and the United States, as well as those of Québec and Vermont, implement meaningful controls on carbon emissions. If left unchecked, continued warming and related hydrologic impacts will increasingly undermine the achievement of our water quality goals.

The management recommendations below are provided to the Canadian and United States federal governments and their partners with the goal of reducing nutrient inputs to the Missisquoi Bay and the frequency and severity of cyanobacteria blooms in this lake segment.

These recommendations are based on the Québec and US reports of the IJC's Champlain Science Advisory Group (CSAG) and other water quality and policy experts in the region, including participants in a facilitated technical workshop in May 2019.

The following recommendations acknowledge several underlying factors critical to understanding nutrient loading and cyanobacteria blooms in Missisquoi Bay, not the least of which are climate change impacts:

- The land use history of the watershed affects the distribution, condition, connectivity, and nutrient storage potential of forests and wetlands,
- The Missisquoi Bay watershed has a land to water ratio of about 40:1, which is relatively high compared to 18:1 for Lake Champlain and less than 3.5:1 for the Great Lakes watersheds,

- Climate change, and the associated potential increase in temperature and extreme event impacts, may likely result in more nutrient loading and more frequent cyanobacteria blooms, and
- Nutrients from agricultural sources within the Missisquoi Bay watershed have been identified as the leading cause of impairment. (Smeltzer and Simoneau 2008; U.S. EPA 2016b)

6.1 Public consultation

This report and the recommendations below were drafted by OBVBM, LCBP, and NEIWPCC, based on review of existing literature and consultation with experts in the watershed; this material was reviewed by the CSAG and made publicly available in several venues:

- The draft report was posted online for public comment; this public comment period closed on December 14, 2019
- Public meetings were held in Venise-en-Québec, QC on November 20th, and in St. Albans, VT on November 21st, 2019.

Responses from the online public comment period and from both public meetings were compiled and are included in Appendix 3. Multiple sections within the report were revised to accommodate comments that were provided during the public comment period.

6.2 Priority recommendations

1. Establish and coordinate a binational phosphorus reduction working group to enhance cooperation and accountability of parties to achieve mutually agreed goals

Many of the recommendations in this report need to be addressed by higher levels of government, but several can and should be addressed within the Action Plan to be developed by the Missisquoi Bay Phosphorus Reduction Task Force.

Although the Agreement between the Government of Québec and the Government of the State of Vermont concerning phosphorus reduction in Missisquoi Bay expired in December 2016, the principles outlined within that MOU should continue to guide the Parties.

a. Agree to maintain the 0.025 mg/L annual average concentration target

b. Create a permanent binational Missisquoi Bay Phosphorus Reduction Task Force as a standing subcommittee of the Lake Champlain Steering Committee, to be tasked with reviewing, developing and assisting in the implementation of actions to reach the above target. This committee will work with partners to develop a binational Action plan to reduce phosphorus loads within a defined timetable. The binational Action Plan should include requirements of applicable water quality management plans, and the Task Force should provide input in the development of future iterations of these plans. This group would coordinate existing management plans in place within Québec and Vermont and would be responsible for defining and assisting in the implementation of measures, and support tracking and monitoring progress through performance indicators

c. The Missisquoi Bay Phosphorus Reduction Task Force will work to ensure consistent transboundary data collection procedures, standardized data quality assurance, and multilingual public access and communication pertaining to phosphorus data, with the goals of unifying scientific methods in the Missisquoi Bay watershed and of carrying one unified message to the public on status and progress

d. The Missisquoi Bay Phosphorus Reduction Task Force will report annually to the Lake Champlain Steering Committee, the OBVBM Board of Directors and to the public on progress toward achieving these goals. The Action Plan will include an accountability element in which the annual report will provide a summary of achievement of the goals outlined within the Action Plan

e. The State and Provincial governments of Vermont and Québec, as well as the federal governments of the United States and Canada, should provide the necessary sustained funding to achieve the clean water goals referenced above

2. Develop a Binational Mass Balance for Phosphorus Imports and Exports in the Missisquoi Bay Watershed

Understanding the amount of phosphorus that is brought into the Missisquoi Bay basin from external sources (imported phosphorus), how phosphorus is cycled through the Missisquoi Bay basin ecosystem, and how much phosphorus is exported, either out of the bay and into the rest of Lake Champlain or out of the watershed by human activity will be critical to addressing the frequency of cyanobacterial blooms in the long-term. A binational phosphorus mass-balance model that addresses movement of phosphorus throughout the Missisquoi Bay basin ecosystem will help to inform management decisions and measure progress toward achieving management goals for the bay.

a. Develop a binational mass balance model for phosphorus in the Missisquoi Bay watershed, and advance transboundary work that addresses total phosphorus inputs, exports, and storage at the sub-watershed, industry, and land-use sector scales

b. Develop and implement a strategy to reduce importation of phosphorus to manage the balance of phosphorus imports and exports in the watershed

3. Reduce the use of phosphorus on the lands of the Missisquoi watershed

While a majority of the phosphorus loading into Missisquoi Bay is from agricultural sources, it is important to consider sources of phosphorus across all land uses in the Missisquoi Basin. The 2016 Vermont phosphorus TMDL for Missisquoi Bay estimates that a 64.3% reduction in total phosphorus load is needed to meet the TMDL allocation for the Missisquoi Bay segment.

In many cases, the nitrogen-to-phosphorus ratio in fertilizers is lower than necessary for most crops. Consequently, to achieve minimum nitrogen application rates, phosphorus is over-applied to agricultural soils, over-enriching them with phosphorus. This phosphorus can then move downstream into Missisquoi Bay during runoff events. If the crops are fertilized with organic fertilizers with the objective of filling the nitrogen requirements, the phosphorus doses provided are then much higher than the crop requirements and will contribute to the enrichment of the soil, then to the phosphorus losses to the waterways. Approximately 33% of the soils analyzed in the Pike River watershed municipalities had saturation rates above the vulnerability threshold of 10% for phosphorus loss (Deslandes et al., 2004; Michaud et al., 2004; Deslandes et al., 2006), illustrating the role of legacy soil phosphorus.

To reduce these impacts and limit soil enrichment, resource managers and agricultural producers must reduce phosphorus inputs at their source.

a. Reduce nutrient inputs by considering the actual phosphorus needs of plants and adapt agronomic recommendations to focus on the capacity of soils to support phosphorus

b. Implement soil management and conservation practices that reduce legacy soil phosphorus, particularly in critical source areas, and develop protocols for long-term, sustainable management of soil phosphorus

c. In Québec, revise the “charts of maximum annual deposits” outlined in Québec regulations to reduce the maximum applications authorized by the Agricultural Operations Regulation chart

d. Remove the inherent risk of reducing phosphorus inputs through a financial compensation program to offset potential yield losses

e. Investigate processes and markets for reclaimed phosphorus and develop innovative solutions to commodify phosphorus into products and export from the watershed

4. Increase the proportion of cropping systems that exhibit less phosphorus loss

Agriculture is important to the regional economy, community, and sense of place for the residents of the Missisquoi Bay region of Québec and Vermont. Management actions focused on agricultural interventions in this Basin should recognize and acknowledge the importance of these social factors. However, agriculture also is the single greatest contributor of phosphorus and sediment to Missisquoi Bay, and significant efforts need to be taken to reduce the pollutant loads from agriculture into the bay if the frequency of harmful cyanobacterial blooms is to be reduced in the future.

The Missisquoi Bay watershed has experienced a significant increase in annual corn and soybean crops, to the detriment of grasslands and small-grain crops over the past 30 years. Inadequate erosion protection provided by soy stubble and corn silage, as well as the relative importance of the area of corn tilled in the fall, means that a substantial proportion of land in the watershed is left bare in late fall and subject to runoff and erosion in winter and spring. In addition, these crops do not provide a window for the summer application of farm fertilizers, while pre-seeding or post-harvest applications have an increased risk of soil compaction and runoff emissions.

Providing financial incentives to producers in the watershed to transition to crops and agricultural methods that contribute less phosphorus is critical.

a. Support programs that promote conversion to perennial forage (grassland) areas for livestock operations, particularly in fields that are vulnerable to erosion

b. Encourage cropping system transition from corn and soy to small grain and other crops that provide soil and water quality benefits, and provide financial support to develop new markets for these crops. This may include development of high-quality hay and grain markets, and re-examining the impacts of subsidy programs such as those dealing with ethanol

c. Increase the acreage of spring and fall cereal crops that will improve soil health and reduce erosion

d. Plant cover crops in the annual cultivation of corn silage, soybeans, spring grains, and other annual crops

e. Promote management of crop residue in spring instead of fall to reduce risk of soil erosion, such as spring stubble plowing and direct seeding

5. Increase protection of river corridors and increase the area of floodplains, wetlands and forest lands and ensure that they are reconnected to promote nutrient retention

Resource managers have begun to explore “green” or nature-based solutions to aid in the reduction of pollutant loads to Lake Champlain. Nature-based solutions can offer less expensive options for mitigating pollutant loads and provide numerous co-benefits, such as thermal cooling, flood mitigation, and habitat improvement for aquatic and riparian species, that are not typically available through traditional nutrient management practices.

Many natural features on the landscape that historically served these purposes have been removed or modified by humans for various purposes: the building of dams, straightening and dredging of rivers, and removal of riparian vegetation and forests have substantially altered the hydrology of the Missisquoi Bay watershed. Restoring these natural features, such as wetlands, floodplains, and forests, can reduce erosive impacts of severe storm events and capture sediment, nutrients, and other pollutants before they are delivered to Missisquoi Bay.

a. Actively pursue the protection of river corridors and restoration of properly functioning waterways by promoting and restoring the dynamic equilibrium and geomorphic function of rivers and streams

b. Expand programs to retire and conserve lands, and acknowledge co-benefits of land conservation, such as flood mitigation, increased wildlife habitat, and new recreational opportunities

c. Promote nature-inspired techniques like constructed wetlands to complement nature-based solutions like floodplain reconnection and riparian buffer plantings

d. Provide financial and technical incentives for the strategic implementation of perennial nature-based or nature-inspired solutions, including incentivized forestry practices and progress-based payments

6. Engage public stakeholders to commit to the goals of safe water and healthy ecosystems

Many of the recommendations contained within this report require regulatory interventions or funding from government agencies or ministries to support research toward optimizing resource dollars to achieve water quality goals. The stakeholders who live and work in the Missisquoi Bay watershed and greater Lake Champlain region can work toward accomplishing important milestones within the management plan for the bay and the lake. Public outreach programs can elevate conversations around protection of the lake and practices that people can do on their own land or in their daily lives to promote and improve the health of Lake Champlain. These stakeholders also can hold their elected officials accountable to water quality goals for Lake Champlain.

Cross-border communication among stakeholder groups is critical toward a common understanding of the management goals and needs for Lake Champlain. Programs that support and augment local education of lake issues and management practices will help increase the support for improvement of the water quality of Missisquoi Bay and greater Lake Champlain.

a. Encourage stakeholder engagement and commitment to clean water and healthy ecosystem goals. This can be achieved in part by expanding existing water quality education and outreach in the Lake Champlain Basin, particularly to underserved communities and groups, and encouraging citizen science and service-learning opportunities

b. Facilitate more watershed-scale cooperation and collaborative educational and engagement opportunities between potential partners, including the United States and Canada, Vermont, New York, and Québec, and among local municipalities, watershed groups, and higher education institutions

The Missisquoi Bay Phosphorus Reduction Task Force will develop opportunities for communicating information to stakeholder groups, including a website and media presence, to receive and respond to stakeholder inquiries. Communication should include coverage of the temporal lag times between watershed practice implementation and water quality responses in receiving waters

6.3 Additional recommendations by theme

Developed areas

While agriculture is the largest contributor of phosphorus to Lake Champlain by land use, other human activities are major factors as well. Support for nutrient management from these land use sectors is essential to realizing water quality goals in Missisquoi Bay.

Per unit of area, developed land contributes more phosphorus than well-managed agricultural land. Impervious surfaces, such as parking lots and rooftops, quickly shed stormwater during rain events, carrying phosphorus and other pollutants into tributaries and Missisquoi Bay. Green stormwater infrastructure practices have been used with success to slow the flow of stormwater, allowing the stormwater to infiltrate into the ground, decreasing the load of phosphorus and additional pollutants to waterways.

Substantial progress has been made in wastewater management, but there is a continuing need to maintain and upgrade this important water infrastructure. Since the 1980s, the Québec government has used an approach based on effluent discharge objectives (EDOs), which are calculated according to surface water quality criteria, characteristics of the host environment, and environmental uses; the MELCC has developed more stringent standards for phosphorus discharges from wastewater treatment facilities, including new requirements specified in the remediation certifications, reducing the maximum allowable concentration to 0.3 mg/L since January 1, 2017. In Vermont, stricter wastewater treatment facility phosphorus load allocations were established as part of the 2016 Lake Champlain TMDL update.

a. Stormwater management research and innovative implementation opportunities should be integrated into municipal and regional planning efforts to reduce inflows to combined sewer systems and support implementation of green stormwater infrastructure practices to reduce overland storm flows. Development opportunities that protect or restore water quality should be encouraged through regulatory tools
b. Regulations governing Québec municipal, and privately-owned infrastructure (including individual and commercial septic systems) should be updated and enforced to ensure compliance. The programs created by Vermont's Clean Water Act provide a template that could be adopted basin-wide.

c. Funding opportunities should be identified to support major infrastructure assessments and upgrades to water pollution control facilities to continue to achieve phosphorus discharge requirements

Agriculture

a. In Vermont, communicate accurate and timely weather forecasts to the agricultural community to encourage smart fertilizer use and manure application as Agro Météo in Québec

b. Increase enforcement and compliance with existing agricultural practice requirements, especially those addressing riparian buffers and restrictions on manure spreading.

c. Strengthen the regulatory frameworks governing the application, storage and export of manure, including those addressing the use of manure injection and incorporation into the soil.

d. Prioritize implementation of management practices toward critical source areas to reduce contributions of bioavailable phosphorus from these sources

e. Promote increased soil health and crop productivity due to BMP implementation to the agricultural community

f. Continue to widely implement and incentivize BMPs shown to be most effective. The State of Vermont and the Province of Québec should consider sustained and, where feasible, new funding for BMP implementation.

g. Develop a process for progress payments to compensate farmers for achieving interim milestones toward water quality improvements on their lands

Regulation and Funding

While substantial federal, state, provincial, and local resources have been devoted to improving water quality in Missisquoi Bay, work remains to be done. Harmonizing management goals and successful policy across the border may allow for jurisdictions to collaborate on new regulatory initiatives and help to combat the perception that governments and stakeholders in other jurisdictions are not doing enough to address Missisquoi Bay's water quality challenges.

Funding for clean water funding is finite. Given this, limited resources should be focused on areas, practices, and techniques that will achieve the greatest amount of phosphorus reduction for each dollar invested. There may also be opportunities to optimize the process for achieving clean water goals by evaluating the efficiency of federal, state, and local agencies' staffing and funding levels and organization.

a. Regulations across the watershed should work toward achievement of common transboundary standards within the regulatory framework of the respective jurisdictions. This includes regulations to be applied to particular land use sectors, including developed, forested, and agricultural land, and strategic enforcement initiatives

b. Expand incentive programs to increase implementation of best management practices with alternative funding streams, including incremental progress-linked payments and alternative tax programs that apply to multiple land uses across the basin, including developed, forested, and agricultural land

c. Finite management resources should be applied to achieve the greatest return on investment toward management goals. The efficiency of the current systems in place for distributing federal, state, and other funds to nutrient reduction programs should be evaluated, with consideration of staffing and organization at the federal, state, and local levels

d. Some resources should be invested in exploration of high-cost, potentially high-risk pilot projects that could potentially yield high phosphorus reductions per dollar invested

Research

Support for research into our understanding of the ecological processes of the Missisquoi Bay system is critical to achieving water quality goals for Missisquoi Bay and the greater Lake Champlain basin. Improved knowledge of efficacies of important best management practices, new or relatively untested management practices, and research into our understanding of ecological systems and processes is critical toward optimizing future management resources to achieve water quality goals.

a. Increase funding for nutrient reduction research applicable to management in the Lake Champlain Basin, and focus this funding and research on the evolution of critical source areas and the highest phosphorus contributing sectors

b. Continue to support research that improves understanding of different forms of phosphorus bioavailability in Missisquoi Bay and strengthens understanding of in-lake nitrogen-phosphorus dynamics

Phosphorus legacy sediment in Missisquoi Bay

A significant portion of annual sediment and phosphorus loads accumulates at the bottom of Missisquoi Bay, creating a latent load of phosphorus and other contaminants. This problem is exacerbated by the fact that sediments accumulate more than they are released by the waters to the outflow. Indeed, 42% of phosphorus loads are eventually moved to the water column, while 58% accumulate in sediments. (HydroQual Inc., 1999)

Reduction of the frequency and severity of cyanobacterial blooms in Missisquoi Bay cannot be achieved without first reducing the amount of phosphorus delivered to the bay from the watershed (external loading) but eventually the amount of phosphorus cycling into the water column from the sediment (internal loading) will need to be addressed.

a. Use internal phosphorus cycling models to facilitate investigation of management techniques for phosphorus removal or inactivation from Missisquoi Bay sediment, in consideration of the known hydrodynamics of the bay and movement of water through the Alburgh-Swanton causeway

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Appendix 1: IJC CSAG Appointment letter

July 26, 2018

Dear Sir or Madam,

We are pleased to appoint you as member of the International Champlain Study Advisory Group (CSAG) for a term effective August 1, 2018 to October 19, 2019. CSAG is being established to assist the Commission in responding to the Missisquoi Bay-Lake Champlain component of the October 19, 2017 reference from governments on water quality in Lakes Champlain and Memphremagog. CSAG will comprise an equal number of members from the United States and Canada (12 members in total). CSAG members will serve the Commission in their personal and professional capacity, not as representatives of their agencies or employers. Members are expected to serve in an impartial manner, performing their duties for the common good of both countries. Participation on the CSAG is voluntary; there will no compensation for the work done during this appointment. Members of the CSAG will be expected to attend events, meetings and workshops and will be responsible for their own expenses, unless otherwise arranged by the Commission. Meetings and workshops will be held within the Study region.

The Lake Champlain Basin Program (LCBP) and Organisme de bassin versant de la baie Missisquoi (OBVBM), organizations active in the basin will produce a technical report for the IJC which identifies the range of nutrient loading issues that are of concern in Missisquoi Bay and Lake Champlain basin and will make preliminary recommendations on how current government and non-government agency efforts and management approaches could be strengthened (see IJC reference, attached). This report is to be submitted to the IJC July 19, 2019. Based on this report, the Commission will formulate its own report which it will submit to governments by October 19, 2019.

The role of CSAG members will be to provide high level direction and advice to the basin organizations on all aspects of the project, including preliminary recommendations. A document describing CSAG responsibilities and anticipated member time commitment is attached.

The International Joint Commission is a binational United States-Canada organization established under the Boundary Waters Treaty of 1909; a link is attached for your information (http://laws.justice.gc.ca/eng/acts/I-17/page-1.html). You may also refer to http://www.ijc.org/ for additional information about the Commission.

As Commission Secretaries, we wish to extend to you our congratulations on your appointment and trust that it will be a rewarding experience, of benefit to you as well as to the Commission. Should you have any questions about CSAG or your duties as an CSAG member, please do not hesitate to contact Glenn Benoy at 613-995-0433 or benoyg@ottawa.ijc.org or Michael Laitta at 202-736-9022 or laittam@washington.ijc.org.

Yours Sincerely,

Camille Mageau and Chuck Lawson

IJC Secretaries

Appendix 2: Standard Questions for Expert Interviews

Before beginning the interview, Ellen provided an introduction to the project and an overview of the interview goals (supplementing the literature review with expert opinions from the watershed).

1. In your role, how often do you consider water quality and cyanobacteria?
    a. Is this consideration seasonal?
2. How much do you interface with stakeholders? How concerned are they with water quality and cyanobacteria?
3. Regarding water quality and cyanobacteria in the Lake, what are some programs and projects that you feel have been successful? Why?
4. What are some programs and projects that you feel have been unsuccessful? Why?
5. Where do you see opportunities for improvement?
    a. Given unlimited funding?
    b. Given a realistic increase in funding?
    c. Given no funding increase, how would you distribute resources?
6. Would you like to add anything as an anonymous Lake and watershed stakeholder?
7. Do you have any suggestions for further people to contact?

Appendix 3: Public Comments

A3.1 Online comments

A total of three comments were submitted to the IJC via their online comment portal:

Comment 1:

Bonjour,

Je m'appelle Jade et je suis à la maîtrise en biologie à l'UQAM. Mes recherches sont portées sur l'impact des changements climatiques sur la dynamique des cyanobactéries dans la Rivière-aux-Brochets et fait parti d'un grand projet en collaboration avec le consortium OURANOS sur les changements climatiques. J'ai donc fait beaucoup de terrain sur la rivière (dans la réserve écologique à son embouchure avec la Baie Missisquoi) durant l'été 2019. De plus je connais bien les lois et politiques sur la gestion des bandes riveraines, ayant travaillé pour un organisme de bassin versant au QC. C'est donc avec ses connaissances que je permettrais les commentaires suivants:

Il devrait y avoir un petit budget alloué à plus d'inspecteurs du MAPAQ afin d'aller donner des amendes aux contrevenants qui déversent leurs fosses à purin et autres matières fécales directement dans les cours d'eau du bassin versant de la Baie, en vertu du Règlement sur les exploitations agricoles (chapitre Q-2, r.26). Aussi, en vertu de ce règlement, je demanderais aux inspecteurs d'aller faire respecter soit le règlement municipal quant à la bande riveraine obligatoire, ou sinon en son absence, faire respecter le règlement de la bande riveraine de 3m de tout cours d'eau/milieu humide et de 1m des fossés agricoles.

De plus, pour les municipalité du bassin versant de la Baie Missisquoi qui n'ont pas de règlement sur la bande riveraine, j'en instaurerais un, basé sur la Politique des rives, du littoral et des plaines inondables, produite par le MELCC et révisée en 2015.

Je crois que du côté QC, ce serait déjà un grand pas dans la bonne direction, en plus des autres efforts déjà mis en œuvre et qui donnent de bons résultats.

Merci de votre attention,

Jade

____

Comment 2:

ken sturm

U.S. Fish and Wildlife Service

Missisquoi NWR

29 Tabor Road

Swanton, VT 05488

United States

Phone

8028684781

Fax

8028682379

Submitted by mnwr on Fri, 11/22/2019 - 14:25

Thank you for your work and the development of actionable recommendations for reducing phosphorus inputs into Lake Champlain and particularly the Missisquoi Bay. As the manager of the Missisquoi National Wildlife Refuge (NWR) I find water quality issues to be one of my top concerns for the future biological integrity of this National Wildlife Refuge. Missisquoi NWR was designated a Ramsar Wetland of International Importance in 2013, the 36th such site in the United States. This designation is well deserved as this refuge protects the largest and likely most biologically significant wetland complex in the Lake Champlain Basin. Hosting tens of thousands of waterfowl and thousands of other water birds the refuge hosts the largest concentration of these species during fall migration in the Champlain Valley. Couple that with the many state threatened and endangered birds, fish and freshwater mussels, this sanctuary is of extreme importance for a variety of federal and state trust wildlife species.

And yet as the manager of this amazing area, I am unable to truly ensure its future protection against the persistent eutrophication emanating from upstream sources.

There are areas in the country that have suffered extreme wildlife impacts because of cyanobacteria blooms. These blooms have been known to aid cycles of avian (type C) botulism in western lakes such as the Salton Sea resulting in large-scale water bird mortality events. There is speculation that ingestion of toxins produced by cyanobacteria are responsible for bird mortality events as well, such as the mass die-off of eared grebes at the Salton Sea in the early 1990’s. Given the current trajectory of warming waters, extended summer weather and longer cyanobacteria blooms, it is possible that this will coincide with the fall migration of thousands of waterfowl at Missisquoi NWR. My fear is that some day in the future this will begin a cycle of avian botulism impacting thousands of waterfowl and shorebirds that the Missisquoi NWR was established to protect.

Of course, there are direct wildlife impacts to cyanobacteria bloom cycles occurring right now in Missisquoi Bay. Since I have been the manager of this refuge, I have witnessed two different die-offs of native mussels and one smaller fish kill in Missisquoi Bay. While not on refuge property, it is obviously troubling. The large-scale degradation of blooms creating anoxic conditions can kill thousands of native fresh water mussels, some of which are state endangered or threatened.

My intent on writing these comments was to bring forward my concerns as a wildlife manager for the future of Missisquoi Bay and the Missisquoi National Wildlife Refuge. While we currently see direct impacts on recreation and tourism, I fear that we may realize impacts to wildlife from these events in the future. I would like to recognize the threat to wildlife on this National Wildlife Refuge and the Missisquoi Bay from eutrophication cycles. I fully support your work to find ways to reduce phosphorus in the Missisquoi River and the Missisquoi Bay, for the benefit of wildlife as well as for tourism and public water-based activities.

Comment 3:

Dear CSAG Members,

The Lake Champlain Committee (LCC) submits the following public comments (attached PDF) in regard to the Draft Study Report on Nutrient Loading and Impacts in Lake Champlain, Missisquoi Bay, and the Richelieu River. Thank you for your consideration of our comments. We welcome the opportunity to further discuss them with you.

We also submitted our comments via the provided email (lclm@ottawa.ijc.org).

December 14, 2019 Champlain Study Advisory Group (CSAG)

Re: Draft Study Report on Nutrient Loading and Impacts in Lake Champlain, Missisquoi Bay, and the Richelieu River

Dear CSAG Members: The Lake Champlain Committee (LCC) submits the following public comments in regard to the Draft Study Report on Nutrient Loading and Impacts in Lake Champlain, Missisquoi Bay, and the Richelieu River. Our comments are laid out in the framework of your six "Priority Recommendations." We encourage the CSAG Members to recommend a total phosphorus target load reduction from the Missisquoi Bay watershed that is greater than 97.2 metric tons per year, as the average phosphorus concentration is 0.050 mg/L, double the 2016 target concentration of 0.025 mg/L.1 In all of your work, we encourage the incorporation of a clear structure for tasks and deadlines, as well as a coordinated public outreach campaign, that reflect the urgency of the reduction goals.

1. Create and coordinate a Bi-national Phosphorus Reduction Task Force to strengthen cooperation and accountability between the Parties in order to achieve mutually agreed goals.

We agree that this is a logical step and recommend that the Task Force include Missisquoi Bay Watershed science experts, a human geographer, a visual communicator, and representatives from identified underserved populations to strengthen cooperation and accountability between stakeholders. The state and provincial agencies need to work in partnership to provide incentives, as well as regulations for reductions. When resource users—for example, farmers—are brought into the problem-solving process, the results are better. We recommend the Task Force engage with agriculturalists to understand their stories. Farmers are the experts on their own practices, why they do them, and what options they have to engage in on-farm changes to contribute to the health of the lake. A trained social scientist knows how to apply a socioecological approach to problem solving; results from this type of work can help state and provincial agencies to work with one another, alongside Missisquoi Bay Watershed communities, to meet reduction goals.

2. Develop a binational mass balance analysis for phosphorus imports and exports in the Missisquoi Bay watershed

We support this recommendation and think the Task Force should proactively explore options for how to lower imports of fertilizer and feed in both Vermont and Québec.

3. Reduce phosphorus application to land in the Missisquoi Bay watershed

We support this recommendation. A way this effort might be improved is through a formalized framework where farmers learn from other farmers. Are there farms with exemplary Nutrient Management Plans that other farmers can learn from? These farmers could be paid to act as resources for how to implement effective phosphorus mitigation practices. The Task Force should recommend more research on how to address legacy phosphorus however, we stress that the issue of phosphorus entering Missisquoi Bay needs to be addressed first.

4. Increase the proportion of crop systems that contribute less phosphorus This is critical and needs to be addressed. State and provincial agencies need to play a leadership role in helping farms transition to crops that contribute significantly less phosphorus, as well as to connect farmers to new markets.

5. Increase the protection and enhancement of floodplains, wetlands, and forest and ensure their reconnection for nutrient storage

It is important to pair regulations with non-regulatory projects to reach nutrient reduction goals. Vermont's Act 76 restructures the current clean water grant programs into a block grant system that will expand the opportunity for such non-regulatory projects; this allows for nutrient reduction goals that couldn't be achieved through regulation alone. Further, these projects will offer a variety of co-benefits and help protect and maintain high quality waters. The current policy of the state of Vermont is no net loss of wetlands. This policy should be modernized with a goal of a net gain of wetlands by encouraging both protection and restoration efforts. Rather than expanding exemptions to fill or drain wetlands, policies should focus on the restoration and enhancement of wetlands to reap the ecosystem services they provide. Additionally, we suggest that the value and wetland restoration potential of Class III wetlands not be underestimated. We also suggest that opportunities be explored to utilize state funds as a non-federal match for other federal grant programs that can support floodplain restoration, such as the Pre-Disaster Mitigation Grant Program and the Hazard Mitigation Grant Program, administered through state emergency management agencies.

6. Engage with public stakeholders to commit to clean water and healthy ecosystem goals

We recommend that the Task Force identify and engage critical public stakeholder groups; a socio-ecological approach would be beneficial. For example, the use of focus groups or surveys could inform ecological recommendations and decisions.

We encourage the IJC and CSAG to expand public outreach efforts to citizens and groups like ours about the study. We did not receive a press release or copy of the draft report, though we read about it in the press. We'd be happy to provide a list of organizations that could be contacted if there is another opportunity to provide comments before release of the final report in 2020.

Thank you for your consideration of our comments. We welcome the opportunity to further discuss them with you.

Sincerely,

Lauren Sopher
Director of Science & Water Programs, Lake Champlain Committee

Lori Fisher
Executive Director, Lake Champlain Committee

A3.2 Public meeting: Venise-en-Québec, Québec

Summary of the Public Meeting Comment Themes

- Outreach/Public Messaging in Canada
  - Many concerns were expressed about the lack of proper buffers, riparian zones, and enforcement.
  - Participants had worries about P reduction goals not being met, as well as the timeframe need to reach the goals and the treatment of sediments in the Bay.
  - There was much interest in the programs, funds and action of the MAPAQ and MELCC to reach the common management goals.
  - Inquiries were made about the last study on the Alburgh-Swanton Causeway removal.

A3.3 Public meeting: St. Albans, Vermont

Summary of Public Meeting Comment Themes

- Outreach/Public Messaging in the United States
  - Concern was expressed that the messages are not effectively getting out to the general public.
  - Attendees commented on the lack of participation in the meeting, especially as compared to the Québec meeting the night before.
  - Emphasis was made that the timing of outreach in Vermont is critical to garner participation, as the population fluctuates with the season.
  - Discussion also included the need to modernize outreach methods to ensure connection with younger generations.
  - There is a need to create opportunities for bi-national coordination at the citizen level, specifically relating to farmers.
- Effectiveness of management efforts/phosphorus reduction
  - Discussion focused on whether we have data to demonstrate that the efforts being made are starting to make a change. It was shared that large scale trends can be difficult to recognize, but that a small scale (e.g., individual rivers, streams) projects are demonstrating successes.
- Agriculture
  - VT has been working to implement BMPs, and is seeing a significant rate in adoption by farmers.
  - An attendant expressed that more research is needed to understand the corn-soy high P runoff ratio that was shown in a graph during the presentation.

Study of nutrient loading and impacts in Lake Memphremagog

Presented by
Memphremagog Study Advisory Group (MSAG)

For
International Joint Commission

January 19th, 2020

Study of nutrient loading and impacts in Lake Memphremagog

Front picture: Photohelico

Study written and coordinated by:

Kendall Lambert, Administrative Director, Memphremagog Watershed Association (MWA) &
Ariane Orjikh, General Manager, Memphremagog Conservation Inc. (MCI)

Study guided by the Memphremagog Study Advisory Group (MSAG)

Initial MSAG members:

CAD MSAG Members	US MSAG Members
Sébastien Bourget *Environmental Scientist, Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)*	Ben Copans *Watershed Coordinator, Vermont Department of Environmental Conservation, Watershed Management Division, (VDEC)*
Alain Gagnon *Agroenvironmental and Water Quality Advisor, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ)*	Frank Maloney *Planner, Northeastern Vermont Development Association (NVDA)*
Julie Grenier (MSAG Co-chair) *Project Coordinator, Conseil de gouvernance de l'eau des bassins versants de la rivière Saint-François (COGESAF)*	Mark Mitchell *Environmental Scientist, Vermont Department of Environmental Conservation, Lakes and Ponds Program (VDEC)*
Daniel Leblanc *Estrie and Montérégie Regional Director, Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)*	Perry Thomas (MSAG Co-chair) *Program Manager, Vermont Department of Environmental Conservation, Lakes and Ponds Management and Protection Program (VDEC)*
Alexandra Roy *Formerly Project Coordinator in sustainable Development, Municipalité régionale de comté (MRC) de Memphrémagog, and then, Constituency Office Manager and Political Attaché, Orford's County, Quebec National Assembly*	Beth Torpey *Professor Community College of Vermont, Board Member, Memphremagog Watershed Association (MWA)*
Serge Villeneuve *Ecology and Water Principal Analyst, Environment and Climate Change Canada (ECCC)*	Bruce Urie *Regional Stewardship Manager Vermont Land Trust (VLT)*

Due to changes in staffing and availability during the project period, Alain Gagnon, Daniel Leblanc, and Perry Thomas were unable to participate until the end of the project. In summer 2019, Mikael Guillou from the Directorate of Agri-environmental practices, MAPAQ, Nathalie Provost, General Manager of Analysis and Expertise, MELCC, and Peter Laflamme, Director of the Watershed Management Division of VDEC, joined the MSAG. Ben Copans, VDEC, took the role of Co-Chair at that time.

These individuals served in their professional capacity and possess the expertise and key knowledge necessary to the development of the report.

Executive Summary

In October 2017, the International Joint Commission (IJC) received a reference from the Governments of Canada and United States asking to identify the range of nutrient loading issues that are of concern in the Lake Memphremagog Basin and make recommendations on how current efforts can be strengthened. The public is concerned about phosphorus levels and proliferation of algal blooms in Lake Memphremagog that can adversely affect human health, ecosystems, and recreational and tourism activities on both side of the border. This binational study provides a portrait of the current state of the Memphremagog watershed (Chapter 2), review of current management efforts (Chapter 3), a science and policy analysis (Chapter 4), suggestions for initiatives coming from networking with key stakeholders (Chapter 5) and recommendations on ways to consolidate and improve binational current efforts geared to reduce concentrations of nutrients, and the proliferation of aquatic plants and cyanobacteria that they cause in Lake Memphremagog (Chapter 6). This study was written and coordinated by the Memphremagog Watershed Association and Memphremagog Conservation Inc. under the guidance of the Memphremagog Study Advisory Group made up of 12 local members. To complete the study and make recommendations, a literature review, a networking survey and a binational Science and Policy workshop were completed, and associated reports were produced.

The conclusion of this study is clear: it is imperative that swift and decisive action is taken to reduce nutrient loading throughout the watershed to reduce nutrient concentrations and the frequency and severity of harmful algal blooms (HABs) in Lake Memphremagog. Although many efforts in both Quebec and Vermont are currently underway to achieve this goal, the science and policy analysis, and networking survey results presented in this report show gaps and opportunities for additional work and programs. Further, due to the effects of climate change and the current state of the watershed, there is an urgency to act immediately and in a binational manner to offset future impacts, prevent further degradation, and move towards improvement of water quality of the lake.

Summary of water quality concerns and current programs

Lake Memphremagog covers an area of 97 km^2, of which three quarters is in Quebec and one quarter in Vermont. Lake Memphremagog is a source of drinking water for approximate 175,000 Canadians and is used for a variety of human activities including swimming, boating, and fishing that attract a large number of tourists and locals. These uses are limited by elevated nutrient levels in the lake and resulting cyanobacteria blooms, 156 of which have been reported between 2006 and 2018.

While it is difficult to measure the other impacts of nutrient loading on Lake Memphremagog, they can have several effects, such as the decrease in biodiversity and changes in species; the increase in plant and animal biomass; the increase in water turbidity and organic matter leading to high sedimentation; and the development of anoxic conditions. These effects may adversely affect human health and the local economy, including the quality or the treatment of potable water, the aesthetic and recreational value of the lake; navigation; and the presence of fish species of recreational sport interest.

The phosphorus concentrations and water quality of Lake Memphremagog vary along its geography. The lake is considered oligo-mesotrophic according to total phosphorus concentrations. Chlorophyll-a concentrations suggest the lake is mesotrophic in the southern half of the lake and oligo-mesotrophic in the northern half of the lake meaning that nutrient levels are moderate in the southern lake and decrease in the northern portion of the lake. Fitch Bay and South Bay are isolated and distinct sections of the lake and are considered eutrophic with high levels of nutrients and frequent algal blooms. Phosphorus levels measured in Vermont have averaged 18 μg/L, exceeding the water quality standard of 14 μg/L. Water quality indicators suggest nutrient levels in the lake have been stable for the last 20 years, but it is predicted that climate change will increase nutrient loading and algal blooms in the lakes of the region. As such, there is immediate need to develop binational solutions to control nutrient loading to reduce current cyanobacteria blooms and prepare for a changing climate across the lake Memphremagog watershed which covers an area of 1,779 km2, 71% of which is in Vermont and 29% in Quebec.

In Quebec, several stakeholders are working to reduce nutrient loading in Lake Memphremagog. The Government of Quebec is mainly responsible for the water resource management, implementing an integrated management of water resources by watershed, and recognizing the Saint-Francis River Watershed Governance Committee (COGESAF) for the implementation of an action plan in the St-Francis integrated water management zone, which includes the Memphremagog watershed. The Memphremagog Regional County Municipality (MRC Memphremagog) is responsible for the establishment of guidelines for the territory management. Municipalities have an important role to play, regulating land development and activities through permits and regulations, and adopting non-regulatory measures and on-the-ground projects. Several initiatives and on-the-ground projects are also taken by non-profit organizations, such as Memphremagog Conservation Inc. (MCI).

In Vermont, nutrient load reduction efforts are supported through partnerships between State and Federal agencies, local organizations, municipalities, and landowners. This work is guided by a phosphorus budget for the lake, called a Total Maximum Daily Load, that sets a 29% phosphorus load reduction target for the Vermont portions of the watershed. Strategies to achieve this goal are outlined in a tactical basin plan, which will be updated on a five-year cycle and will track progress in meeting the phosphorus reduction target. State regulations and funding to support phosphorus reduction efforts across all source sectors were included in Act 64 (2015) and Act 76 (2019). Local organizations have developed partnerships to guide these efforts including a Memphremagog specific stormwater collaborative and Regional Conservation Partnership Programs targeting agricultural lands.

The Science and Policy Analysis presented in Chapter 4, concluded that reducing nutrient loading in Lake Memphremagog will require careful planning and understanding of current state of water quality, areas of concern, and reduction targets. Also, although there are several efforts and projects underway to increase best management practice (BMP) installation to reduce nutrient loading, widespread adoption of BMPs, monitoring, and investment in clean water projects must be strengthened to reduce nutrient loading. The Quebec Vermont Steering Committee is an established leadership group for the Memphremagog Watershed that provides a binational forum for the presentation of materials and in-depth analyses, and for environmental collaboration within the watershed.

The recommendations for a binational approach to reduce the nutrient loads causing the proliferation of cyanobacteria in Lake Memphremagog are:

1. Establish watershed nutrient loading reduction goals through a binational watershed model;
2. Adopt and expand practical solutions to reduce nutrient loading by land use type through the installation of BMPs, monitoring, and investment in clean water projects:
   - 2.1. Agriculture – Adopt widespread on-farm BMPs supported by resources for implementation and direct service providers;
   - 2.2. Developed Lands – Adopt BMPs and stormwater regulations for new development projects and increased implementation of retrofit projects for existing development;
   - 2.3. Natural Lands – Identify priority conservation areas that protect essential ecological services provided by natural lands in the watershed and implement programs and provide incentives to conserve and restore these lands;
   - 2.4. To support all practical solutions on all land use types, it is further recommended that the following are incorporated into each recommendation:
     - a) Incorporate climate change impacts into all decision-making in order to ensure nutrient loading targets are met and investments in BMPs are long-term and that finite resources are used effectively.
     - b) Conduct an analysis of existing enforcement of regulation to determine if there are gaps in enforcement areas, and to develop a plan to address gaps and identify opportunities for improvement.
     - c) In order to enforce regulation, it is recommended that state and provincial agencies and those invested with enforcement authority are provided with increased resources and more effectively target enforcement systems to reach this goal.
     - d) Focus funding initiatives from state, provincial, and federal sources on achieving the binational goals developed from these recommendations.
     - e) Incorporate education and awareness to all projects to ensure that more BMPs are implemented, to ensure local, state/provincial and federal by-in, and additional participation in projects.
3. Strengthen the cooperation through Quebec Vermont Steering Committee to implement a long-term strategy

These recommendations are more fully described in Chapter 6.

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List of Acronyms

ACA	Appalachian Corridor Appalachien
AFSQ	Association forestière du sud du Québec / Southern Quebec Forestry Association
AMFE	Agence de mise en valeur de la forêt privée de l'Estrie / Agency for the Enhancement of the Private Forest of Estrie
AMP	Acceptable Management Practices for forestry (VT)
APLS	Association des propriétaires du lac des Sitelles / Lake des Sitelles property owners Association
ARDBLM	Association pour la revitalisation du delta et des Baies du lac Memphrémagog/ Association for the revitalization of the Lake Memphremagog delta and bays
BMP	Best Management Practice
CAEE	Club agroenvironmental de l'Estrie / Agroenvironmental Club of Estrie
CCAE	Clubs-conseils en agroenvironnement / Agro-Environment Advisory Clubs
Chla	Chlorophyll-a
COGESAF	Conseil de gouvernance de l'eau des bassins versants de la rivière Saint-François / Saint-Francois Watershed Steering Committee
CWA	Clean Water Act (US)
CWSRF	Clean Water State Revolving Fund (VT)
CWSP	Clean Water Service Provider (VT)
DOS	United States Department of State
ECCC	Environment and Climate Change Canada
EPA	United States Environment Protection Agency
EQIP	Environmental Quality Incentives Program (US)
FAP	Farm Agronomics Program (VT)
FFQ	Fondation de la Faune du Québec / Quebec Wildlife Foundation
FRFCE	Fiducie de recherche sur la forêt des Cantons-de-l'Est / Forest Research Trust of Eastern Townships
GAS	Global Affairs Canada
GLFC	Great Lakes Fisheries Commission (US)
GSI	Green Stormwater Infrastructure
HAB	Harmful algal bloom
IJC	International Joint Commission
IRDA	Institut de recherche et de développement en agroenvironnement / Agroenvironmental Rechearch and Development Institute
LAMRAC	Association du Marais-de-la Rivière-aux-Cerises
LQE	Loi sur la qualité de l'environnement / Environment Quality Act
MAMOT	Ministère des Affaires municipales et de l'Occupation du territoire / Ministry of Municipal Affairs and Land Occupancy

MAMH	Ministère des Affaires municipales et de l'Habitation/ Ministry of Municipal Affairs and Housing
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec / Ministry of Agriculture, Fisheries and Food of Quebec
MCI	Memphremagog Conservation inc.
MELCC	Ministère de l'Environment et de la Lutte contre les changements climatiques / Ministry of Environment and Fight against Climate Change
MERN	Ministère de l'Énergie et des Ressources naturelles / Ministry of Energy and Natural Resources
MFFP	Ministère des Forêts, Faune et Parcs / Ministry of Forests, Wildlife and Parks
MRC	Municipalité régionale de comté / Regional County Municipality
MRGP	Municipal Roads General Permit (VT)
MSAG	Memphremagog Study Advisory Group
MSSS	Ministère de la Santé et des Services sociaux / Ministry of Health and Social Services
MTQ	Ministère des Transports du Québec / Ministry of Transport of Quebec
mT/y	Metric tons per year
MWA	Memphremagog Watershed Association
MWF	Memphremagog Wetlands Foundation
NEWSVT	New England Waste Services of Vermont, Inc.
NMP	Nutrient Management Plan
NPDES	National Pollutant Discharge Elimination System Permit (US)
NRCD	Natural Resources Conservation District
NRCS	Natural Resources Conservation Service
NVDA	Northeastern Vermont Development Association
NWSC	NorthWoods Stewardship Center
OBV	Organisme de bassin versant / Watershed organization
OER	Objectifs environnementaux de rejets / Environmental Discharge Objectives
PAA	Plan d'accompagnement agroenvironnemental/ Agro-environmental support plan
PDE	Plan directeur de l'eau / Water Master Plan
PRMHH	Plan régional des milieux humides et hydriques / Regional Wetlands and Bodies of Water Plan
RAPPEL	Regroupement des Associations pour la Protection de l'Environnement des Lacs et des bassins versants / Regrouping of Associations for the Protection of Environment of Lakes and Watersheds
RAPs	Required Agricultural Practices (VT)
RCPP	Regional Conservation Partnership Program
REA	Règlement sur les exploitations agricoles / Agricultural Operations Regulation
REI	Road erosion inventory
RSVL	Réseau de surveillance volontaire des lacs / Volunteer Lake Monitoring Network

SAD	Schéma d'aménagement et de développement / Land Use Planning and Development Plan
SCLL	Société de Conservation du lac Lovering / Lake Lovering Conservation Society
SEPAQ	Société des établissements de plein air du Québec
SGA	Stream Geomorphic Assessment (VT)
SQE	Stratégie québécoise de l'eau / Quebec Water Strategy
SWC	Memphremagog Stormwater Collaborative
TBP	Tactical Basin Plan (VT)
TMDL	Total Maximum Daily Load (US)
TP	Total Phosphorus
UPA	Union des producteurs agricoles / Agricultural Producers Union
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UQAM	Université du Québec à Montréal / Quebec University in Montreal
VAAFM	Vermont Agency of Agriculture, Food, & Markets
VANR	Vermont Agency of Natural Resources
VDEC	Vermont Department of Environmental Conservation
VDH	Vermont Department of Health
VFPR	Vermont Department of Forest, Parks, and Recreation
VFWD	Vermont Fish and Wildlife Department
VLMP	Vermont Lay Monitoring Program
VLT	Vermont Land Trust
VTrans	Vermont Agency of Transportation
WCA	Watersheds Consulting Associates
WWTF	Wastewater Treatment Facilities

Chapter 1
Introduction

1.1. Project Background

The International Joint Commission (IJC) is an international organization guided by the Boundary Waters Treaty signed by Canada and the United States in 1909. The treaty provides general principles for preventing and resolving disputes over waters shared between the two countries and for settling other transboundary issues. The IJC studies and recommends solutions to transboundary issues when asked to do so by the national governments. When the IJC receives a government request, called a reference, it appoints a board with equal numbers of experts from each country (IJC, 2018).

On October 19, 2017, the IJC received a reference from Global Affairs Canada (GAC) and the U.S. Department of State (DOS) regarding water quality in “Lakes Champlain and Memphremagog”. The reference asked to the IJC to identify the range of nutrient loading issues that are of concern in the Lake Memphremagog Basin and make recommendations on how current efforts can be strengthened (Global Affairs Canada, 2017; United States Department of State, 2017). It should be noted that concerns regarding the environmental impact of the New England Waste Services of Vermont, Inc. (NEWSVT) landfill in Coventry were raised by the public during the course of the study. As with other industry, phosphorus loading from the landfill is represented within loading estimates presented in the report. As this reference is focused solely on nutrient loading, a broader analysis of the landfill and other impacts on Lake Memphremagog is outside of the scope of this reference.

The IJC developed an initial work plan for the Lake Memphremagog portion of the reference on February 19, 2018. Soon thereafter, the IJC contracted with the basin organizations Memphremagog Conservation Inc. (MCI) from Magog, Quebec, and the Memphremagog Watershed Association (MWA) from Newport, Vermont, to examine current programs and measures that address elevated nutrient levels and algal blooms, and to assist the IJC in making recommendations on how to strengthen these efforts.

Initially, MCI and MWA were to submit the final report on July 19th, 2019 to the IJC, to be released by the IJC on October 19th, 2019. However, due to the United States government shut down starting in December 2018 and going into January 2019, the project was delayed. On March 1st, 2019, the IJC granted the study a 6-month extension, with MCI and MWA submitting the final report to the IJC on January 19th, 2020.

1.2. Study Approach

At the beginning of the project period, the Basin Organizations worked closely with the IJC to establish a Memphremagog Study Advisory Group (MSAG). This group met and provided feedback and guidance on the report and process throughout the project period. The initial MSAG members were:

CAD MSAG Members	US MSAG Members
Sébastien Bourget, Environmental Scientist, Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)	**Ben Copans**, Watershed Coordinator, Vermont Department of Environmental Conservation, Watershed Management Division, (VDEC)
Alain Gagnon, Agroenvironmental and Water Quality Advisor, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ)	**Frank Maloney**, Planner, Northeastern Vermont Development Association (NVDA)
Julie Grenier, Project Coordinator, Conseil de gouvernance de l'eau des bassins versants de la rivière Saint-François (COGESAF)	**Mark Mitchell**, Environmental Scientist, Vermont Department of Environmental Conservation, Lakes and Ponds Program (VDEC)
Daniel Leblanc, Estrie and Montérégie Regional Director, Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)	**Perry Thomas**, Program Manager, Vermont Department of Environmental Conservation, Lakes and Ponds Management and Protection Program (VDEC)
Alexandra Roy, Formerly Project Coordinator in sustainable Development, Municipalité régionale de comté (MRC) de Memphrémagog, and then, Constituency Office Manager and Political Attaché, Orford's Constituency, Quebec National Assembly	**Beth Torpey,** Professor Community College of Vermont, Board Member, Memphremagog Watershed Association (MWA)
Serge Villeneuve, Ecology and Water Principal Analyst, Environment and Climate Change Canada (ECCC)	**Bruce Urie**, Regional Stewardship Manager Vermont Land Trust (VLT)

Julie Grenier and Perry Thomas were elected by the MSAG to serve as co-chairs. Due to changes in staffing and availability during the project period, Alain Gagnon, Daniel Leblanc, and Perry Thomas were unable to participate until the end of the project. In June of 2019, Mikael Guillou from the Directorate of Agri-environmental practices, MAPAQ, and Nathalie Provost, General Manager of Analysis and Expertise, MELCC, joined the MSAG. Peter Laflamme, Director of the Watershed Management Division of VDEC, formally replaced Perry Thomas in July of 2019, with Ben Copans, VDEC, taking on the role of Co-Chair at that time.

To produce this report, the Basin Organizations and the MSAG worked together to:

1. Produce a literature review of current science, policy, and best management practices in the watershed to understand the current state of nutrient loading and impacts, as well as current efforts to reduce nutrient loading (Chapters 2 and 3)
2. Network with key stakeholders by creating a stakeholder survey. This was sent to key experts in the watershed to understand opinions, challenges, current efforts, and possible improvements regarding nutrient loading. Results from the survey were compiled in a separate Networking Report and used as primary research, in the analysis, and to develop suggestions presented in the Memphremagog Report.
3. Provide an analysis of current science and policy regarding nutrient loading (Chapter 4).
4. Develop suggestions by country (Chapter 5) and binational recommendations (Chapter 6) to strengthen current efforts to reduce nutrient loading.

On September 20th, 2019, a binational science and policy workshop was held in Newport, Vermont with experts from both countries. The experts were asked to review parts of the preliminary report in advance of the workshop. At the workshop, attendees provided feedback on the draft recommendations, as well as other report sections as needed. This feedback is presented in a separate Workshop Report and was incorporated into the final report, which was put online in November, 2019 for a 30 day public comment period.

Twelve public comments were received by the basin organizations via email during the public comment period. Comments were reviewed and discussed by the MSAG in January 2020 to decide whether or not to integrate them into the report. Many of comments were accepted; however, comments and responses will not be published in this report due to privacy concerns. Individuals interested in the response to his/her specific comment may contact the basin organizations. The report was sent in January 2020 to IJC to review and revise over a three-month period.

Chapter 2 Summary

Memphremagog Watershed Overview

The headwaters of the Memphremagog Watershed are located in Northeast Kingdom of Vermont, USA (Figure 1). The water flows north into the Estrie region in Quebec, CAN. Lake Memphremagog is an international body of water. The watershed is a subwatershed of the St. Francis river watershed, which eventually flows into the St. Lawrence River and out to the Atlantic Ocean.

General Watershed Facts

- Total drainage area: 1,779 km^2
    - 71% of drainage area is in VT
    - 29% of drainage area in QC
- Major tributaries:
    - Black River (VT)
    - Clyde River (VT)
    - Barton River (VT)
    - Johns River (VT)
    - Castle River (QC)
    - Cherry River (QC)
    - Fitch Brook (QC)
- Lake Memphremagog is the largest lake in the watershed and covers an area of approximate 97 km^2. It is also a source of drinking water for approximate 175,000 Canadians.

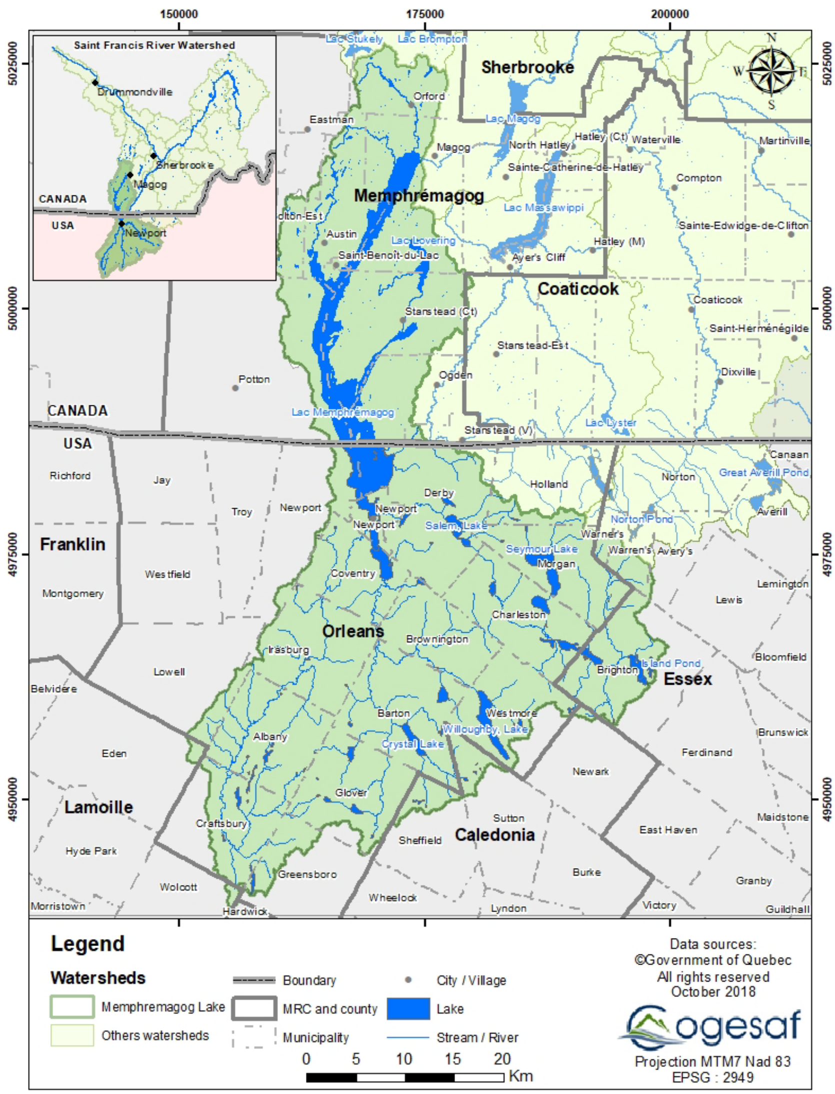


Figure S2-1 Lake Memphremagog Watershed

Activities in the Watershed

Lake Memphremagog and the lakes, ponds, and tributaries of the watershed are used for a variety of human activities including swimming, boating, and fishing. The wide range of recreational activities available attracts a large number of tourists and locals alike every year, making it a major tourist draw in the Eastern Townships in Quebec and the Northeast Kingdom of Vermont.

Land Use

The majority of land cover in the Memphremagog Watershed in both Quebec and Vermont is natural lands which includes forest and water/wetland (Figure 2). 78% of the land in Vermont is natural lands or 982 km^2 and 82% of the land in Quebec or 421 km^2. Agriculture is also a significant land use in Vermont, comprising 17% or 217 km^2 of the Vermont watershed. This is compared to 10% or 49 km^2 of the Quebec watershed. The developed lands, including paved and dirt roads, account for 5% of 69 km^2 of the land in Vermont and 8% or 41 km^2 in Quebec.

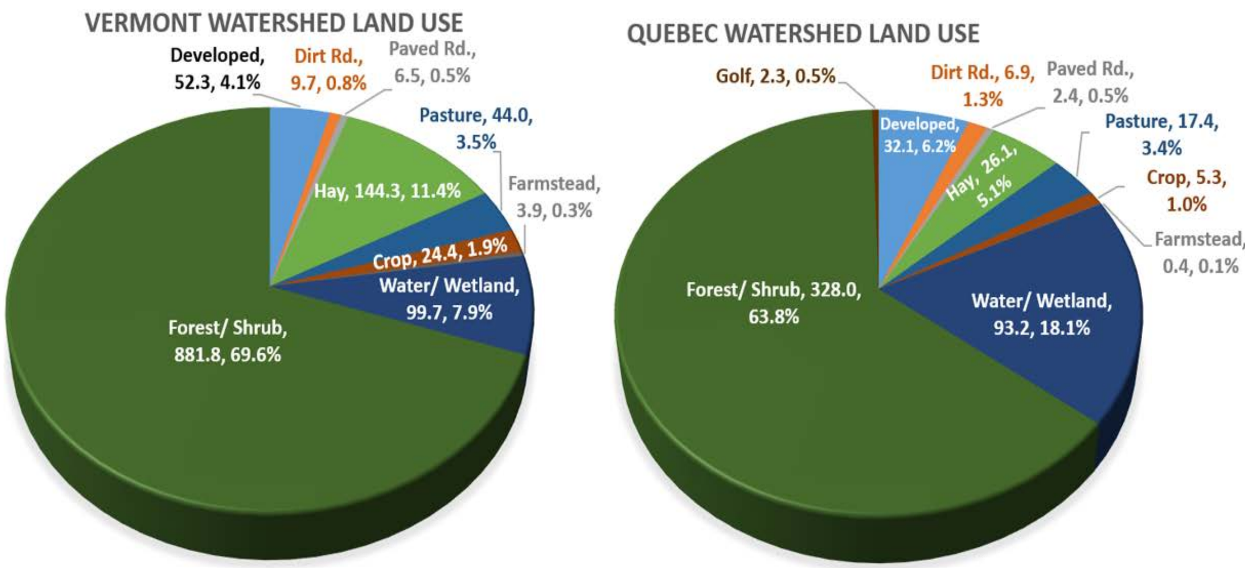


Figure S2-2 Vermont and Quebec Watershed land use in km^2 and percent land cover

Lake Memphremagog Water Quality Data

The Ministry of the Environment and the Fight against Climate Change of Quebec (MELCC) has monitored the water quality of Lake Memphremagog at 10 stations covering all areas of the lake since the early 2000s. According to the trophic status classification chart used by the MELCC, the lake is globally at an oligo-mesotrophic level according to the total phosphorus concentration, whereas according to the indicator of algal biomass, the chlorophyll-a concentration, it is situated at the mesotrophic level in the southern half of the lake and at the oligo-mesotrophic level in the northern half of the lake. Fitch Bay, which is an isolated and distinct section of the lake, shows a more advanced state of eutrophication. Subject to the uncertainty regarding representativeness of historical data, the phosphorus concentration would have been stable at the majority of the lake stations since the start of the monitoring program, although there is a slight decrease when aggregating the stations. On the other hand, the chlorophyll concentration shows stability at all stations and for the lake as a whole over the same period. The water quality indicators suggest that the lake situation has been stable for almost 20 years. The results for Quebec and Vermont are consistent in this respect.

The Vermont Lay Monitoring program (VLMP) has sampled for total phosphorus concentrations on Lake Memphremagog since 1985. Total phosphorus trends have been statistically stable since then. 2018 Lake Score card data indicates that total phosphorus on the main lake in Vermont during the 2018 summer was 19.1 μg/L, with total phosphorus in South Bay in the 2018 spring was 20.2 μg/L and 2018 summer 22.6 μg/L. The standard for total phosphorus in a lake set by the Vermont Department of Environmental Conservation (VDEC) is 14 ug/l for the main lake and 25 μg/L for the South Bay segment. Water quality standards for the main lake and South Bay in Vermont are different based on the characteristics of the lake segment, including the depth and mixing. Tributary monitoring data from Vermont has identified several areas with elevated mean phosphorus concentrations which are target areas for water quality improvement efforts. Average total nitrogen concentrations from over 980 samples from 2005 through 2018 in the lake in Vermont were 0.31 mg/L. These nitrogen levels are generally considered low.

Memphremagog Watershed Phosphorus Loading Estimates

Due to elevated concentrations of phosphorus in the US portion of the main lake, VDEC was required to set a Total Maximum Daily Load (TMDL) for phosphorus. To set a TMDL, VDEC used a land use export model to estimate the amount of phosphorus loading, and then recommended reductions on the Vermont portion of the watershed to meet our clean water goals. The TMDL was finalized by VDEC and approved by the US Environmental Protection Agency in 2017. Although this study focused on Vermont, it does provide an estimate of phosphorus loading from both countries and is the best data currently available (VDEC, 2017d).

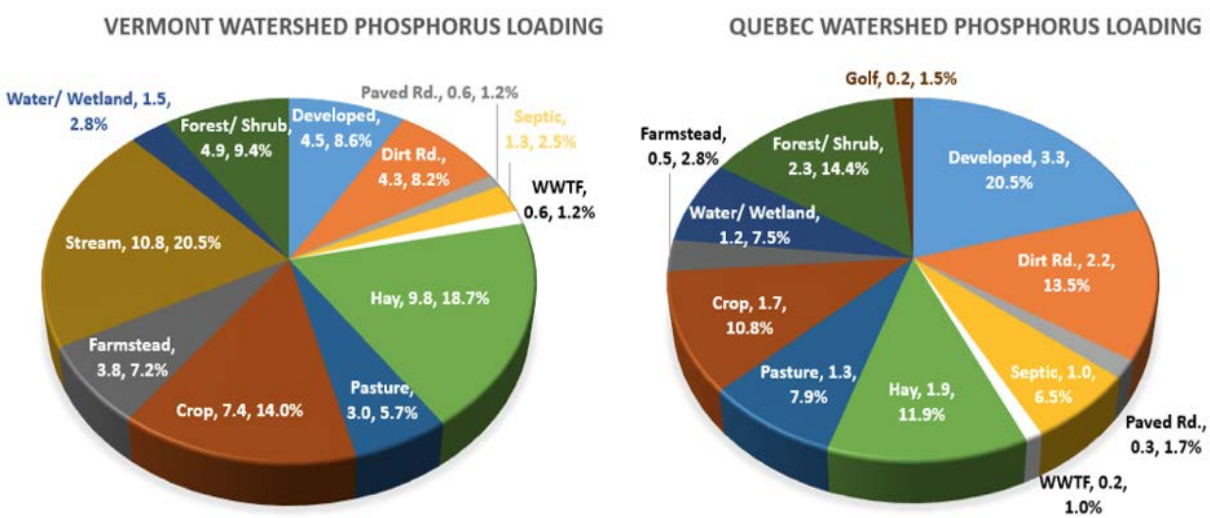


Figure S2-3 Estimated phosphorus loading by land use type to Lake Memphremagog in metric tons per year (mT/y) and percent loading

Impacts of phosphorus loading on water quality

Cyanobacteria, also known as "blue-green algae", are aquatic prokaryotes that under the right conditions can form blooms, which refer to the result of a massive proliferation phase, resulting in a significant appearance of biomass (Figure 4). Some species are capable of producing toxic compounds known as cyanotoxins. The contact, the ingestion or the inhalation of cyanobacteria can be harmful to human or animal health.

Between 2006 and 2018, 145 cyanobacteria blooms were reported by citizens, organizations or municipalities to the MELCC on the Quebec side of Lake Memphremagog. Between 2006-2017 there were 11 observations of cyanobacteria blooms made by Cyanobacteria Volunteer Monitors on the Vermont portion of Lake Memphremagog.

Figure S2-4 Cyanobacteria Bloom in Lake Memphremagog
Photo Credit: MCI

Other potential effects:

- Increased aquatic plant growth
- Increased cost for the treatment of drinking water
- Decrease in aesthetic and recreational value of the lake
- Fish species of recreational sport interest may disappear
- Decrease of property values

Chapter 2

Description of Lake Memphremagog and its watershed

2.1. Overview of Lake Memphremagog Watershed

2.1.1. Location and surface area of the watershed

The Lake Memphremagog Watershed drainage area is 1,779 square kilometers (km^2) (687 square miles (mi^2)). 71% of the drainage area is in Vermont and 29% is in Quebec (VDEC, 2017a). The water flows from the Northeast Kingdom of Vermont, northward to the Estrie region in Quebec. The watershed is a subwatershed of the St. Francis River Watershed, which flows into the St. Lawrence River (Figure 2-1) and into the Atlantic Ocean.

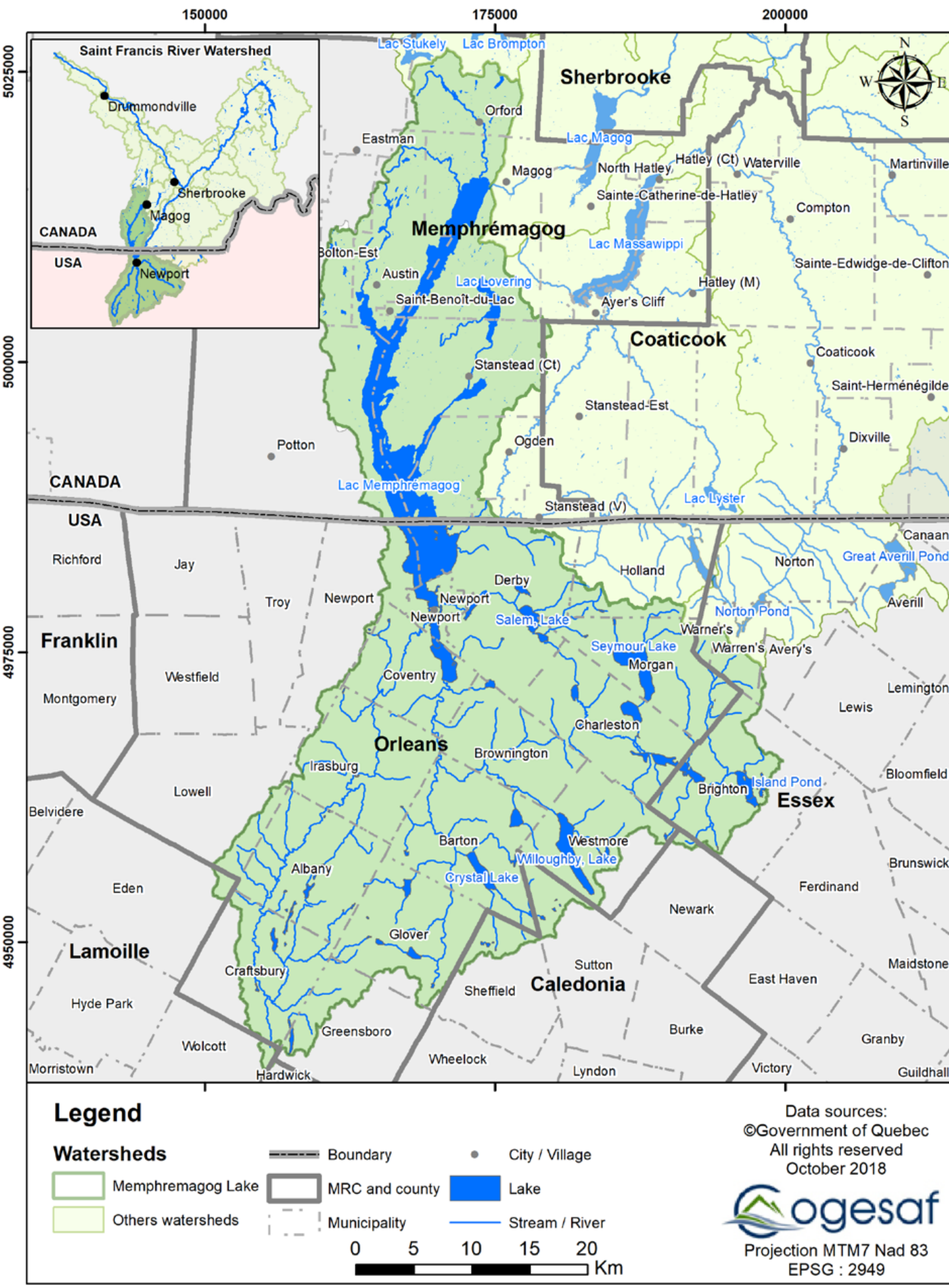


Figure 2-1. Lake Memphremagog Watershed

2.1.2. Hydrology and geomorphology

The largest lake in the watershed, Lake Memphremagog covers an area of approximately 97 km^2 (37mi^2) with a watershed to lake area ratio of 18 (VDEC, 2017b). The lake crosses the US/Canadian border, with three quarters of its area in Quebec and one quarter in Vermont. Water from Lake Memphremagog flows out through the Magog River, Quebec. The average lake depth is 20 m (65.5 ft) and the maximum depth is 107 m (351.1ft; VDEC, 2017b; see Appendix 2-1). The average residence time of the water in Lake Memphremagog from 2009-2012 was 1.65 years (VDEC, 2017b).

The water level of Lake Memphremagog is influenced by the Memphremagog Dam located on the Magog River in Magog, Quebec. In effort to manage water levels of the lake, an international agreement was ratified in 1935 that sets principles governing the outflow of water from the dam (United States, 2019). Water level monitoring by the US Geological Survey and Environment and Climate Change Canada show that the lake is generally kept at 207-208 m (680 to 684 ft). Figure 2-2 shows the target lake level for the City of Magog in red, with the actual lake level in 2018 in black, and target upper elevation in blue.

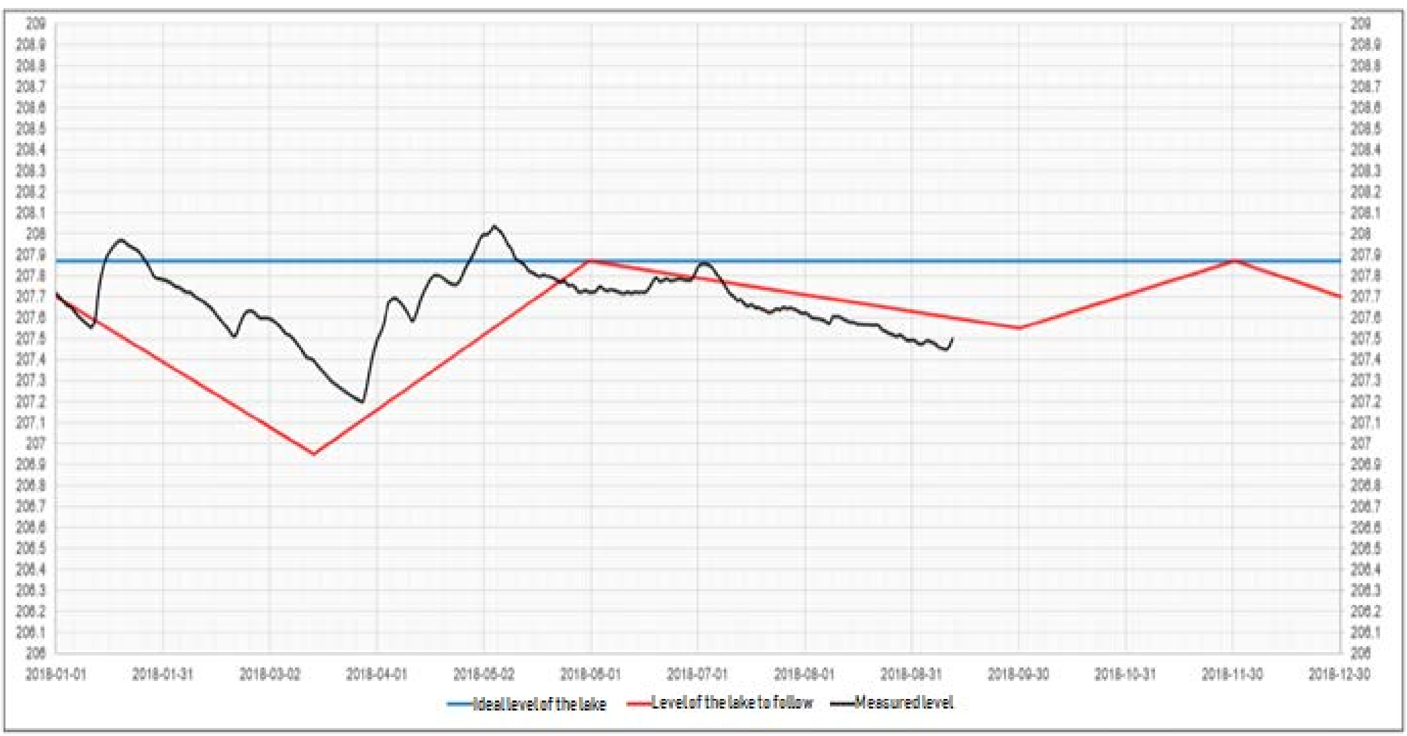


Figure 2-2. Water levels of Lake Memphremagog
Source: Magog, 2018a.

There are three major rivers which drain into Lake Memphremagog, the Clyde, Black, and Barton Rivers, all located in Vermont. The John's River, a smaller tributary which follows the Quebec/Vermont border also drains in from the Vermont side. In Quebec, the main tributaries are the Castle River, the Cherry River, and Fitch Brook. There are additional lakes, ponds, and over one hundred streams in the watershed of various size that feed Lake Memphremagog (MCI, 2011a).

The flows of the tributaries were estimated for the 2017 Lake Memphremagog Phosphorus Total Maximum Daily Load (TMDL). The complete methodology for flow estimation is found in the modeling documentation for the Lake Memphremagog TMDL (VDEC, 2017b).

2.1.3. Topography, Geography, and Soil

Lake Memphremagog formed approximately 12,000 years ago as a glacial ice sheet melted and receded northward. Current land formations including many lakes and ponds are a result of the last glacial event. Glacial till and exposed bedrock are found in upland areas, while alluvial and lake deposits are found in the valleys (Dyer *et al*., 2011; Stewart & MacClintock, 1969).

Geologically, the watershed lies on the Waits River and Giles Mountain Formations. Most of the bedrock is metamorphosed limestone, schist, and phylite with deposits of marine organisms. This easily weathered bedrock rich in calcium provides highly fertile soils that have been colonized by dense northern hardwood forests. Soil types in this region are generally very productive and supportive for agriculture. In addition, there are significant granite deposits. For example, nearly 45% of the Clyde River sub-watershed has granite bedrock (Dyer *et al*., 2008).

Surficial geology in the Quebec portion of the watershed is characterized by soils formed from different types of till deposits, dotted of rocky lands at the north and at the west portions of the watershed, with some organic soils and other types of soils located around the watershed (IRDA, 2008a; 2008b, 2008c, 2008d, 2008e, 2008f). Surficial geology is similar for the upland areas of the Vermont portion of the watershed. However, large sandy deltaic and outwash deposits are found in Vermont along the Black and Willoughby Rivers, upper portions of the Barton and Clyde Rivers, and in areas surrounding Lake Memphremagog (Stewart & MacClintock, 1969).

Lake Memphremagog is at 208 m (682 ft) in elevation (Dyer *et al*., 2011). The Vermont portion of the watershed is relatively low in elevation, with the western side bordered by the Lowell Mountain range rising 773 m (2,535 ft) above sea level. In the southern side of the watershed, Bald Mountain, rising 1,010 m (3,315 ft) above sea level, is the highest point in elevation (Dyer *et al*., 2008).

According to the Ecological Reference Framework adopted by the government of Quebec (MDDEFP, 2013), Lake Memphremagog watershed is part of the Appalachian natural province. The western part of the Quebec portion of the watershed, included in the Green Mountains natural region, has a mountainous and hilly topography with slopes greater than 30% around the Mounts Orford, Giroux, Owl's Head, Elephant, Sugar Loaf's and Hog's Back areas (Appendix 2-2). The highest point is Mount Orford rising 853 m (2,798 ft) above sea level. The east side of the Quebec watershed, included in the Plateau d'Estrie-Beauce natural region, has a hilly topography and the Bunker Hill is the only major topographic element.

2.1.4. Climate

Northeastern Vermont and the Estrie have a variable climate with distinct seasons. Weather patterns are characterized by changeability, large temperature ranges both daily and annually, and significant differences in weather between the same season depending on the year. Daily temperatures and snowfall are affected by the altitude and specific area, while precipitation is equitable throughout the entire area. Frequent thunderstorms in the summer and large snowstorms in the winter are common. On average, the area receives 101 centimeters (cm) (39.9 inches (in)) of annual rain, 256cm (101in) of annual snow. Average summer high temperatures for July is 26° Celsius (C) (79° Fahrenheit (F)), with 12°C (55°F) for low, conversely, mid-winter averages for January are -4°C (24°F) for the high, and on average -16°C (3°F) for low temperatures (Vermont Weather, 2018).

2.1.5. Climate Change Impacts

Climate change is expected to continue to alter precipitation patterns and increase average temperatures in Vermont and Quebec. An increase in the frequency and intensity of storm events in Vermont and Quebec has already been observed (EPA, 2016; Ouranos, 2015). Average precipitation for the state of Vermont has increased by 2.5cm (1in) per decade between 1941 and 2014 (Galford *et al*., 2014). Similarly, average precipitation for the south of Quebec has increased by 2.5cm (1in) per decade between 1960 and 2013 (MDDELCC, 2015a). Precipitation increases have occurred mainly during the spring and fall events, while snow precipitation has decreased annually (Mekis & Vincent, 2011). According to the 2018 Hydroclimatic Atlas of Southern Quebec, the fall and summer flood peaks will probably continue to increase by the year 2050 (gouvernement du Québec, 2018a).

Average temperatures in Vermont have risen by 1.5°C (2.7°F) between 1941 and 2014, with 0.2°C (0.4°F) of that increase occurring between 2004-2014 alone (Galford *et al*., 2014). Average temperatures in the south of Quebec have also risen by 1.5 - 2.0°C (2.0 and 3.6°F) between 1961 and 2010 (MELCC, 2019a). The increasing average temperatures is causing milder winters and will likely continue the trend of converting winter snowfall to winter rain (Ouranos, 2015).

Climate change must be taken into account when developing management plans and recommendations to reduce nutrient loading in the Memphremagog watershed. An increase in the intensity of storm events will likely result in increased stormwater flows that can lead to flooding, riverbank instability, runoff, and increased pollution and nutrient loading (Xia *et al*., 2015). Additionally, warmer average annual temperatures are predicted and could lead to increased thermal stress on water bodies, potentially affecting the intensity and duration of algal blooms (VDEC, 2017a). Climate change may also prolong thermal stratification, potentially leading to a decrease in the dissolved oxygen concentration in the bottom water and an increase of phosphorus released from sediments (Xia *et al*., 2015). As such, the impact of climate change on future nutrient loading and algal blooms must be considered.

2.1.6. Administrative Boundaries, Population, and Demographics

In Vermont, the Lake Memphremagog Watershed spans Essex and Orleans counties. These counties are United States Department of Agriculture (USDA) designated rural areas. Newport City located at the southern end of Lake Memphremagog is the largest city in the Vermont portion of the watershed, and the most densely populated area with a population of 4,589 at the time of the 2010 US Census (Newport City, 2018). In Vermont, municipal, state, and federal policy can affect water quality and/or land use regulations.

Given that the watershed has different boundaries from town and county lines, an exact population estimate for the "watershed" was not calculated. Table 2-1 shows all Vermont municipalities that have land in the watershed with area of land in km^2 and percentage of each town in the watershed. Further, the table shows the full population of the town at the time of the last US Census (US Census, 2018). Newport City has the largest population and that is 100% in the watershed, followed by Derby, which is 93.7% in the watershed, and Barton, which is 100% in the watershed. The US census estimates that the population of Orleans County – which largely overlaps with the Lake Memphremagog watershed has dropped by 1.2% from April 1, 2010 and July 1, 2018.

Table 2-1. Vermont municipalities of Lake Memphremagog Watershed

Municipality name	**Population (2010 Census)**	**Percent of municipality in watershed**	**km^2 in watershed**
Averys Gore	0	3%	1
Newark	581	2%	2
Wolcott	1,676	2%	2
Eden	1,323	2%	4
Warners Grant	0	55%	5
Warren Gore	4	44%	12
Lowell	879	10%	14
Sheffield	703	19%	16
Holland	629	18%	18
Sutton	1,029	18%	18
Newport City	4,589	100%	20
Newport Town	1,594	22%	24
Greensboro	762	25%	25
Craftsbury	1,206	65%	67
Coventry	1,086	100%	72
Brownington	988	100%	73
Westmore	350	79%	77
Brighton	1,222	57%	80
Morgan	749	99%	87
Glover	1,122	92%	92

Charleston	1,023	100%	100
Albany	941	100%	101
Irasburg	1,163	97%	103
Barton	2,810	100%	115
Derby	4,621	94%	139

The counties which make up the watershed have the highest poverty rates in the state of Vermont. The average poverty rate from 2011-2015 for the state of Vermont was 11.5%, whereas the poverty rates for Essex and Orleans Counties were 15% and 15.5% respectively (Vermont State Data Center, 2017).

In Quebec, the Lake Memphremagog Watershed spans two federal districts, Brome-Missisquoi and Compton-Stanstead, one provincial district, Orford, and one administrative region, Estrie. There are 10 municipalities in the Quebec portion of the watershed with more than 1 km^2 in the watershed (Table 2-2). Almost all the municipalities are included in the Memphremagog regional county municipality (MRC), which is composed of 17 total municipalities. Only the municipality of Stanstead-Est, with around 2 km^2 in the watershed, is included in the Coaticook MRC.

Table 2-2. Canadian municipalities in the Lake Memphremagog Watershed

Canadian Municipalities	Population in 2016[1]	% of the municipality in the watershed[2]	km^2 in the watershed[2]
Saint-Benoit-du-lac	32	100%	2
Stanstead-Est	584	1.7%	2
City of Stanstead	2,788	14%	3
Bolton-Est	940	29%	23
Ogden	741	64%	48
Orford Township	4,337	35%	48
Potton Township	1,852	21%	55
Austin	1,485	96%	71
City of Magog	26,669	64%	92
Stanstead Township	1,036	96%	109

Source : [1]Statistiques Canada, 2018;
[2]MRC Memphremagog, 2018, unpublished data.

For the last fifty years, the permanent population of the MRC Memphremagog experienced constant growth, with an increase of 20.4 % from 2001 and 2016. The population growth for the MRC is higher than the Estrie and the Province of Quebec (MRC de Memphrémagog, 2018). From 2011 and 2036, it is predicted that the population will increase by 20.3% (MRC de Memphrémagog, 2018). The City of Magog is the largest city in the watershed, with an estimated population of 26,669 and a density of 184.6 people per km^2 (Statistiques Canada, 2018). In Quebec, municipal, regional county, provincial, and federal policy can affect water quality and/or land use regulations.

Low-income household rate of the MRC is lower than the provincial average and the Estrie. The average low-income rate from 2010-2014 for the Province of Quebec was 8.6% and 7.7% for the Estrie, whereas the low-income rates for the MRC was 6.5%, with a decrease each year (Institut de la statistique du Québec, 2017). In 2018-2019, the median price of a single-family home sold in the main municipalities of the Quebec portion of the watershed (which has more than 3 km^2 in in the watershed) was CAN$316,125 for Orford, CAN$277,000 for Austin, CAN$262,500 for Potton, CAN$242,618 for Magog, compared to CAN$ 255,000 in the Province of Quebec and CAN$195,500 in Estrie (Centris, 2019; data unavailable for Bolton-Est, Ogden and Stanstead Township).

2.1.7. Lake Uses

In Vermont, Lake Memphremagog is designated as a Class B(2) waterbody under the Vermont Water Quality Standards, 2016. This means that the lake is managed to support uses including swimming, boating, fishing, aquatic biota, aquatic habitat, aesthetics, drinking water source and irrigation.

In addition to its designation, Lake Memphremagog and the lakes, ponds, and tributaries of the watershed are used for a variety of human activities including swimming, boating, and fishing. The wide range of recreational activities available attracts a large number of tourists and locals alike every year, making it a major tourist draw in the Eastern Townships in Quebec and in Vermont.

In the Quebec side of Lake Memphremagog, there are six public beaches, five municipal boat launches, 27 marinas, and more than 4000 permanent boats, with more than 2000 motorboats (MRC Memphremagog, 2019, unpublished data; MCI, 2012). The majority of the marinas and boats are located in the Town of Magog, in the North of the Lake (MCI, 2012). Vermont has one public beach, one municipal boat launch, and three Fish and Wildlife (state owned) access points. Lake Memphremagog and the Clyde River are also a part of the Northern Forest Canoe Trail; a 1,190 km (740 mi) canoe trail spanning from Old Forge, New York to Fort Kent, Maine.

The watershed is home to many popular fishing destinations in both Quebec and Vermont. For the Eastern Townships, Lake Memphremagog is the most important fishing spot in the area (Roy, S., MFFP, 2018, pers. comm.). Although eleven species are commonly fished, the salmonids are the most economically valuable species.

Lake Memphremagog is a drinking water source for more than 175,000 people living mostly in the City of Sherbrooke, the City of Magog, the municipality of Potton, and the municipality of Saint-Benoit-du-Lac. Other private waterside residents in both Quebec and Vermont may take their drinking water directly from the lake. There is no public drinking water uptake on the Vermont portion of the lake.

2.1.8. Land Use

Figure 2-3 shows Vermont and Quebec watershed land use in km^2 and percent area. The majority of the watershed in both Vermont and Quebec is natural lands characterized by forest/shrub and water/wetland cover. Natural lands account for 78% (982 km^2) of the land in Vermont and 82% (421 km^2) of the land in Quebec. Agriculture is also a significant land use in Vermont, comprising 17% or 217 km^2 of the Vermont watershed. This is compared to 10% or 49 km^2 of the Quebec watershed. The developed lands, including paved and dirt roads, account for 5% (69 km^2) of the land in Vermont and 8% (41 km^2) in Quebec.

The map of Lake Memphremagog watershed land use is in Appendix 2-3. More details on how Vermont Department of Environmental Conservation (VDEC) calculated land use values are available online:
https://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Memph%20TMDL%20documentation%208-2-17.pdf

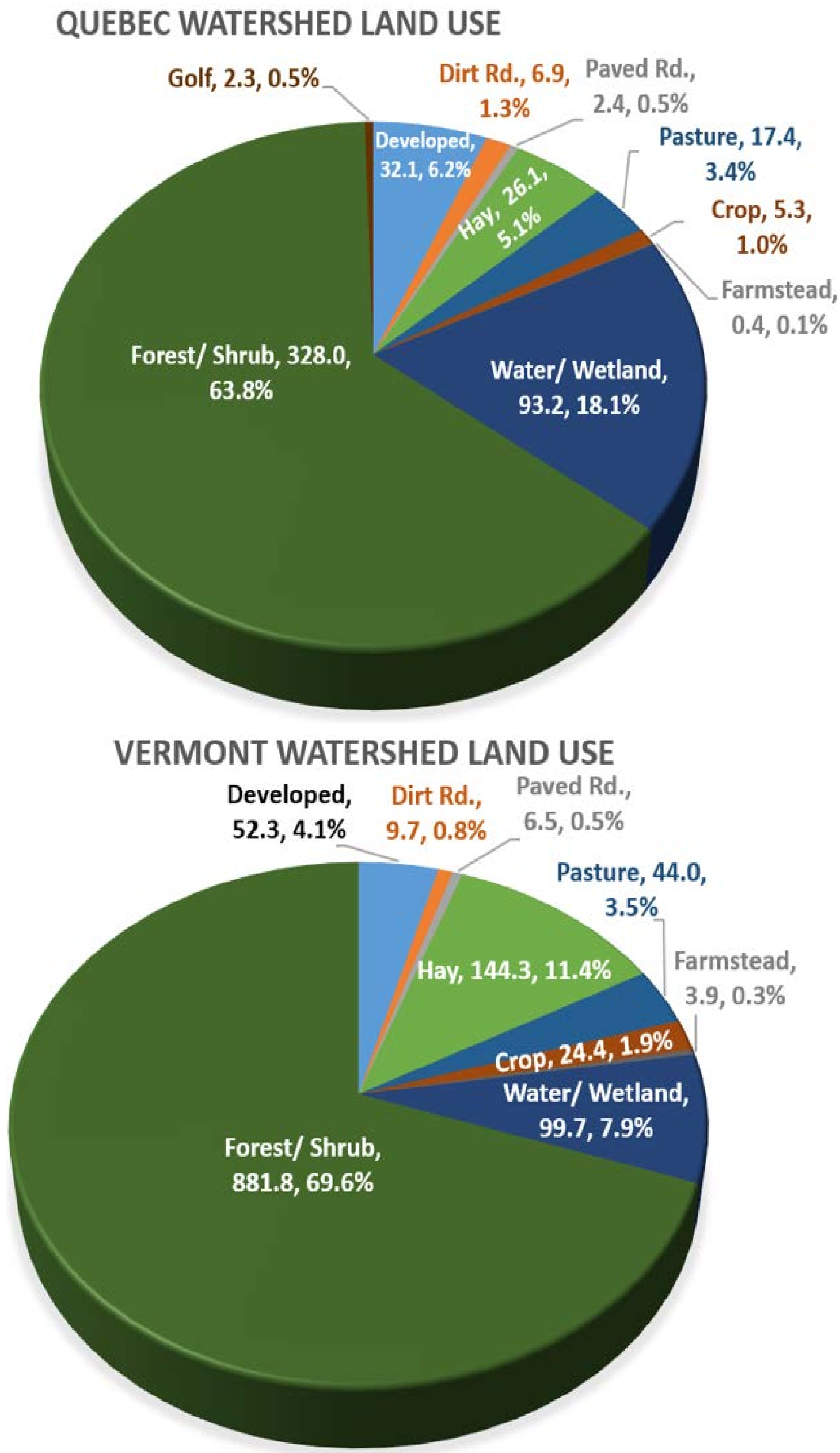


Figure 2-3. Quebec and Vermont Watershed Land Use in km^2 and percent land cover

Agriculture in the Quebec portion of the watershed

The Quebec portion of the Lake Memphremagog watershed has 53 registered agricultural producers which their civic address of the main production site of the farm is in the watershed; with a total area of 56.9 km^2. According to farm registration cards, horticultural, fruit crops, and annual crops are largely in the minority.

Production type	Area (km^2)	Proportion (%)
Annual crops (corn, soya, cereal)	2.9	5.1
Perennial crops (grassland or pasture)	25.5	44.9
Horticultural and fruit crops	0.8	1.4
Forest, sugar bush, fallow	27.7	48.6
Total area of agricultural land	56.9	100

Source: (MAPAQ, 2019, unpublished data).

The 53 agricultural producers indicate conducting direct sowing or minimum tillage on 119 ha, corresponding to 41% of annual crops (290 ha). 28 farms (53%) operate livestock farming, mainly beef cattle, poultry, and dairy cattle. This distribution explains the large number of manure storages in the field.

	Animal unit	Proportion (%)
Beef Cattle	1501	54.5
Poultry	716	26.0
Dairy Cattle	352	12.8
Sheeps	116	4.2
Horses	50	1.8
Others	21	0.7
Total	2756	100

The animal density corresponds to 0.48 AU / ha of agricultural surface and 0.97 AU / ha of surface in annual and perennial crops. This average animal density can pose challenges in terms of management of organic fertilizers mainly on perennial crops (dates of application, doses, modes of supply, distances from watercourses and ditches). However, soil phosphorus enrichment appears to be limited according to the Quebec Soil Test Results Database. On a compilation of 1012 soil analyzes carried out between 2000 and 2017 in the MRC Memphremagog, the average soil phosphorus content was 68 kg / ha (median 48 kg / ha) and its average saturation rate P / Al of 2.7. % (median 1.7%; MAPAQ, 2019, unpublished data).

2.1.9. Protected areas

Appendix 2-4 shows the Quebec and Vermont protected areas in Lake Memphremagog watershed. In Quebec, a proportion of 9.0% of the watershed is protected, when in Vermont, the proportion is 14.5% (Rivest, C., COGESAF, 2019, unpublished data).

2.2. Water quality data: Lake Memphremagog and its tributaries

Water quality data in this report include data from tributaries and Lake Memphremagog. It should be noted that monitoring protocols and laboratory analyses differ between Vermont and Quebec. This may influence the median and mean values and makes the median and mean values between the two countries not directly comparable.

2.2.1. Tributary water quality data

2.2.1.1. *Quebec tributary water quality data*

The MRC Memphremagog coordinates a tributary monitoring program that has sampled over 40 sites throughout the Quebec portion of the Memphremagog Watershed since 1998 (see section 3.2.1.2). Figure 2-4 presents the concentration medians obtained for total phosphorus from 2005 to 2018. Five sub-watersheds exceed the Quebec criteria for surface water quality to limit the excessive growth of algae and aquatic plants in streams and rivers (30 µg/L). There are no areas with a mean phosphorus concentration of 44 µg/L or greater in the Quebec portion of the watershed. This value is used by Vermont to prioritize areas to implement efforts to reduce phosphorus in the watershed (VDEC 2017d.)

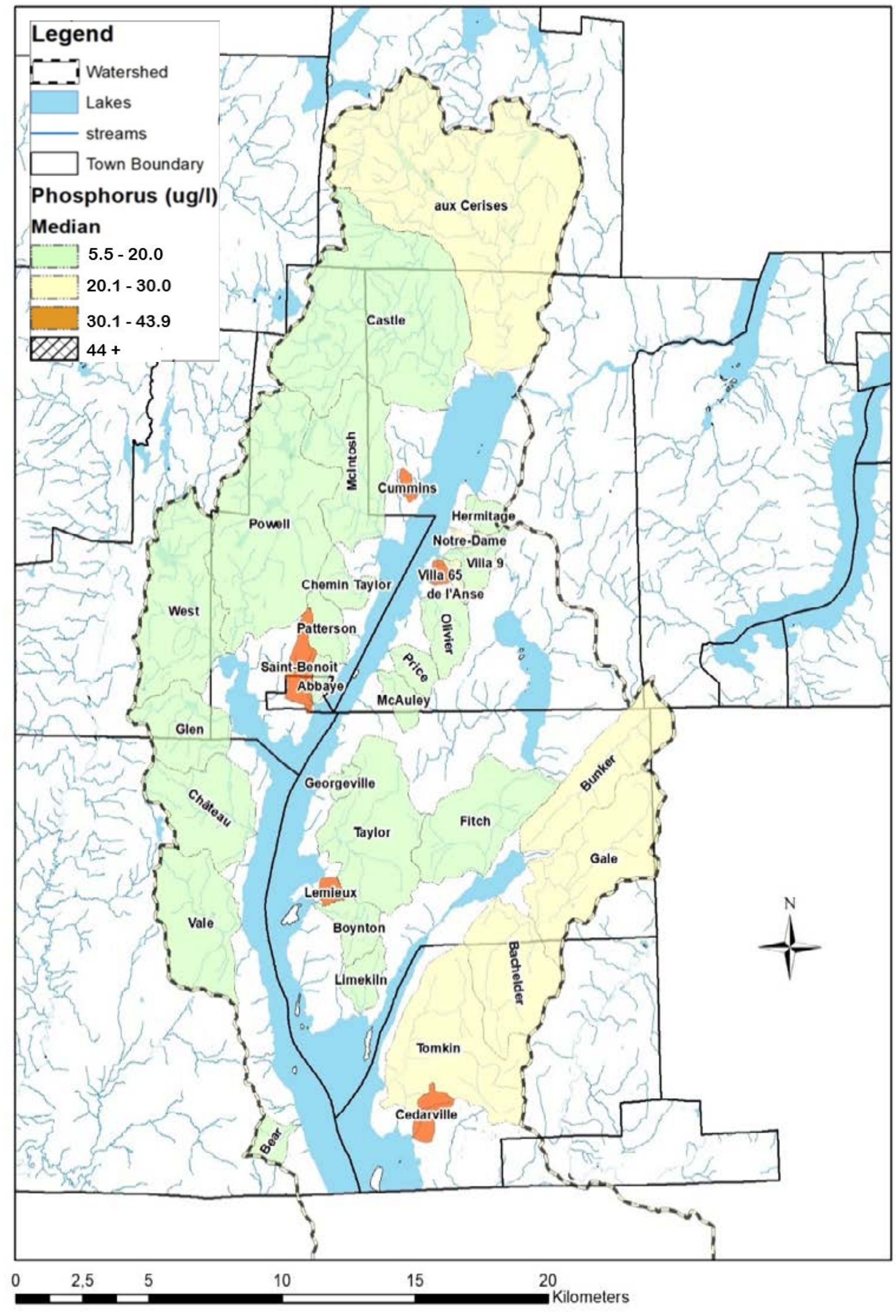


Figure 2-4. Concentration medians of total phosphorus from 2005 to 2018 for the tributaries of the Quebec portion of the watershed.

2.2.1.2. *Vermont tributary water quality data*

Supported by the LaRosa Partnership Program through the VDEC, the tributary monitoring program has sampled over 153 sites throughout the Vermont portion of the Memphremagog Watershed since 2005 (see section 3.2.2.3). Figure 2-5 presents the concentration medians obtained for total phosphorus from 2005 to 2016. Watersheds with mean phosphorus values above 44 μg/L have been identified as target areas for phosphorus reduction efforts across the watershed (VDEC 2017d.)

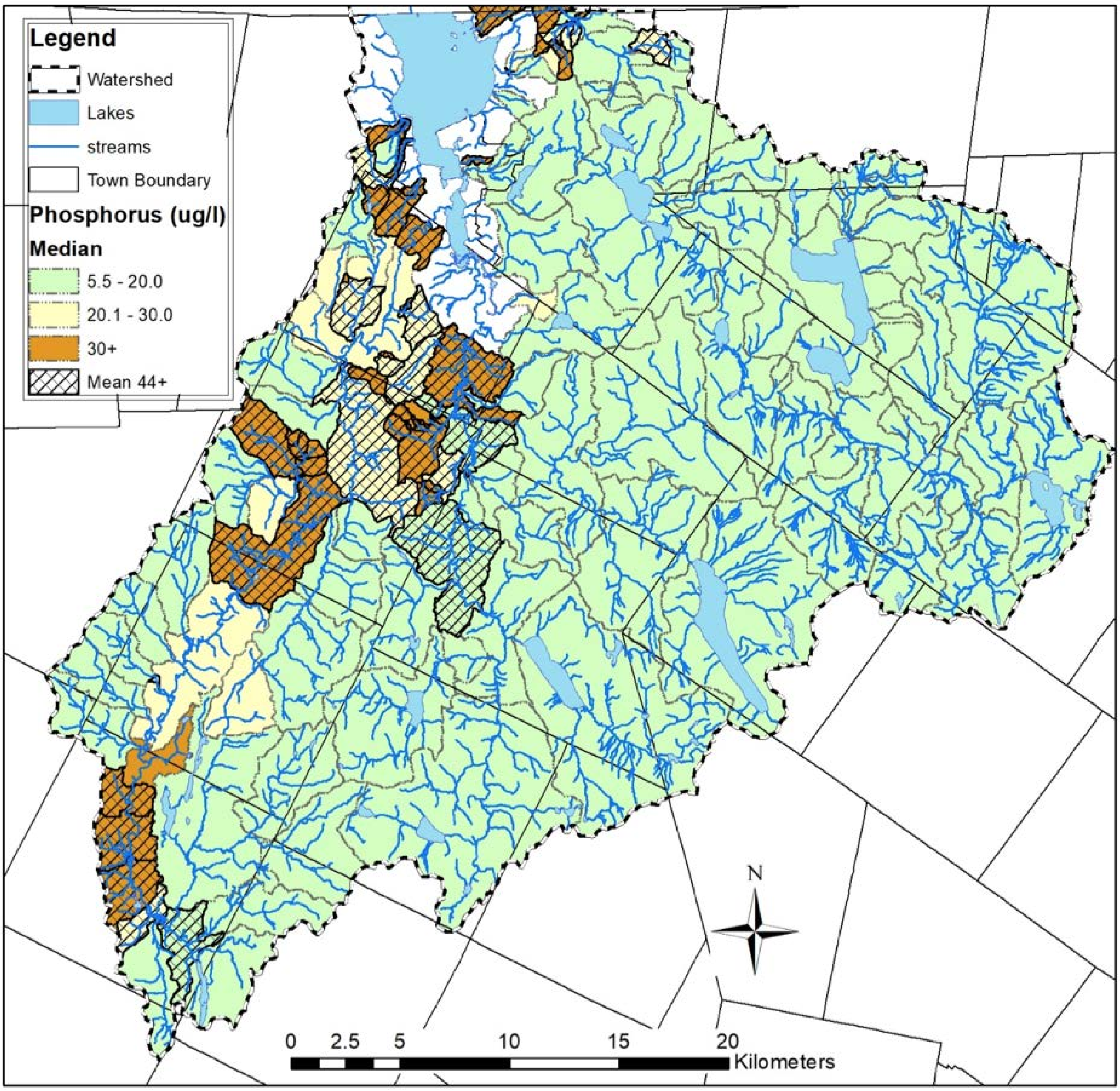


Figure 2-5. Concentration medians of total phosphorus from 2005 to 2016 for the tributaries of the Vermont portion of the watershed. Areas with elevated mean phosphorus concentrations are also shown as these are target areas for water quality improvement efforts in Vermont.

2.2.2. Lake Memphremagog water quality data

Twelve water quality sampling sites are located on Lake Memphremagog and its outlet, the Magog River (Figure 2-6). In Quebec, since 1999, nine sites have been sampled by the Ministry of Environment and Fight against Climate Change (MELCC, *Ministère de l'Environment et de la Lutte contre les changements climatiques*) in collaboration with Memphrémagog Conservation inc. (MCI), when the outlet is sampled since 2002 (see section 3.2.1.2). In Vermont, two sites have been sampled through the Lay Monitoring program since 1985: one in the center of South Bay and one located in center of the lake off Whipple Point (Memph 03; see section 3.2.2.3). Samples were also taken from 2005 to 2012 through the Vermont Lake Assessment program at the same locations as the Lay Monitoring Program. The Vermont Lake Assessment program also sampled at a site in the middle portion of Lake Memphremagog, which has also been sampled by MELCC (Station 249/Memph 04; see section 3.2.2.2).

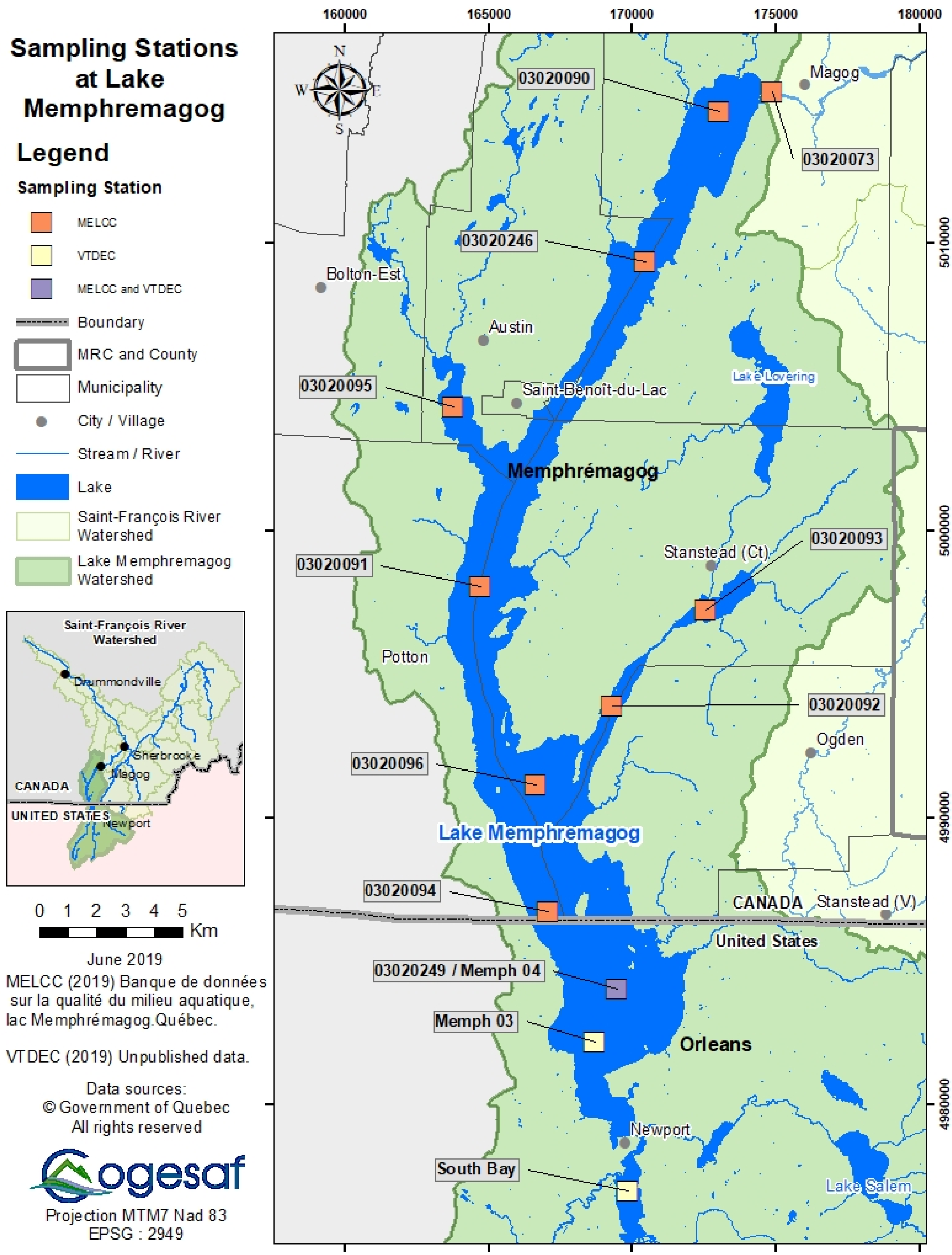


Figure 2-6. Location of water quality monitoring sites in Lake Memphremagog

2.2.2.1. *Lake Memphremagog water quality data: Quebec monitoring sites*

Context

The Ministry of Environment and Fight against Climate Change of Quebec (MELCC, *Ministère de l'Environment et de la Lutte contre les changements climatiques du Québec*) monitors the water quality of Lake Memphremagog at nine stations on the Lake since 1999 and at its outlet since 2002 (Figure XX). The distribution of the stations makes it possible to have a relatively good spatial coverage of the various areas of the Lake. Similar to the monitoring done by Vermont, it is focused on the trophic status assessment based on the measurement of total phosphorus (TP) and chlorophyll-a (chl-a) concentrations (http://www.environnement.gouv.qc.ca/eau/rsvl/methodes.htm). The inconsistency in the availability of the transparency data measured with the Secchi disk (TRAN) over the years does not permit the use of this variable to highlight changes in lake productivity. Transparency is the least accurate indicator of trophic status.

The sampling technique has remained stable from 1999 to today. However, the method of conservation of the samplings and measurement of the total phosphorus was the subject of modifications in 2009 and 2011. These led to declines in the data that were detected and quantified very recently following a rigorous evaluation of all analytical results and possible sources of bias. The final results of this work are not yet available. In order to be able to use Quebec phosphorus data for this report, the data have been corrected using temporary correction templates. Although these can produce data sets that appear consistent and plausible, great caution is required in their analysis and interpretation. The findings and conclusions are therefore necessarily cautious at this stage and details of the uncertainty inherent of the results are presented.

The number of samples taken annually was generally four divided in June, July and August, and it reached 7 in some years including May and the period from September to November. To give equal weight for each year, only June, July and August data were used. Long-term interannual average values and trend analyzes were performed over two periods, from 1999 to 2018 (9 stations) and from 2002 to 2018 (10 stations). The period 2002 to 2018 excludes the results from 1999 to 2001 which are the most heterogeneous in terms of the number of samples and because of the absence of the outlet station. The comparison of the results of the two periods makes it possible to highlight the effect of these three years.

It should be noted that total phosphorus data for 2018 are not corrected data, but analytical results produced using the modified and proven analytical method and procedures. These results are reliable. Despite the adjustments made on the Quebec side, the difference with Vermont monitoring data remains statistically significant, in the order of 1.8 µg/L higher for Vermont according to the results of paired samples analyzed in parallel in 2018.

The differences between the Vermont monitoring data and the Quebec monitoring data in the southern part of the Lake are higher than the one mentioned above. In addition to the inaccuracy of the correction models and the peculiarities of analytical chemistry methods and procedures, other factors may be involved in this difference, including the sampling protocol. Quebec and Vermont continue the evaluation of these factors.

Trophic status

Figure 2-7 presents the trophic status classification chart for lakes used by the MELCC. The limits of the major trophic classes are consistent with the recommendations of the Canadian Council of Ministers of the Environment (CCME) and historically used as a result of the Organisation for Economic Co-operation and Development (OECD)'s work on eutrophication. Transition zones are based on a review of the most widely used empirical values in eastern North America. The values defining the trophic classes for total phosphorus are higher than those used by Vermont (Section 2.3.2.2), while the limits for chlorophyll are similar.

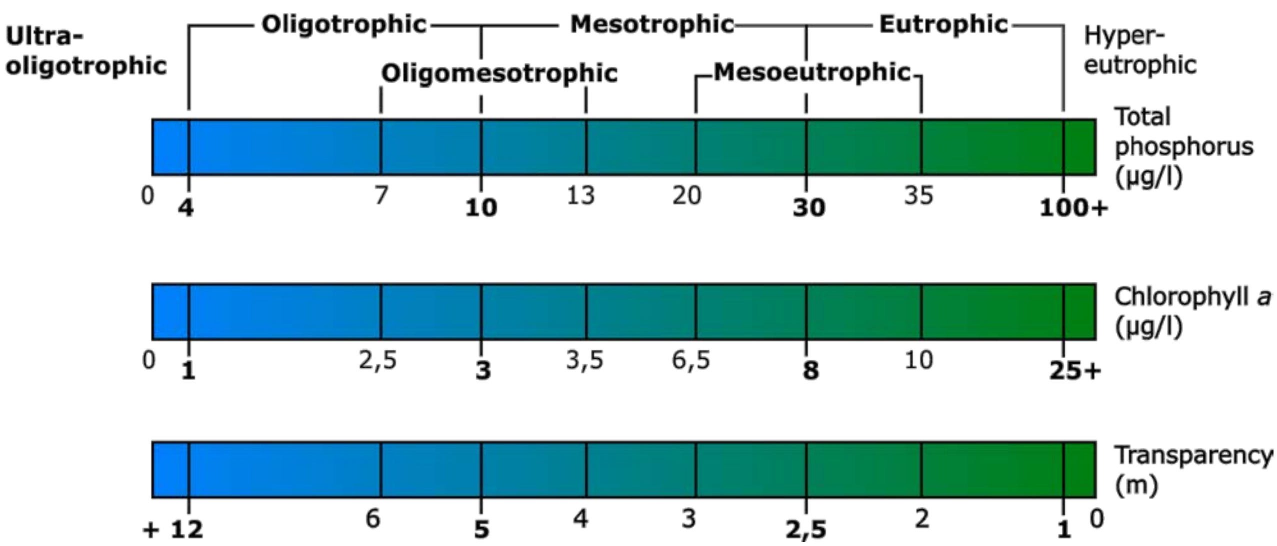


Figure 2-7. Diagram of the trophic status of lakes used by the MELCC

Based on the average phosphorus concentration since 1999 or 2002 as well as in 2018 (Table 2-3), Memphremagog Lake would be at an oligo-mesotrophic (OM) level at all stations, with the exception of North-East Fitch Bay, which is definitely mesotrophic (M), at the edge of the meso-eutrophic (ME) transition zone. Overall, when considering all the grouped stations, the lake is at an oligo-mesotrophic level. The northeastern section of Fitch Bay is a distinct body of water separated from the rest of the lake. It is unlikely that the trophic status of the lake will change significantly following the final correction of historical phosphorus data.

Table 2-3. Average total phosphorus (TP) concentrations and trophic status at Lake Memphremagog stations.

Station	**Average Total Phosphorus Concentration (µg/L)**			**Trophic Status**		
	1999-2018	2002-2018	2018	1999-2018	2002-2018	2018
M249 (03020249)	12.8	12.5	11.7	OM	OM	OM
M94 (03020094)	11.4	11.1	10.5	OM	OM	OM
M96 (03020096)	11.7	11.4	9.5	OM	OM	OM
M92 (03020092)	11.2	11.0	13.0	OM	OM	OM
M91 (03020091)	10.4	10.4	7.9	OM	OM	OM
M95 (03020095)	9.4	9.4	7.4	OM	OM	OM
M246 (03020246)	9.7	9.8	7.7	OM	OM	OM
M90 (03020090)	9.8	9.7	8.1	OM	OM	OM
M73 (03020073)	-	11.4	8.8	-	OM	OM
M93 (03020093)	20.2	19.4	21.1	ME	M	ME
Grouped stations	11.9	11.7	10.6	OM	OM	OM

OM: Oligo-mesotrophic, M: Mesotrophic, ME: Meso-eutrophic

The trophic status signal given by the concentration of chlorophyll is not as homogeneous (Table 2.4). In the southern sections, at the latitude of Fitch Bay and the center of the lake (M249, M94, M96, M92 and M91), the average measured concentrations are at a mesotrophic lake level for the three periods considered, with the exception of the M91 station at the center of the lake which was at an oligo-mesotrophic level in 2018 (Table 2.4). In the sections of Sargent Bay, the northern portion of the lake and the outlet (M95, M246, M90 and M73), the average concentration corresponds to a lake with an oligo-mesotrophic level. Although the average lake concentration is generally mesotrophic, there appears to be a significant decrease between the southern and northern portion of the lake, which is approximately at the latitude of M91. As with phosphorus, the northeastern portion of Fitch Bay is much more degraded and has a eutrophic status according to the chlorophyll concentration.

Table 2-4. Average concentrations of chlorophyll-a and trophic status at Lake Memphremagog stations.

Station	**Average Chlorophyll-a Concentration (µg/L)**			**Trophic Status**		
	1999-2018	2002-2018	2018	1999-2018	2002-2018	2018
M249 (03020249)	4.5	4.4	4.0	M	M	M
M94 (03020094)	4.2	4.1	3.9	M	M	M
M96 (03020096)	4.2	4.1	3.5	M	M	M
M92 (03020092)	4.4	4.3	3.7	M	M	M
M91 (03020091)	3.7	3.7	2.9	M	M	OM
M95 (03020095)	3.0	3.0	2.8	OM	OM	OM
M246 (03020246)	3.4	3.4	3.0	OM	OM	OM
M90 (03020090)	3.0	2.7	2.6	OM	OM	OM
M73 (03020073)	-	3.1	2.6	-	OM	OM
M93 (03020093)	11.2	10.9	13.6	E	E	E
Grouped stations	4.7	4.4	4.3	M	M	M

OM: Oligo-mesotrophic, M: Mesotrophic, ME: Meso-eutrophic

There is a mismatch in the phosphorus concentration data between Vermont and Quebec at the M249 joint station in the south basin, while the concentrations of chlorophyll are similar. For both Quebec and Vermont data, there is a difference in the trophic status signal between phosphorus and chlorophyll, but this is inverted in both sets of data. Phosphorus shows greater eutrophication compared to chlorophyll in the Vermont results, whereas it is the opposite with Quebec data in this portion of the lake. This is due to the upward mismatch between Vermont TP results compared to Quebec, as well as the difference in trophic status scales. However, the consistency of the trophic status signal from chlorophyll data between the two monitoring programs at this station should be noted. Although both are related, the chlorophyll concentration is a variable that expresses the effects of eutrophication more than total phosphorus.

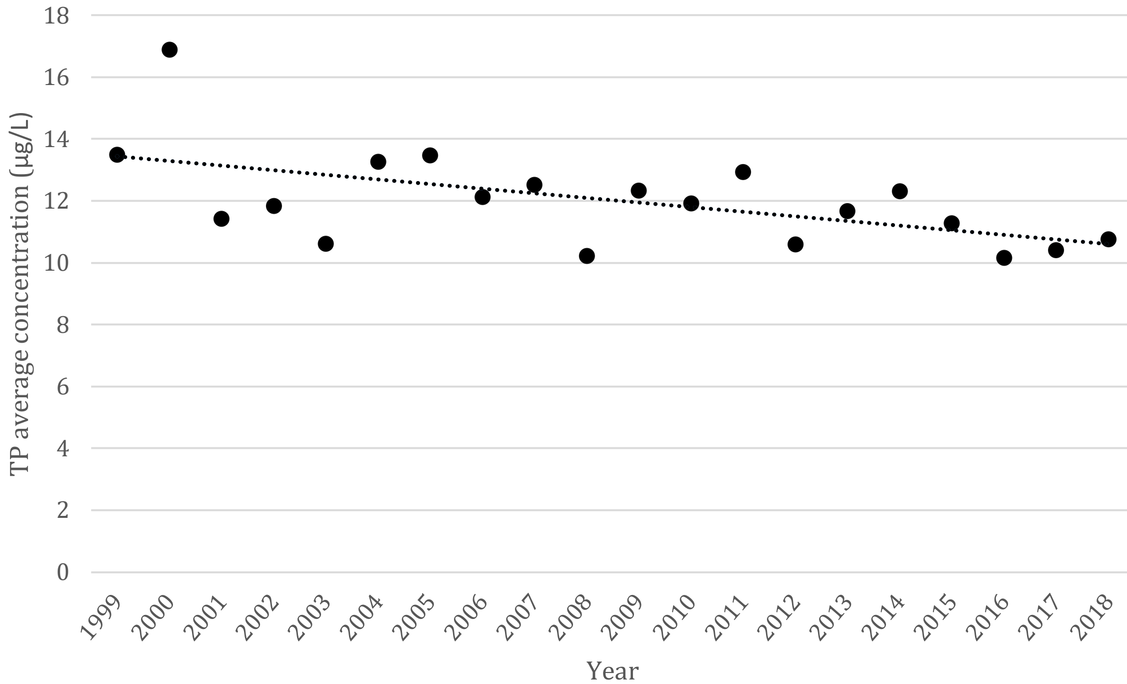
Evolution of water quality

A temporal trend analysis by station and for the grouped stations was performed on the total phosphorus and chlorophyll data for the periods 1999 to 2018 and 2002 to 2018 using the Mann-Kendall test and the linear regression on the annual average concentrations. Considering results between the two methods are broadly concordant, only those of the Mann-Kendall test are presented. Overall, for all combined stations, there is a statistically significant decrease in total phosphorus concentration for the period 1999 to 2018 (Table 2-5). Although the decline is visually apparent also for the period 2002 to 2018 (Figure 2-8), it is slightly above the significance level α of 0.05. On the other hand, the analysis by station highlights a lack of statistically significant trend for the vast majority of them, despite the fact that graphically there is an appearance of decrease for other stations, as also reflects the relatively low error probability level α. The strongly significant decline at M96 off Fitch Bay and the decline at M94 at the border for the period 1999 to 2018 stand out. The high results of the year 2000 (Figure 2-8) explain in part the significant decrease over the period 1999 to 2018 for the grouped stations. The results for Quebec and Vermont at the M249 station in the southern basin are consistent.

Table 2-5. Mann-Kendall trend test results of average annual TP concentrations at Memphremagog Lake stations.

Station	1999-2018 Trend		2002-2018 Trend	
	Tend.	P	Tend.	p
M249 (03020249)	→	0.064	→	0.484
M94 (03020094)	↘	0.015	→	0.064
M96 (03020096)	↘	0.002	↘	0.007
M92 (03020092)	→	0.315	→	0.434
M91 (03020091)	→	0.230	→	0.202
M95 (03020095)	→	0.056	↘	0.036
M246 (03020246)	→	0.417	→	0.232
M90 (03020090)	→	0.206	→	0.108
M73 (03020073)	-	-	→	0.392
M93 (03020093)	→	0.974	→	0.108
Stations groupées	↘	0.012	→	0.064

→ : no significant trend, ↘ : significant downward trend



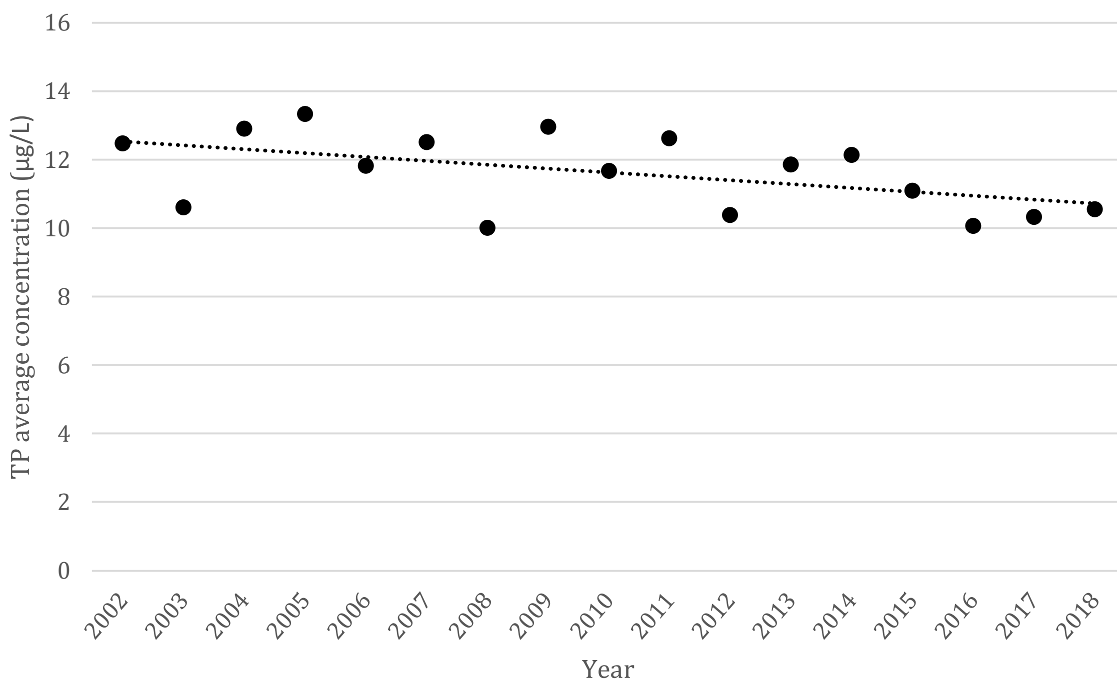


Figure 2-8. Average annual PT concentrations for the periods 1999-2018 (9 stations, top graph) and 2002-2018 (10 stations, bottom graph).

Uncertainty about the accuracy of the total phosphorus corrected data at this stage implies that results of the trend analysis should be interpreted cautiously. Small changes in the correction models could switch the result of the statistical analysis. At this time, it can be interpreted that the phosphorus concentration in Lake Memphremagog is either stable or slightly decreased.

On the other hand, the results of the trend analysis on chlorophyll data leave no ambiguity on the stability of this important water quality variable with respect to eutrophication (Table 2-6, Figure 2-9). The results are definitely insignificant at all stations and grouped stations for the two periods of analysis. Only site M96 off Fitch Bay is approaching the α threshold of 0.05 for the period 1999-2018. This is the station and the period when phosphorus decline is the most significant ($p = 0.002$). Chlorophyll results are consistent with those from Vermont at M249 at the south basin.

Chlorophyll data indicate that the trophic status of Lake Memphremagog has not changed since the early 2000s. Due to the stability in the method used for the determination of chlorophyll-a and given that the data from TP and chl-a are paired, these results support the finding of stability in phosphorus concentration, or a decline with insufficient magnitude to also be reflected in the algal biomass indicator.

Table 2-6. Mann-Kendall trend test results on annual average chlorophyll-a concentrations at Memphremagog Lake stations.

Station	**1999-2018 Trend**		**2002-2018 Trend**	
	Trend	p	Trend	p
M249 (03020249)	→	0.495	→	0.484
M94 (03020094)	→	0.529	→	0.902
M96 (03020096)	→	0.080	→	0.266
M92 (03020092)	→	0.294	→	0.837
M91 (03020091)	→	0.552	→	0.458
M95 (03020095)	→	0.600	→	0.621
M246 (03020246)	→	0.441	→	0.650
M90 (03020090)	→	0.916	→	0.458
M73 (03020073)	-	-	→	0.964
M93 (03020093)	→	0.576	→	0.127
Grouped station	→	0.944	→	0.484

→ : no significant trend

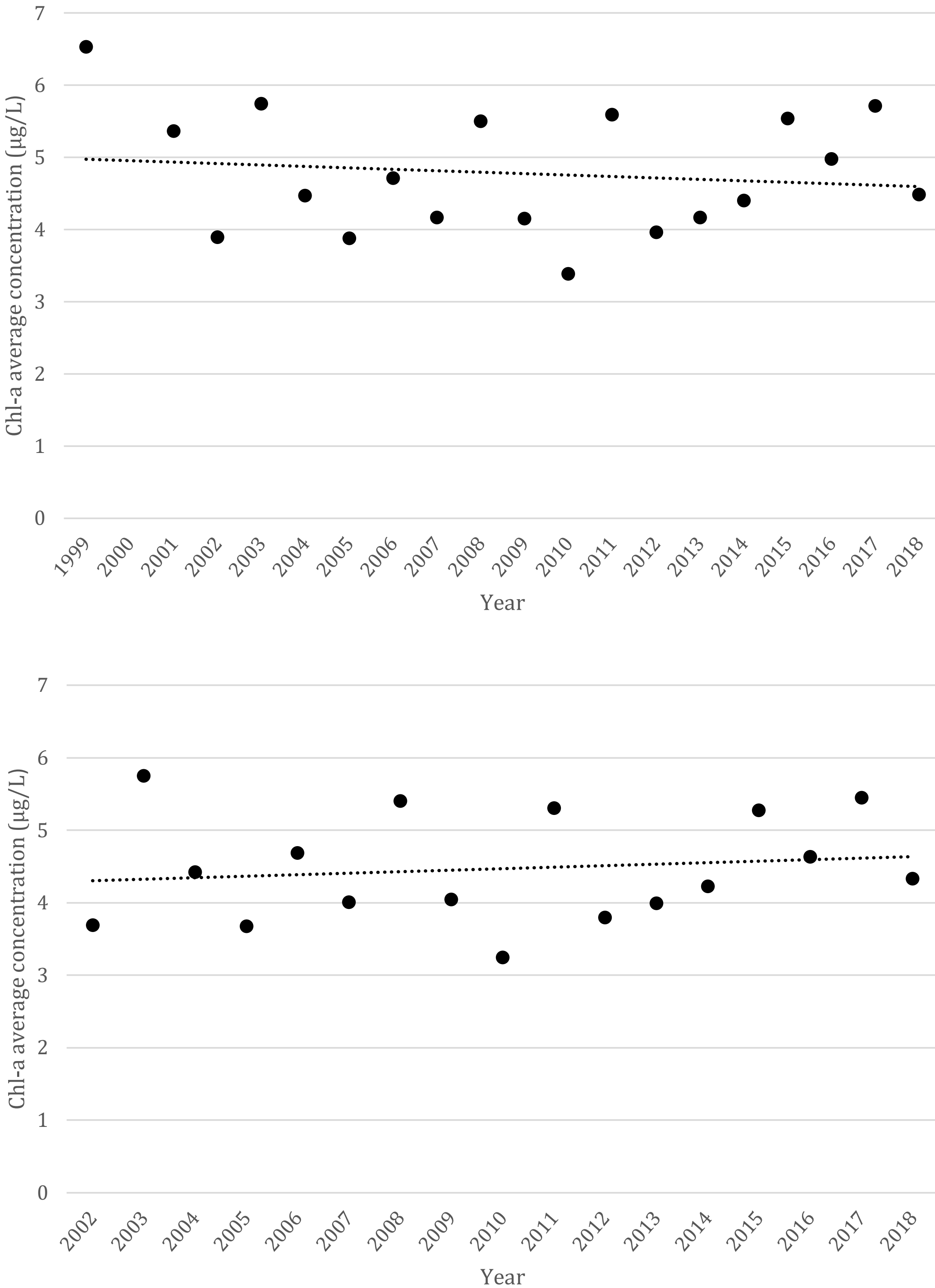


Figure 2-9. Average annual concentrations of chlorophyll-a for the periods 1999-2018 (9 stations, top graph) and 2002-2018 (10 stations, bottom graph).

2.2.2.2. *Lake Memphremagog water quality data: Vermont monitoring sites*

According to the 2018 Vermont DEC Lake Score Card water quality trend analyses (Figure 2-10), Lake Memphremagog is stable overall in since 1985 based on summer Lay Monitoring total phosphorus (TP) and chlorophyll-a (Chla) using Kendall's Tau rank correlation test using a P value of 0.05. Summer and spring TP levels from the main lake with samples taken from Whipple Point Station/Memph 03 (Figure 2-10) remain consistently above the VDEC standard of 14 µg/L. Samples taken from the South Bay Station (Figure 2-11) show statistically stable trends, and TP typically below the VDEC standard of 25 µg/L. The TP standard for the main lake and South Bay are different based on the characteristics of the lake segment, including the depth and mixing.

For more information on how to read the Lake Score cards or how the data is calculated for Figure 2-10 and 2-11, please see:
https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/2017%20How%20Lakes%20are%20Scored_final%20Apr%2012.pdf

Total nitrogen has also been sampled by VDEC biweekly as part of a TMDL monitoring study from 2005 through 2012, and annually as part of the spring phosphorus monitoring program. Average total nitrogen concentrations from over 980 samples from 2005 through 2018 at sites Memph 03 and Memph 04 in Vermont were 0.31 mg/L at both locations. These nitrogen levels are generally considered low. The average of the nitrogen to phosphorus ratios for the lake based on the spring phosphorus monitoring program from 2009 – 2017 was 24 to 1 and lakes with ratios below 20 to 1 are more likely to support cyanobacteria blooms particularly in warm water.

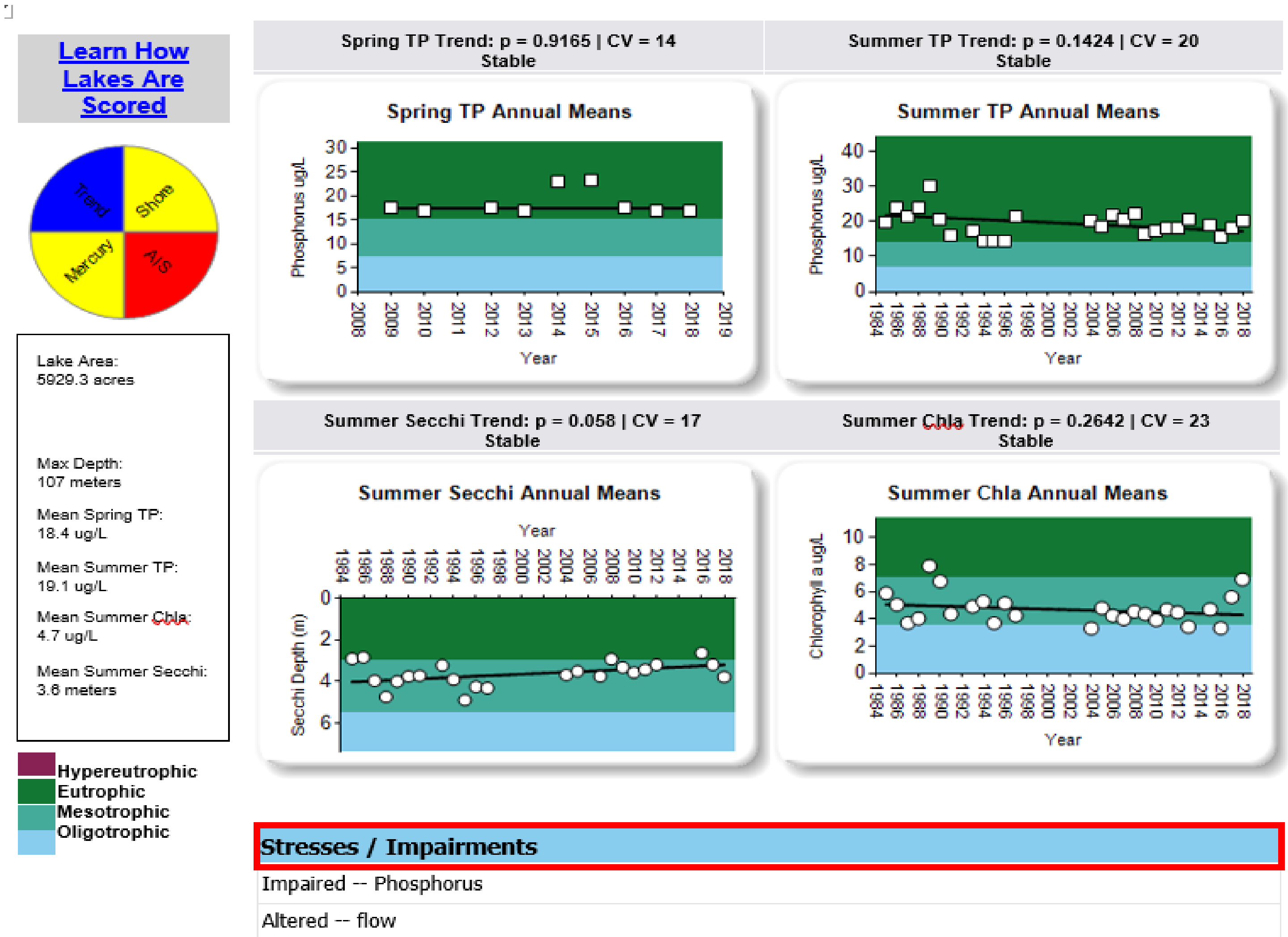


Figure 2-10. Memph 03 Monitoring Station: Lake Memphremagog Score Card Trends and Status Report with data from 1985 through 2018.

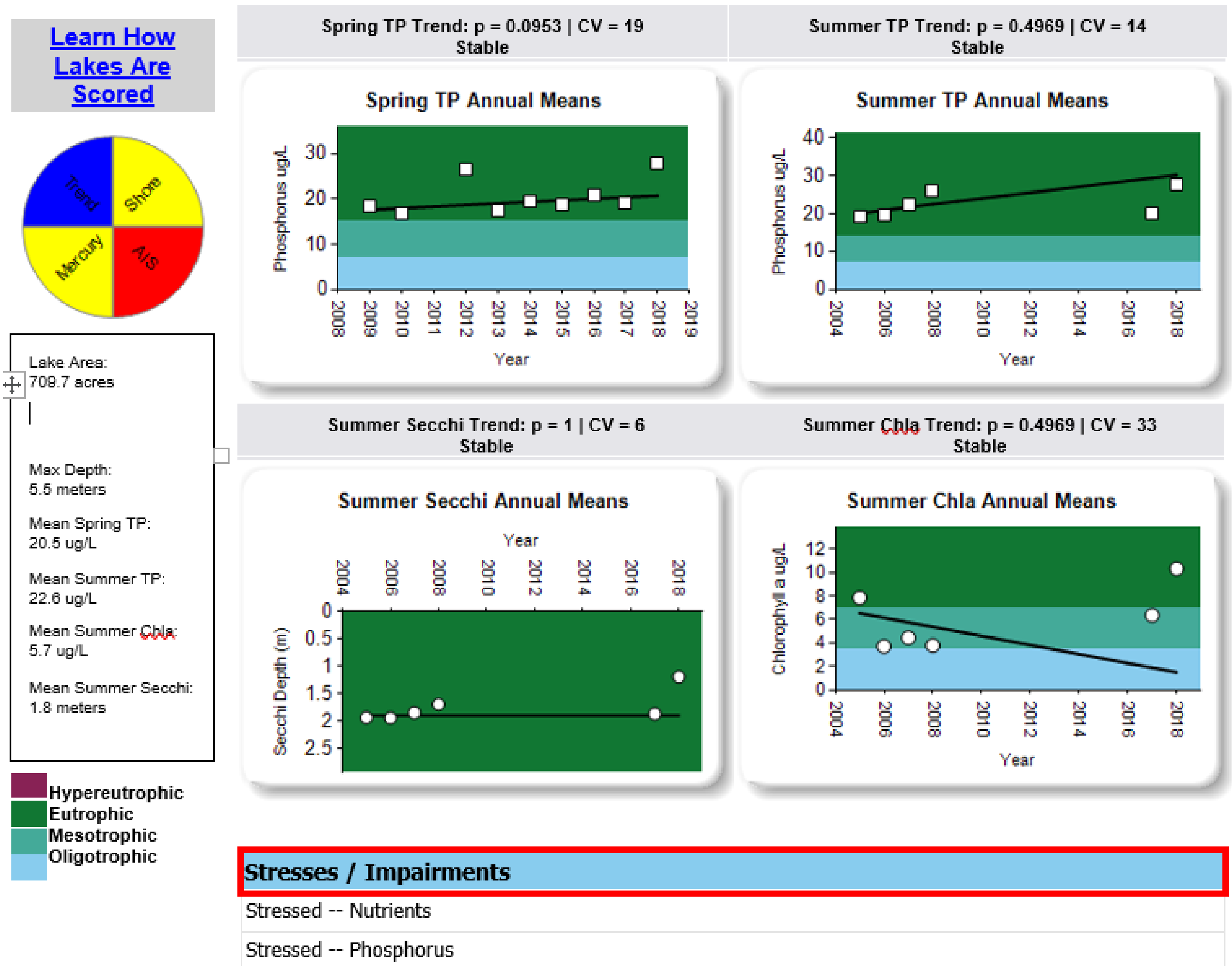


Figure 2-11. South Bay Monitoring Station: Lake Memphremagog South Bay Score Card Trends and Status Report with data from 2005 through 2018.

2.3. Nutrient Sources

Figure 2-12 and Table 2-7 show the estimated watershed phosphorus loading by land use type for Vermont and Quebec. These results are based on a phosphorus land use export model and are presented in percent loading and metric tons per year (mT/y). This model and the loading estimates were developed by VDEC as a part of the Lake Memphremagog Total Daily Maximum Load (TMDL) for phosphorus, which was finalized by VDEC and approved by the United States Environment Protection Agency (EPA). For more information on the process, models, and results of the TMDL, please see section 3.2.2.2.

Materials are also available online at:
https://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Basin17_TBP_Signed.pdf

It should be emphasized that these phosphorus loading figures are estimates, and that there is significant uncertainty inherent in the modeling process. This model was calibrated based on loading data from the Vermont tributaries only. This means that there is even greater uncertainty in the Quebec figures compared to the Vermont figures; however, the TMDL estimates are currently the most comprehensive available and provide a valuable starting point to discuss additional research needs and opportunities, as well as loading reductions. Descriptions of phosphorus loading by land use type follow Figure 2-12 and Table 2-7; that loading data is also from TMDL estimates.

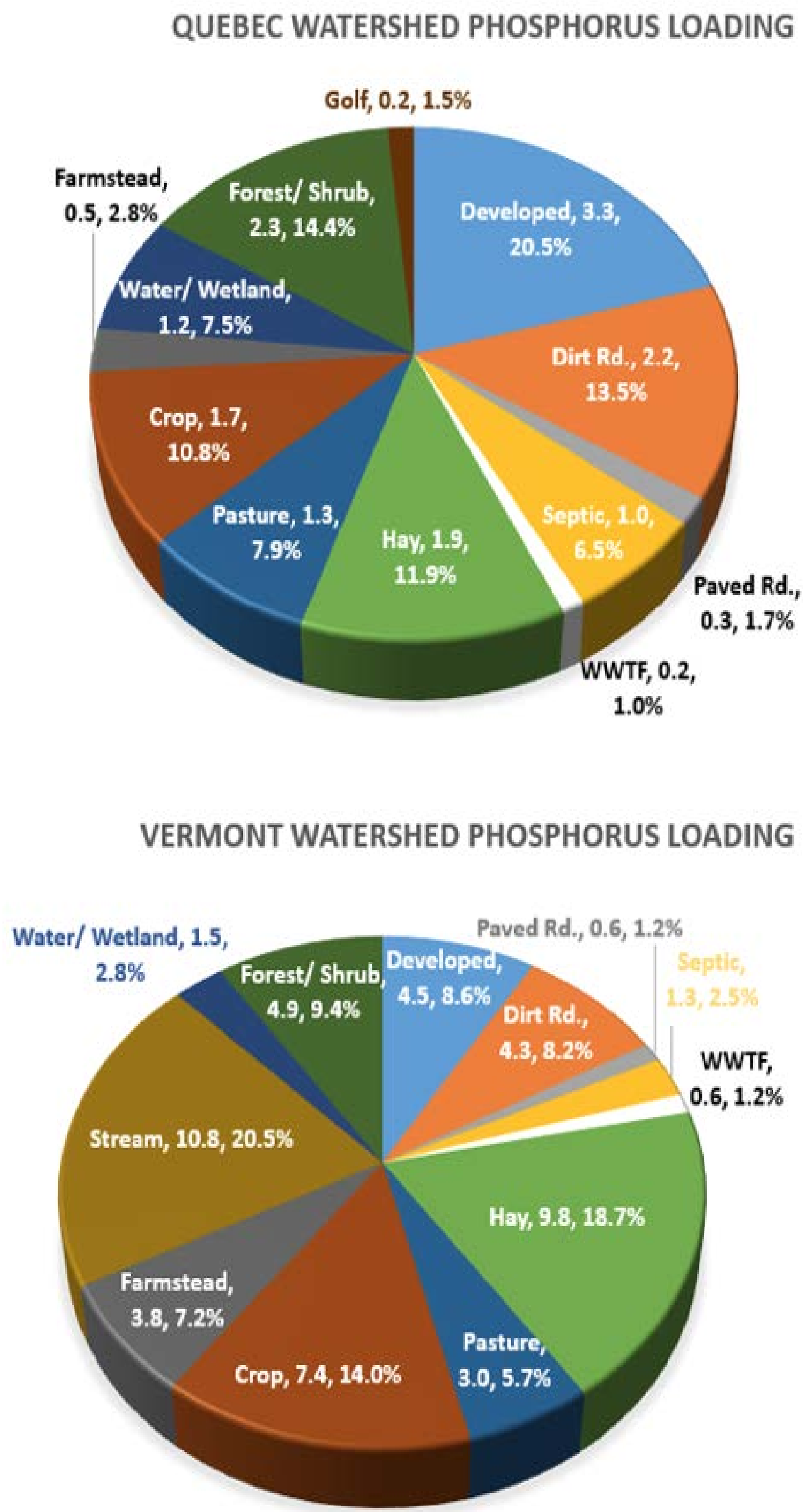


Figure 2-12. Estimated phosphorus loading by land use type to Lake Memphremagog in metric tons per year (mT/y) and percent loading

Table 2-7. Estimated phosphorus loading by land use type to Lake Memphremagog in metric tons per year (mT/y) and percent loading

Land Use Type	Estimated loading from Quebec Watershed (mT/y)	Estimated loading from Vermont Watershed (mT/y)	Total Estimated Loading (mT/y)
Crop	1.7	7.4	9.1
Developed Land	3.3	4.5	7.8
Dirt Roads	2.2	4.3	6.5
Farmstead	0.5	3.8	4.3
Forest/Shrub	2.3	4.9	7.2
Golf	0.2	N/A	0.2
Hay	1.9	9.8	11.7
Pasture	1.3	3.0	4.3
Paved Roads	0.3	0.6	0.9
Septic	1.0	1.3	2.3
Stream	N/A	10.8	10.8
Water/Wetland	1.2	1.5	2.7
WWTF	0.2	0.6	.8
Total estimated loading	16.1	52.7	68.7

2.3.1. Agricultural Sources - TMDL estimates

On the Vermont side of the watershed, runoff from agricultural lands is the largest source of phosphorus loading into the tributaries of Lake Memphremagog (VDEC, 2017c).

Based on the TMDL model, is it estimated that agricultural runoff from the Vermont watershed contributes 24 mT/y of phosphorus into Lake Memphremagog or 45.6% of the total Vermont loading. Agriculture in Quebec is estimated to contribute 5.4 mT/y of the phosphorus or 33.4% of total Quebec loading.

2.3.2. Developed Lands- TMDL estimates

Developed Lands are estimated to contribute 10.7 mT/y or 20.5% of the total phosphorus loading from Vermont to Lake Memphremagog which comes from developed parcels, dirt roads, paved roads, and private septic. In the Quebec watershed, developed lands are the largest sources of phosphorus estimated to contribute 6.8 mT/y or 42.2% of the total loading from Quebec.

2.3.3. Point Sources- TMDL estimates

Vermont has four Municipal Wastewater Treatment Facilities (WWTF) that discharge into the Lake Memphremagog watershed. Combined, these facilities are estimated to contribute 0.6 mT/y or 1.2% of the total Vermont phosphorus loading into Lake Memphremagog (Figure 2-12). The largest of these WWTF is located in Newport City, with the three others in Barton, Brighton, and Orleans (a village under the municipal jurisdiction of Barton, Vermont). The Quebec portion also has four WWTF that discharge into the Lake Memphremagog watershed: two in the municipality of Stanstead Township (Fitch Bay and Georgeville), one in Saint-Benoit-du-Lac and one in the municipality of Orford Township (Vezina & Desilets, 2009; Orford, 2018). WWTF in Quebec are estimated to contribute 0.2 mT/y or 1% of the total phosphorus loading from Quebec. Table 2-8 shows the annual phosphorus load estimates in kg/year from all the WWTF in the watershed. These values were used to estimate loading in the TMDL model with updates for the St. Benoit and Orford facilities which were upgraded after the TMDL modeling was completed.

NEWSVT Coventry Landfill

Concerns were expressed about the potential phosphorus loading from the New England Waste Services of Vermont, Inc. (NEWSVT) Coventry Landfill and associated leachate treatment in the watershed as part of the stakeholder survey. Construction and operational stormwater permits are in place for this facility which require treatment practices that limit potential phosphorus loading from stormwater runoff. The Coventry Landfill also accounts for less than one percent of the impervious surface area in the Vermont portion of the watershed not related to roads. The Newport WWTF has received leachate from the Coventry Landfill, but the WWTF has a permit limitation on phosphorus loading and treatment designed to remove phosphorus. There are no indications that phosphorus loading has increased with the treatment of leachate at this facility and phosphorus loading levels have remained far below what is permitted for this WWTF (VDEC 2017b). Based on this analysis there is no indication that the Coventry Landfill or its leachate is a significant source of nutrients to Lake Memphremagog.

Table 2-8. Annual phosphorus load estimates for each WWTF

WWTF	**Annual phosphorus load estimates (kg/year)**
Barton (VT)	113
Brighton (VT)	295
Fitch Bay (QC)	10
Georgeville (QC)	1
Newport (VT)	391
Orford (QC)	104
Orleans (VT)	35
St-Benoit (QC)	3

2.3.4. Recreational Sources- TMDL estimates

Currently, Vermont does not have an estimate of the phosphorus loading from specific recreational sources included in the TMDL. The only contributing recreational source accounted for in the TMDL in Vermont would be golf courses, of which there are three within the Memphremagog watershed; however, phosphorus from golf courses is accounted for in the developed lands portion of the Vermont TMDL model. There are no downhill ski areas within the watershed in Vermont and two in Quebec (Owl's Head and Orford Mounts). In Quebec, it is estimated that the six golf courses contribute 0.2 mT/y of phosphorus or 1.5% of the total Quebec loading. Another recreational source of nutrients in Lake Memphremagog that was not estimated in the TMDL model is the loading from boating activities. Boating practices causes shoreline erosion within 300 m or less of the shore, and the resuspension of sediments in shallow areas of the lake (Mercier-Blais & Prairie, 2014; Raymond & Galvez-Cloutier, 2015). The impact of black waters discharge from boats on the lake is unknown, but free public discharge stations are located only at the two extremity of the lake, in Magog and Newport.

2.3.5. Other-TMDL estimates

Other sources of phosphorus contribute 17.2 mT/y or 32.7% of the total Vermont loading into Lake Memphremagog. Using TMDL estimates, this breaks down to 2.8% from water/wetlands, 9.4% from forests/shrubs, and 20.5% from stream channel erosion. Stream channel erosion is primarily caused by conversions from natural land to cleared land or agricultural land. In Quebec, loading from forest/shrubs and water/wetlands are estimated to contribute 3.5 mT/y or 21.9% of the total loading from Quebec. This breaks down to 7.5% from wetland/water and 14.4% from forest/shrub. Loading estimates from stream channel erosion in Quebec were not calculated in the TMDL. In Vermont, the majority of phosphorus loading from the stream channel erosion was estimated to come from the lower reaches of the Black and Barton Rivers of which there are not any rivers of a similar size in the Quebec portion of the watershed. For this reason, it is not expected that stream channel erosion would be a significant loading source for the Quebec portions of the watershed but additional analysis is needed to confirm.

2.4. Effects of Nutrients on the Lake Memphremagog Ecosystem

While eutrophication can be a natural process of aging of lakes characterized by an increase in the productivity of a lake, excessive inputs of nutrients (particularly phosphorus, which is the principal limiting nutrient for algae) from human activities can have several negative effects on aquatic ecosystems, like Lake Memphremagog: i) the decrease in biodiversity and changes in dominant biota; ii) the decline in ecologically sensitive species and increase in tolerant species; iii) the increase in plant and animal biomass; iv) the increase in turbidity; v) the increase in organic matter, leading to high sedimentation; vi) the development of anoxic conditions (Environment Canada, 2004).

2.4.1. Cyanobacteria blooms

Cyanobacteria, also known as “blue-green algae”, are aquatic prokaryotes that under the right conditions can form blooms, which refer to the result of a massive proliferation phase, resulting in a significant appearance of biomass, that may persist longer or shorter depending on the case (Lavoie *et al.*, 2007b). Under certain conditions, cyanobacteria rise to the surface and accumulate in the form of scum. The scum can then be swept by the wind and can concentrate near the shore. Some species are capable of producing toxic compounds known as cyanotoxins. The contact, the ingestion or the inhalation of cyanobacteria or cyanotoxins can affect the health birds, fish, and other wildlife, as well as humans. Cyanobacteria blooms can impact swimming, other recreational activities and water supply uses, and some beaches may be closed to swimmers. The cyanotoxins can be difficult to remove from water without specific treatment systems (Ellis, 2009).

Phosphorus is generally the principal nutrient responsible for cyanobacteria blooms (Lavoie *et al.*, 2007b). Some meteorological factors also influence the accumulation of cyanobacteria by affecting the thermic stratification of lakes: calm periods and high temperatures favour the stability of the water column which benefit the cyanobacteria. While phosphorus and the stability of the water column seem to be the main factors responsible for the cyanobacteria proliferation, nitrogen is also a determining factor in the production of the toxins according to several studies (Lavoie *et al.*, 2007b). Climate change can stimulate the formation of algal blooms by increasing water temperatures and the frequency of high intensity rainfall events. Several species of cyanobacteria will further develop when the waters are warmer. In addition, high intensity rainfall events leach soil and lead to more phosphorus in water bodies.

Between 2006 and 2018, 145 cyanobacteria bloom observations have been reported by citizens, organizations or municipalities to the Ministry of Environment and Fight against Climate Change (MELCC, *Ministère de l'Environment et de la Lutte contre les Changements Climatiques*) on the Quebec side of Lake Memphremagog (Appendix 2-5). The most bloom observations have been reported in Fitch Bay (38), Greene Bay (26) and Magog Bay (19), particularly in 2007 (18), 2008 (30) and 2012 (20). Not all the 145 reported cyanobacteria blooms were analyzed in the laboratory by MELCC to confirm the presence of a bloom. The MELCC considers that 20,000 cells/mL reflects the presence of a bloom. From 2004 to 2018 inclusively, 39 samples confirmed the presence of a cyanobacteria bloom (≥20,000 cells/mL) on the 149 samples analyzed with microscope by the MELCC (MELCC, 2019, unpublished data).

Between 2006-2017 there were 11 observations of cyanobacteria made by cyanobacteria volunteer monitors on the Vermont portion of Lake Memphremagog. The results presented do not necessarily mean that the issue of cyanobacteria is more important on the Quebec portion of the lake. Cyanobacteria monitoring and sampling methods are different in Quebec and Vermont and the results are not comparable. Appendix 2-5 lists the date and location of recorded observations. Full data sets are available as part of the annual summaries of Vermont's volunteer monitoring data from 2012 to the present is available online at: http://www.healthvermont.gov/tracking/cyanobacteria-tracker .

2.4.2. Hypoxia

Hypoxia, or low oxygen, is commonly defined as dissolved oxygen levels at or below the 2-3 mg/L range (Arend, 2011). It occurs in the bottom layer (hypolimnion) of some highly productive areas of lakes typically during the late summer. As organic matter such as algae decomposes, bacteria consume oxygen in the water column, leading to oxygen depletion. Insofar as nutrient loading can increase the frequency, density and duration of algal blooms, nutrient loading indirectly increases the frequency and areal extent of hypoxia in lakes. Hypoxia can have negative impact on fish. It can limit fish growth, survival, and reproductive capacity, can lead to shifts in species distribution and, less frequently, lead to fish kills. In extreme cases, anoxia (absence of oxygen) can lead to the release of phosphorus linked to the iron in the sediments and can represent an additional phosphorus load to a water body.

Profiles of dissolved oxygen were taken six times a year between May and August, in 2013 to 2016, at 10 stations in Lake Memphremagog (MCI, 2013a; 2014a; 2015a; 2016a). One of these profiles was also done in October of 2016 at the 10 stations. These results show that hypoxia has never been observed at three of the 10 stations (Magog River, Sargent Bay and the central part of the lake, where the cable of the oximeter do not reach the bottom). Hypoxia has been measured on rare occasions at the bottom of six stations (from one to three times on the 24 sampling days; site 03020090, 03020092, 03020093, 03020094, 03020096, 03020246 of Figure 2-6, see Appendix 2-6). Hypoxia occurs frequently at only one station, at the last 4m of the south-west station of Fitch Bay, which is around 17m deep (site 03020092). The bottom of this station has low concentrations of oxygen every year from the month of July to the end of the monitoring season. Frequent profiles have been taken in Vermont since 2005 in both South Bay and at two locations in the center of the main lake in Vermont and there have only been isolated occurrences of hypoxia measured at one meter above the bottom in the main lake stations (Memph 03 and Memph 04 of Figure 2-6). The segmented lake model developed for the Lake Memphremagog phosphorus TMDL did not suggest substantial internal phosphorus loading from any lake segments. There is a need to better characterize the potential for internal phosphorus loading particularly with considerations for changes in the length of stratification which may occur with climate change.

2.4.3. Effects on aquatic fauna and flora

When phosphorous becomes too abundant, it causes excessive growth of aquatic plants and affects the composition of aquatic fauna present. It is difficult to characterize the effect of nutrients on wildlife in Lake Memphremagog, because few projects have studied the evolution of the flora and fauna. In 2004 and 2005, the project Operation Healthy Lake described the condition of the littoral zone around Lake Memphremagog (sediments, aquatic plants and green algae) (RAPPEL & MCI, 2005; 2006). The study showed that a number of regions of the littoral zone present a considerable accumulation of fine particles, a proliferation of aquatic plants, significant communities of Eurasian watermilfoil and abundant green algae. In 2015, a study in Fitch Bay showed an increase of aquatic plants coverage on the littoral from 41% to 55 % between 2004 and 2015 (MCI, 2016b).

Since 2002, the Ministry of Forests, Wildlife and Parks (MFFP, *Ministère des Forêts, de la Faune et des Parcs*) sampled 32 species of fish in Lake Memphremagog including five species of salmonids, as the Lake Trout (*Salvelinus namaycush*) and the Landlocked Salmon (*Salmo salar)*, indicator species of the environment quality (MFFP, 2018, unpublished data). As explained previously, the algae blooms and the hypoxia can have different impacts on the fish communities. The suspended matters rich in nutrients can also have impacts on wildlife: they can cause abrasion of the gills of fishes, fill in spawning grounds, decrease dissolved oxygen concentrations in the water, and create muddy bottoms favorable to the implantation and growth of aquatic plants. The impacts of the suspended matters are more visible at the mouth of some tributaries of Lake Memphremagog, including Castle Brook and Fitch Brook, where deltas have formed (JFSA, 2016; Beaudin *et al*., 2017).

Various invasive species are found in Lake Memphremagog, including the Eurasian watermilfoil (*Myriophyllum spicatum*), curly leaf pondweed (*Potamogeton crispus*), starry stonewort (*Nitellopsis obtusa*) and zebra mussel (*Dreissena polymorpha*) (RAPPEL & MCI, 2005; 2006; VDEC, 2015; Picard & Doyon, 2018). The Eurasian watermilfoil is the more abundant exotic invasive plant in Lake Memphremagog: it is found in nearly the entire littoral zone of the lake (RAPPEL & MCI, 2005; 2006; MELCC, 2018). Curly leaf pondweed is found in various areas around the lake (RAPPEL & MCI, 2005; 2006). Starry stonewort was found in 2015 in Scott's Cove in the Vermont portion of Lake Memphremagog. It has since been found in South Bay and in the main lake in Vermont, but has not yet been found in Quebec (VDEC, 2015a). The establishment of zebra mussel colonies was confirmed in 2018 in Quebec but have not been found in Vermont (Picard & Doyon, 2018).

2.4.4. Human Health and socio-economic effects

Nutrient loading in an aquatic ecosystem may adversely affect human health and local economy in numerous ways: i) the treatment of potable water may be difficult and costly; ii) the water supply may have an unacceptable taste or odor problem; iii) the water may be harmful to health; iv) the aesthetic/ recreational value of the water body may decrease; v) the macrophyte growth may impede water flow and navigation; vi) important species for the local economy (e.g. salmonids) may disappear (Environment Canada, 2004).

Nutrient loading can have adverse effects on human health of the lake users by increasing the risk of swimmer's itch (or cercarial dermatitis) and the frequency of the cyanobacteria blooms in Lake Memphremagog. Swimmer's itch is an immune reaction caused by schistosomes (parasites) found in aquatic snails and birds. It occurs after people are infected by a free-living transmission stage of the parasite (cercaria) which emerge from the snail in search of the next host. The parasite is unable to complete its life cycle in humans, and the cercaria dies in human skin, causing itchy papules lasting up to ten days. The risk of swimmer's itch in France and Russia has been linked to eutrophication as the nutrients increase the snail and bird population (Locke & Marcogliese, 2005). In Lake Memphremagog, the trends in this infection frequency is unknown, but 23 cases were recorded in the Quebec side of lake Memphremagog during the summer of 2013 (MCI, 2013b).

Concerning cyanobacteria impacts on human health, for the Province of Quebec, the health standard is 1.5 µg/L of the microcystin-LR (MC-LR) equivalent toxicity for drinking water by the *Regulation respecting the quality of drinking water* (*Règlement sur la qualité de l'eau potable*, Chapitre Q-2, r. 40) from the *Environment Quality Act* (LQE, *Loi sur la qualité de l'environnement*). The guideline for swimming and other recreational water activities is less than 16 µg/L MC-LR equivalent toxicity (INSPQ, 2017). An epidemiologic study done in three lakes in the Province of Quebec showed that the risk of severe gastrointestinal symptoms occurring during recreational activities with direct or indirect contact with water, increases according to cyanobacteria abundance classes: less than 20,000 cel./mL; from 20,000 to 100,000 cel./mL; and more than 100,000 cel./ml (Lévesques *et al*., 2014).

The microcystin-LR equivalent toxicity concentrations in cyanobacteria blooms in Lake Memphremagog were evaluated by the MELCC between 2004 and 2018 (Quebec/Vermont Steering Committee, 2008; MELCC, 2018, unpublished data). On the 39 cyanobacteria samples confirmed for blooms by microscope (≥20 000 cells/mL), 30 were analyzed for microcystins. The microcystin results were:

- 17 samples without microcystin detection;
- 8 samples with microscytin detection but lower than 1.5 µg/L MC-LR equivalent toxicity;
- 4 samples from 1,5 µg/L to less than 16 µg/L MC-LR equivalent toxicity. Note that 1,5 µg/L maximum shouldn't normally be apply for lake water. That's a standard for drinking water. Then, the standard value should be applied at the faucet water after water treatment;
- 1 sample over recreational guideline of 16 µg/L MC-LR equivalent toxicity.[1]

To prevent the effects of cyanobacteria blooms on human health, the Ministry of Health and Social Services (MSSS, *Ministère de la Santé et des Services sociaux*) recommends to stay 3m away from a cyanobacteria bloom, avoid contact with it, avoid any activities of direct or indirect contact with water 24 hours after it disappearance, and to rinse quickly with uncontaminated water after an inadvertent contact (Gouvernement du Québec, 2019a).

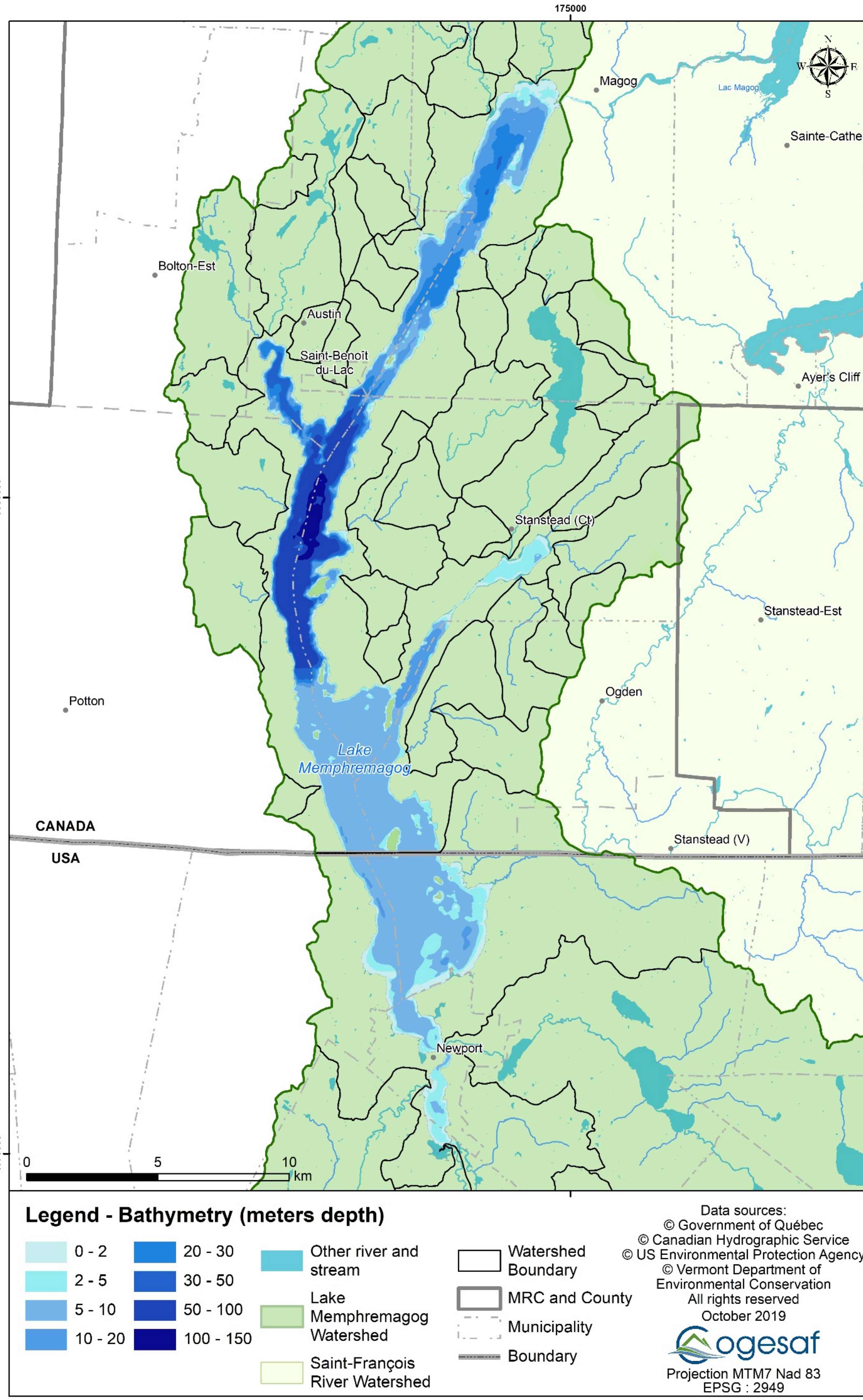
The incidence of cyanobacteria blooms can also have socio-economic effects on the users of the lake. Preventive drinking water avoidance advisories had been issued in 2007 in Potton and Saint-Benoit-du-Lac (MDDEFP, 2014). Some residents around the lake who own individual water intake may have avoided or stopped to use Lake Memphremagog as their drinking water source. Public preventive warnings and beach closures are sometimes issued in swimming areas in both Quebec and Vermont. The last warning issued because of the presence of cyanobacteria blooms was between July 1st and July 4th, 2018 for a beach at Magog (Doyon, S., MCI, 2019, pers. com.). The impact off the cyanobacteria blooms on the property values around Lake Memphremagog are unknown, but a decrease of the value of the properties have been observed around other water bodies (Blais, 2002).

[1] Note that cyanobacteria densities and cyanotoxins concentrations change quickly in time and space. Then, those results show pictures for specific times and days and specific locations in lake.

It is difficult to measure how the increase of the aquatic plant cover and of the suspended matter concentrations (which affect the esthetic quality of the water) affect the recreation, tourism, and property values around Lake Memphremagog. One socio-economic effect example is the reduction of the boating practice in some areas. A segment of Castle Brook was straightened in the beginning of the 1960s to allow boating to Lake Memphremagog (JFSA, 2016). The capacity to navigate in this tributary was a relevant incentive to purchase a residence for whom arrived after this significant modification of Castle Brook. Since then, the brook began to fill with sediments mainly because of a normal morphological readjustment of the straightened segment (JFSA, 2016). The boating practice is now threatened in this area. It is estimated that best management practices would reduce sediment loading of 5 to 15% of the total annual loading and will allow to extend the boating practice in this area (JFSA, 2016).

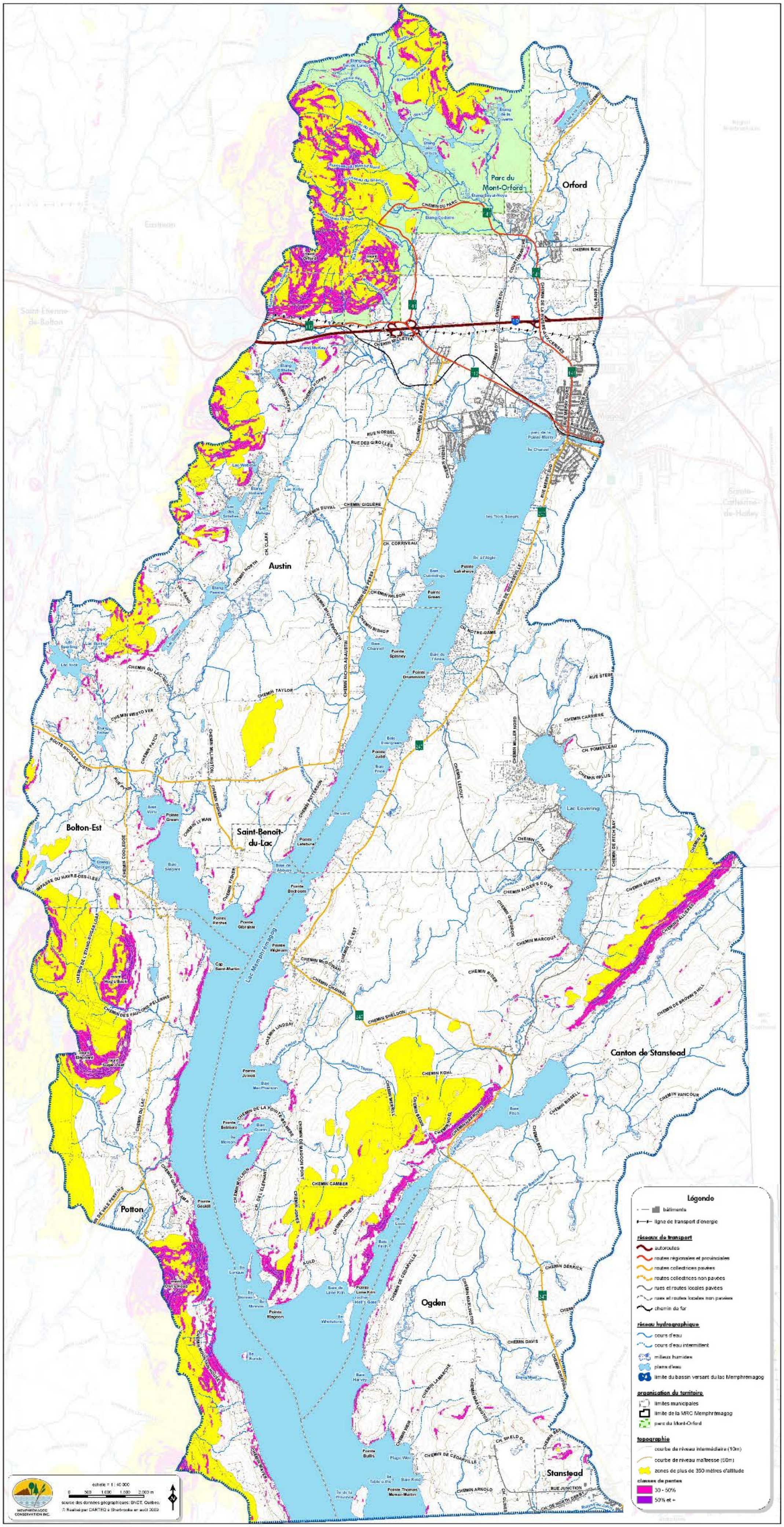
Appendix 2-1

Bathymetry of Lake Memphremagog


175000
5000000
4975000
Magog
Lac Magog
Sainte-Cather
Bolton-Est
Austin
Saint-Benoît
du-Lac
Ayer's Cliff
Stanstead (Ct)
Stanstead-Est
Potton
Ogden
Lake
Memphremagog
CANADA
USA
Stanstead (V)
Newport
0
5
10
km
Legend - Bathymetry (meters depth)
0 - 2
2 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 100
100 - 150
Other river and stream
Lake Memphremagog Watershed
Saint-François River Watershed
Watershed Boundary
MRC and County
Municipality
Boundary
Data sources:
© Government of Québec
© Canadian Hydrographic Service
© US Environmental Protection Agency
© Vermont Department of Environmental Conservation
All rights reserved
October 2019
ogesaf
Projection MTM7 Nad 83
EPSG : 2949

Appendix 2-2

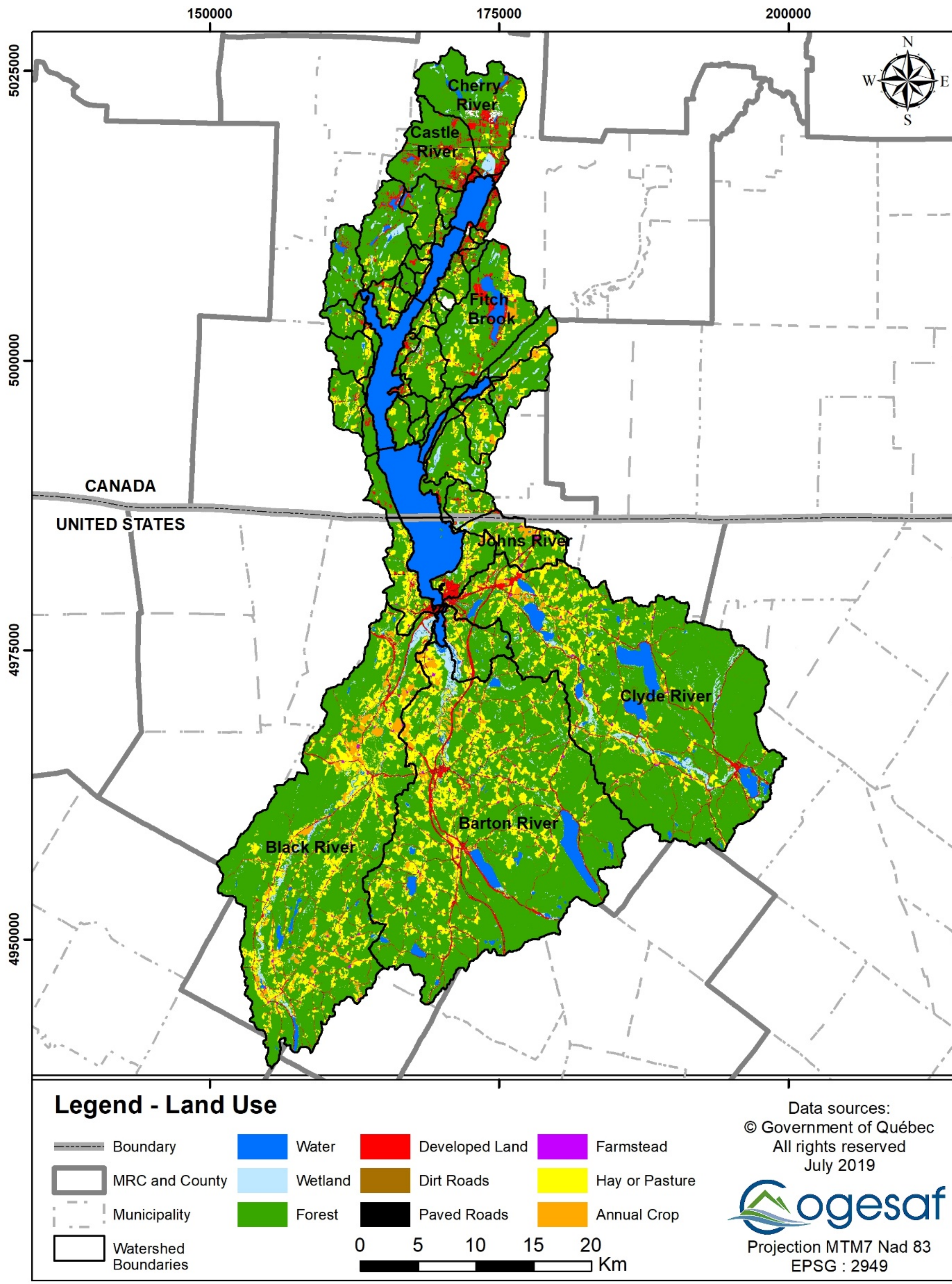
Lake Memphremagog Watershed: Steep slopes and elevation areas higher than 350m



Parc du Mont-Orford
Orford
Austin
Saint-Benoît-du-Lac
Bolton-Est
Lac Memphrémagog
Lac Lovering
Canton de Stanstead
Potton
Ogden
Stanstead
Légende
bâtiments
ligne de transport d'énergie
réseaux de transport
autoroutes
routes régionales et provinciales
routes collectrices pavées
routes collectrices non pavées
rues et routes locales pavées
rues et routes locales non pavées
chemin de fer
réseau hydrographique
cours d'eau
cours d'eau intermittent
milieux humides
plans d'eau
limite du bassin versant du lac Memphrémagog
organisation du territoire
limites municipales
limite de la MRC Memphrémagog
parc du Mont-Orford
topographie
courbe de niveau intermédiaire (10m)
courbe de niveau maîtresse (50m)
zones de plus de 350 mètres d'altitude
classes de pentes
30 - 50%
50% et +
MEMPHRÉMAGOG CONSERVATION INC.
échelle = 1 : 40 000
0 500 1 000 1 500 2 000 m
source des données géographiques: BNDT, Québec.
Réalisé par CARTEQ à Sherbrooke en août 2009.

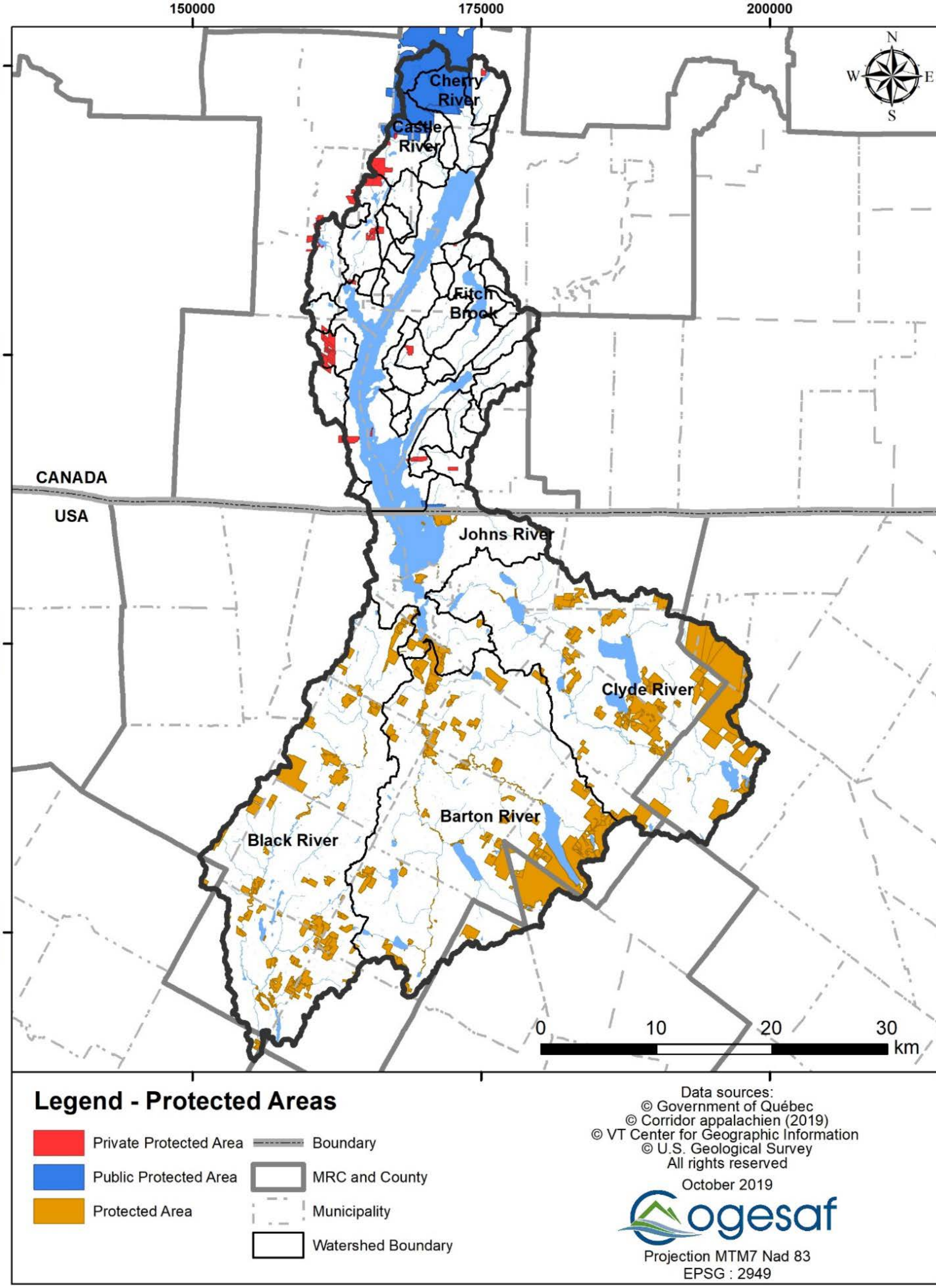
Appendix 2-3

Map of Lake Memphremagog Watershed Land Use


150000
175000
200000
5025000
5000000
4975000
4950000
N
S
E
W
Cherry River
Castle River
Fitch Brook
CANADA
UNITED STATES
Johns River
Clyde River
Barton River
Black River
Legend - Land Use
Boundary
MRC and County
Municipality
Watershed Boundaries
Water
Wetland
Forest
Developed Land
Dirt Roads
Paved Roads
Farmstead
Hay or Pasture
Annual Crop
0 5 10 15 20
Km
Data sources:
© Government of Québec
All rights reserved
July 2019
ogesaf
Projection MTM7 Nad 83
EPSG : 2949

Appendix 2-4

Protected Areas in Lake Memphremagog Watershed, Canada and United States



Note: In Quebec, the entire superficies of the protected areas are shown on the map, when in Vermont, the superficies inside the watershed appear. In Quebec, a differentiation between private and public protected areas is available.

Appendix 2-5

Reported Cyanobacteria Observations on Lake Memphremagog, Canada and United States

Table 2-9. Reported Cyanobacteria Observations in the Quebec portion of Lake Memphremagog, 2006-2018

Date	Location
08-25-2006	Cedarville Dock
10-06-2006	Carlton Oliver Road Potton; Greene Bay
11-10-2006	Southière Beach
06-18-2007	Greene Bay
06-25-2007	Greene Bay
07-03-2007	Forand landing Fitch Bay
07-10-2007	Fitch Bay; Greene Bay
07-31-2007	Greene Bay
08-02-2007	Macpherson Bay
09-18-2007	Marina Fitch Bay
09-23-2007	Channel Bay
09-27-2007	Carlton Oliver Road Potton; Entrance of Fitch Bay at the tip of the Wetstone Island
10-18-2007	Greene Bay
10-19-2007	Greene Bay
11-04-2007	Viens Road Magog
10-05-2007	Sargent Bay; Quinn Bay; Knowlton landing
10-06-2007	Between the Abbey and Bryant's landing
06-22-2008	Channel Bay; Greene Bay
06-23-2008	Channel Bay; Greene Bay; Saint-Benoît-du-lac
06-25-2008	Between Southière-sur-lel-lac and Cummins Bay; Channel Bay; Greene Bay
06-26-2008	Hermitage Club; De l'Anse Bay; Marina Magog
06-27-2008	Hermitage Club; Fitch Bay
06-29-2008	Knowlton Landing; Greene Bay
07-06-2008	Bullis Point
07-20-2008	From Cummins Bay to Bryant’s Landing Austin
08-05-2008	Fitch Bay
08-11-2008	Greene Bay
09-13-2008	From Owl’s Head to Newport; Fitch Bay
09-23-2008	Villas de l’Anse
10-13-2008	East side of Magoon Point, Hermitage Club
10-15-2008	Hermitage Club
10-18-2008	From Southière Beach to Bryant's landing
10-26-2008	Greene Bay
10-27-2008	Greene Bay
11-06-2008	Sargent Bay
11-08-2008	Greene Bay
06-19-2009	Fitch Bay
06-23-2009	Greene Bay
06-28-2009	Greene Bay
07-09-2009	des Cantons Beach
10-04-2009	Greene Bay
06-13-2010	Channel Bay; Bryant's landing; Greene Bay; Sargent Bay; Southière Beach; Marina Saint-Benoît;
06-14-2010	Fitch Bay
06-18-2010	Marina Saint-Benoît; William Abbott Road Potton
06-22-2010	Quinn Bay

06-10-2011	Bryant's Landing
07-19-2011	All the lake
07-28-2011	Marina Merry Club
09-20-2011	Fitch Bay (Forand Park)
09-25-2011	Owl's Head until the US border
10-19-2011	Fitch Bay
10-27-2011	Fitch Bay
11-15-2011	Greene Bay
11-24-2011	Fitch Bay (Bombardier Road)
12-06-2011	Sargent Bay
07-01-2012	From Magog to Sargent Bay; Greene Bay
07-11-2012	All the lake
07-13-2012	Greene Bay
07-15-2012	William Abbott Road Potton; Beach Ouest Macpherson Dock
07-16-2012	Knowlton Landing Road
07-20-2012	Fischer Road Austin;
07-21-2012	Descente 22 Ogden
07-23-2012	Descente 22 Ogden
07-28-2012	Vale Perkins Dock
07-29-2012	Fitch Bay
08-09-2012	Fitch Bay
08-24-2012	Narrow Road Fitch Bay
09-02-2012	Magoon Point; Fitch Bay
10-02-2012	Fitch Bay; Lime Kiln Bay
10-12-2017	Fitch Bay (Bosquets fleury Road)
10-26-2012	Magog Bay
06-13-2013	De l'Anse Bay; Sargent Bay; Greene Bay; Center of the lake near Lord Island
06-26-2013	Greene Bay; Sargent Bay
06-27-2013	Greene Bay
07-22-2013	Sargent Bay
08-17-2013	Fitch Bay
10-12-2013	Viens Road Magog
10-29-2013	Owl's Head
07-30-2014	Magog Bay
09-19-2014	Fitch Bay
11-17-2014	Fitch Bay
06-30-2015	Marina Merry Club
07-07-2015	Magog Bay (De l'Ouest Beach)
07-25-2015	Fitch Bay
07-29-2015	Fitch Bay
08-07-2015	Fitch Bay (Forand Park)
08-08-2015	Fitch Bay (North-East)
08-22-2015	Fitch Bay (North-East)
09-01-2015	Fitch Bay (North-East)
09-02-2015	Fitch Bay (Bosquet Fleury Road)
09-21-2015	Fitch Bay (Bosquet Fleury Road)

06-25-2016	All the lake
06-28-2016	Greene Bay
06-29-2016	Merry sud Road Magog
07-12-2016	Greene Bay; Bryant Landing; Glassford Road
08-02-2016	Fitch Bay (North-East)
08-09-2016	Fitch Bay (Bedwell Road)
08-20-2016	Fitch Bay (North-East)
09-02-2016	Marina Merry Club
06-19-2017	Magog Bay (De l'Ouest Beach and De l'Est Beach)
06-20-2017	Arrow Head Road Stanstead
06-27-2018	Greene Bay; Sargent Bay; Castle brook; Merry Point
06-29-2018	Sargent Bay; Yacht Club Bay
06-30-2018	Fitch Bay; Magoon Point
07-04-2018	Marina Merry Club
08-07-2018	Fitch Bay (North-East)
08-12-2018	Narrow Road Fitch Bay
08-27-2018	Fitch Bay (North-East)
09-14-2018	Fitch Bay

(MELCC, 2018, unpublished data)

Table 2-10. Reported cyanobacteria in Vermont portion of Lake Memphremagog by volunteer monitors, 2006-2017

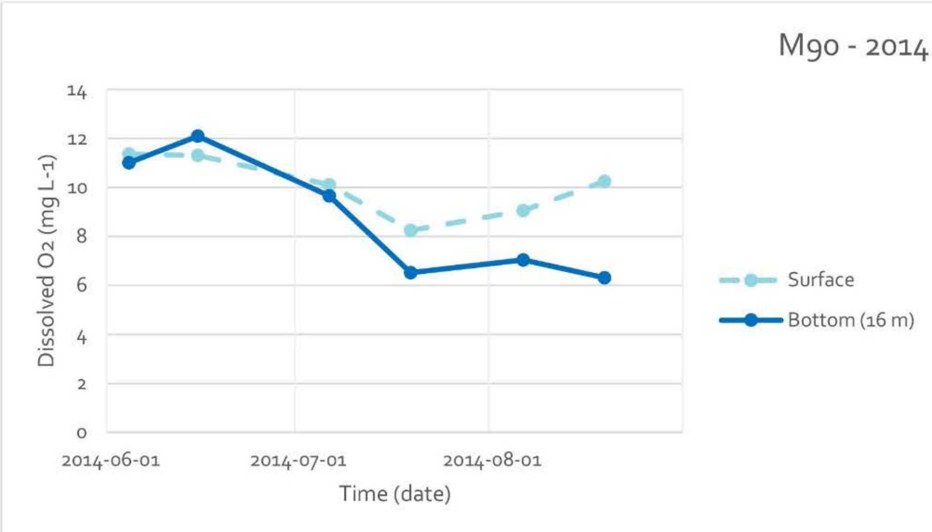
Date	Location
08-17-2006	Eagle Point
09-12-2006	Newport waterfront
06-09-2010	Derby Bay
10-12-2010	Prouty Bay
10-26-2010	North Derby Bay
10-24-2011	Eagle Point WMA
10-02-2012	Newport and east shore just south of the border
09-23-2015	Derby Bay
09-27-2016	Eagle Point WMA
09-12-2017	Newport City Dock
09-14-2017	Newport City Dock

(Vermont Department of Health, 2018; K Lambert, Pers. Comm, 2018)

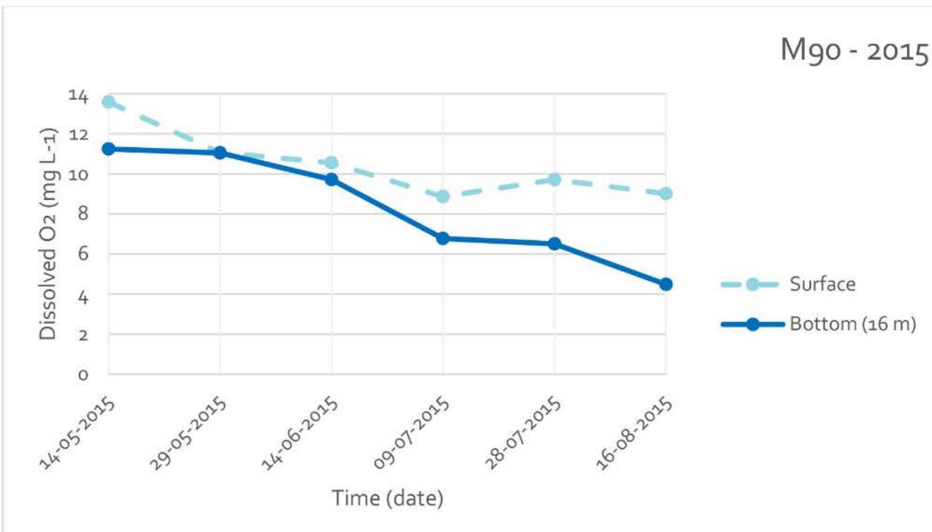
Appendix 2-6

Dissolved oxygen concentrations at 8 stations of Lake Memphremagog between 2014 and 2016

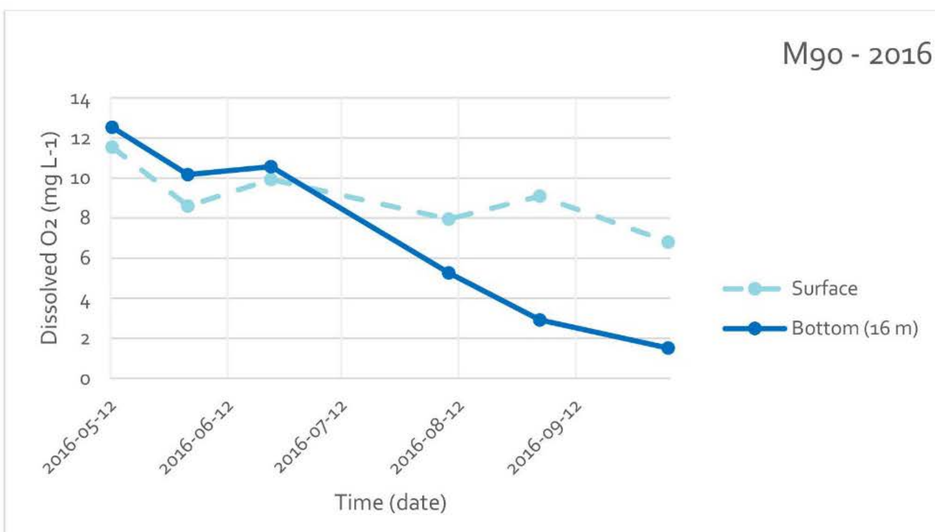
(see Figure 2-6 for the localization of the stations)



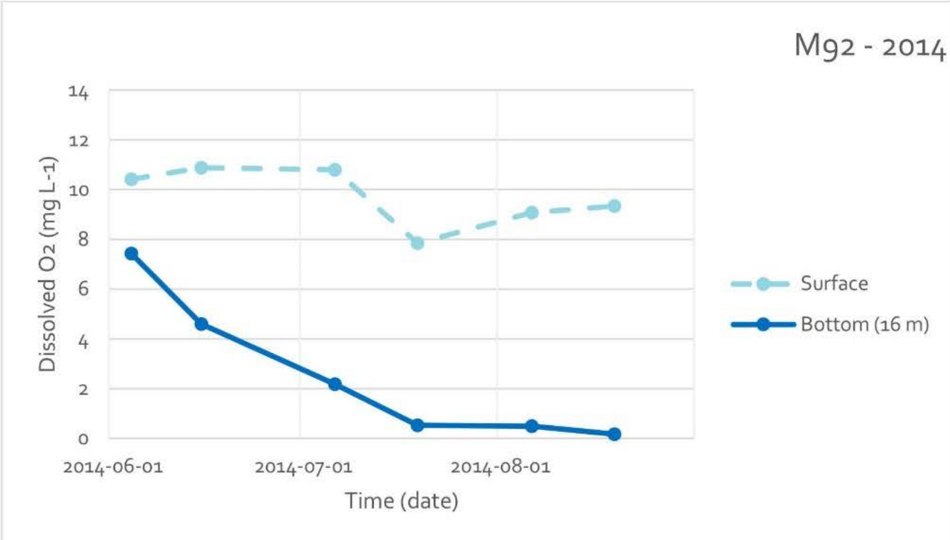
M90 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (16 m)

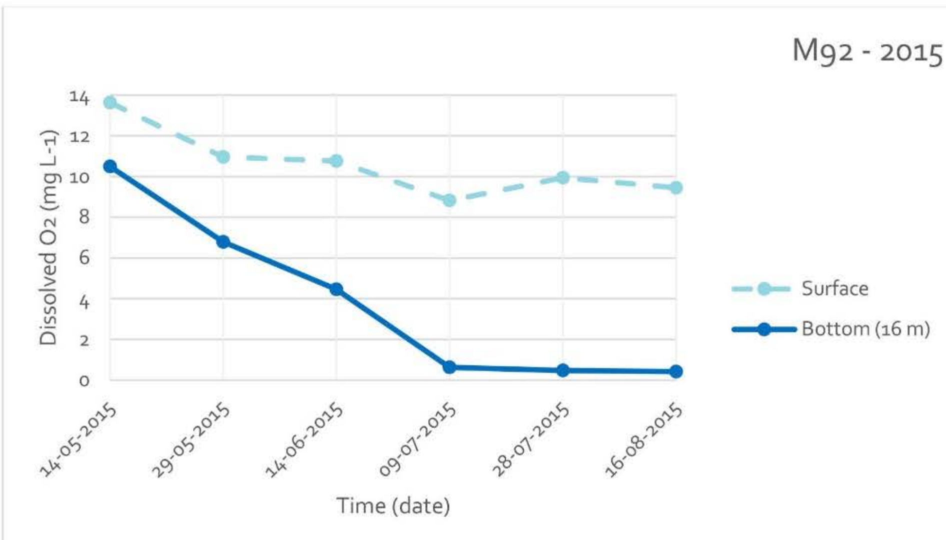


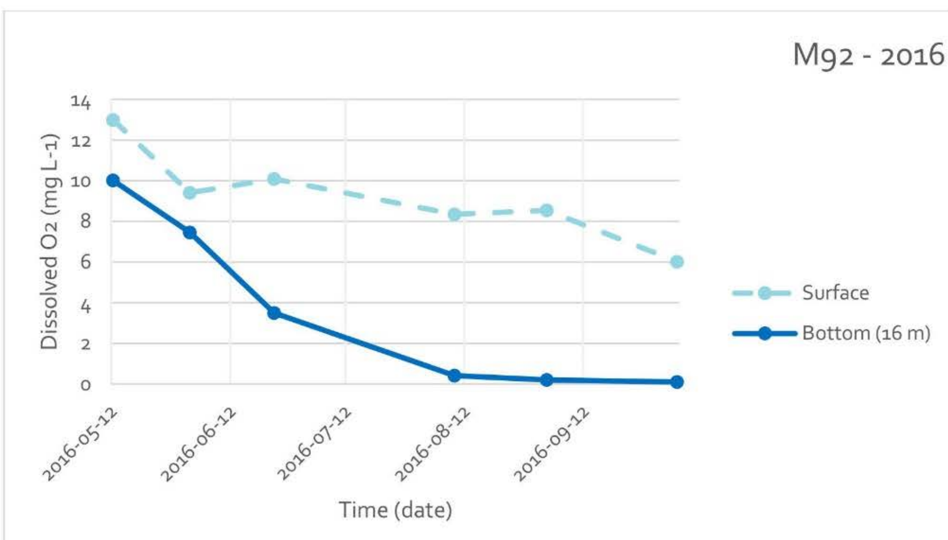
M90 - 2015
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (16 m)

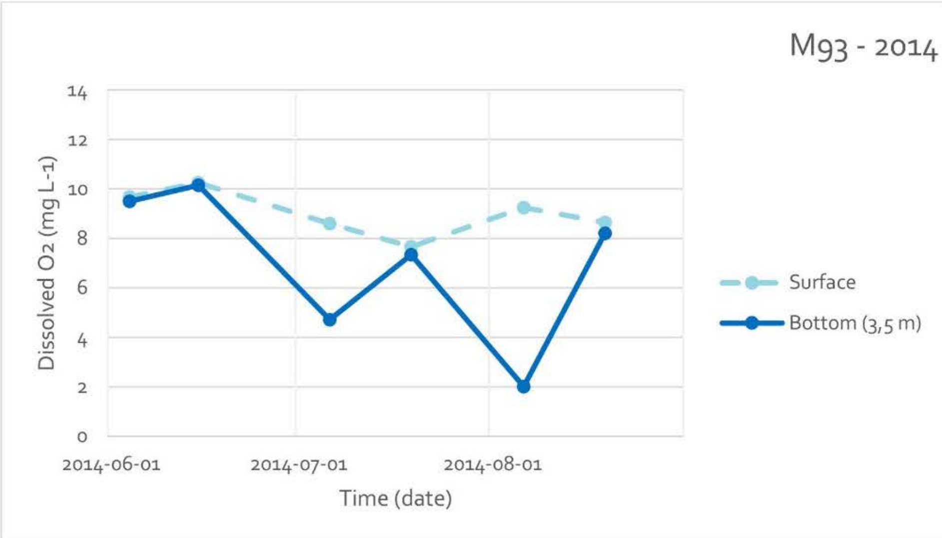


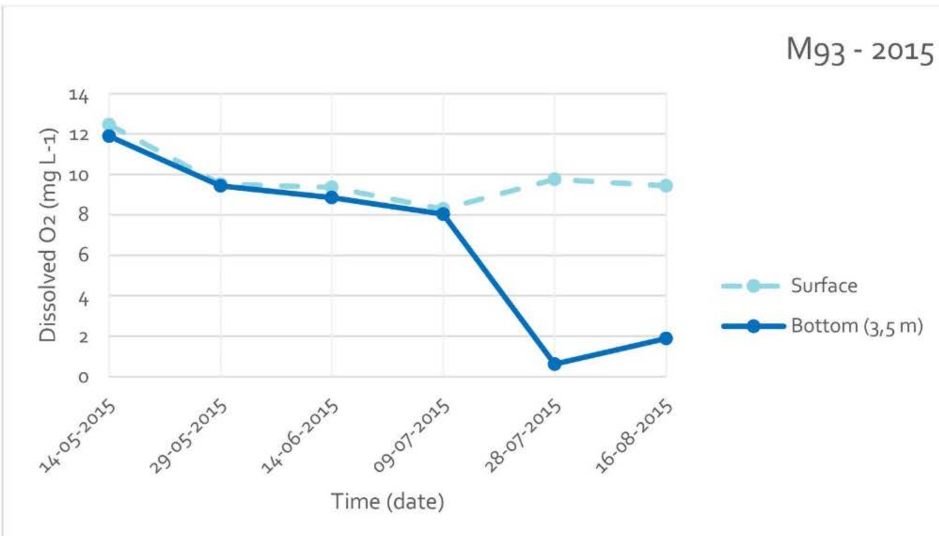
M90 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (16 m)

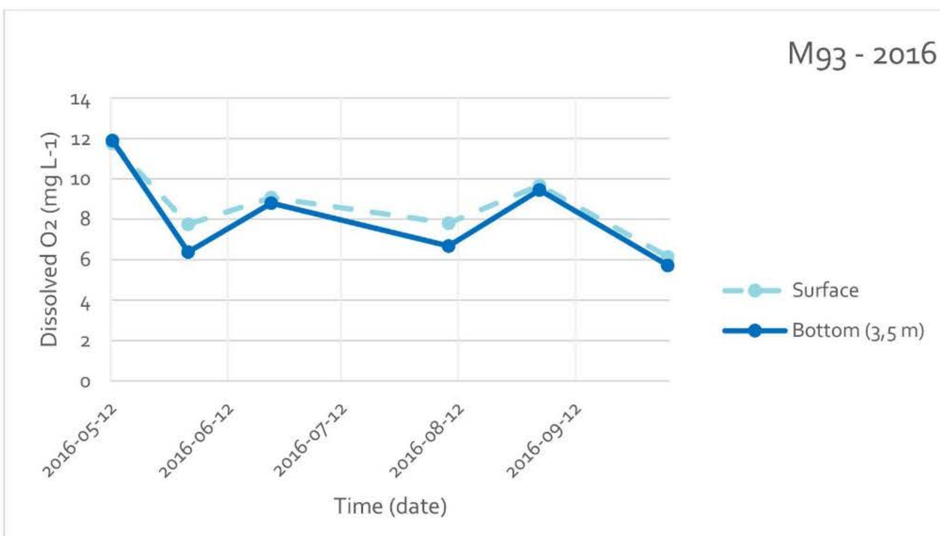

M92 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (16 m)

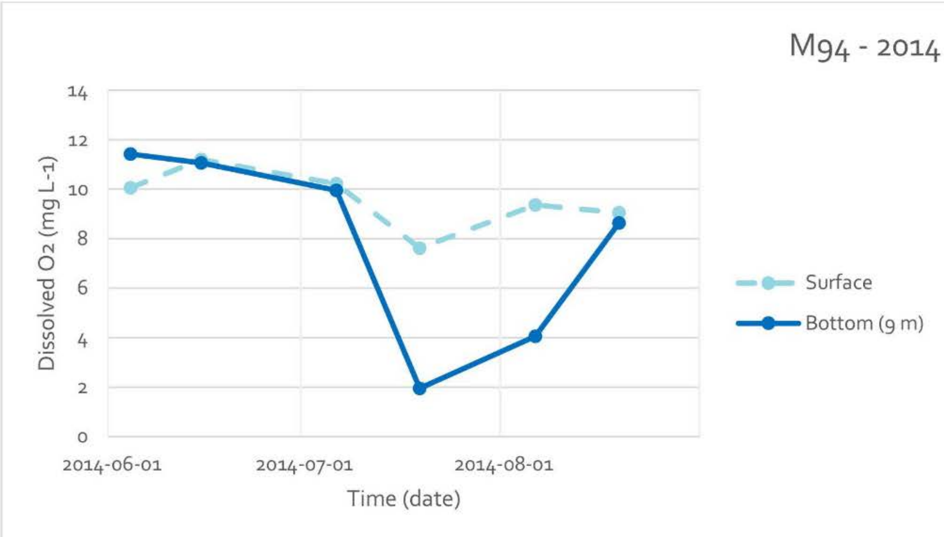

M92 - 2015
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (16 m)

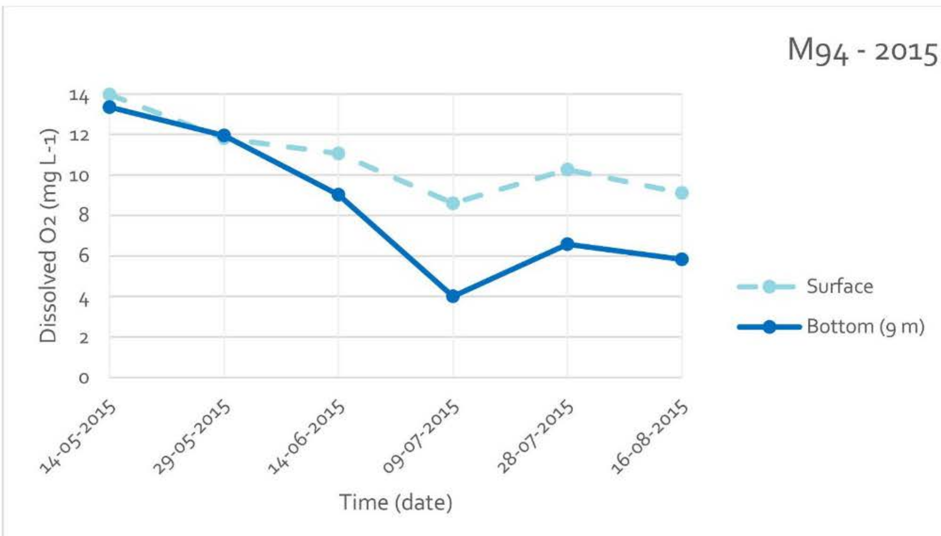

M92 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (16 m)

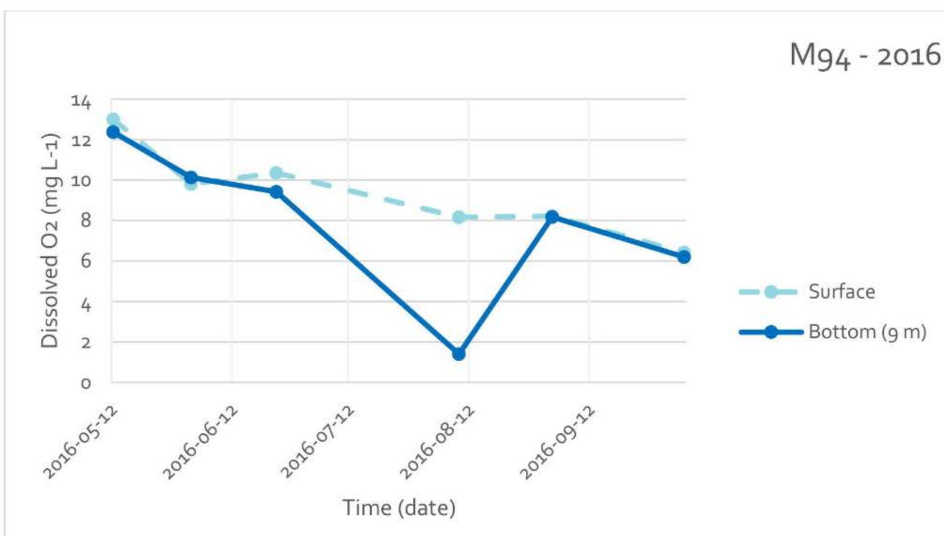

M93 - 2014
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (3,5 m)

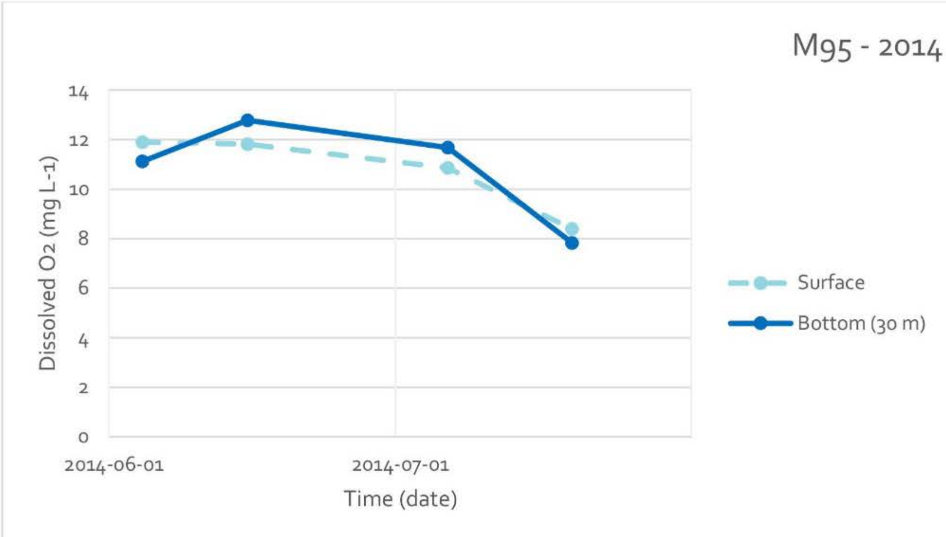

M93 - 2015
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (3,5 m)


M93 - 2016
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (3,5 m)

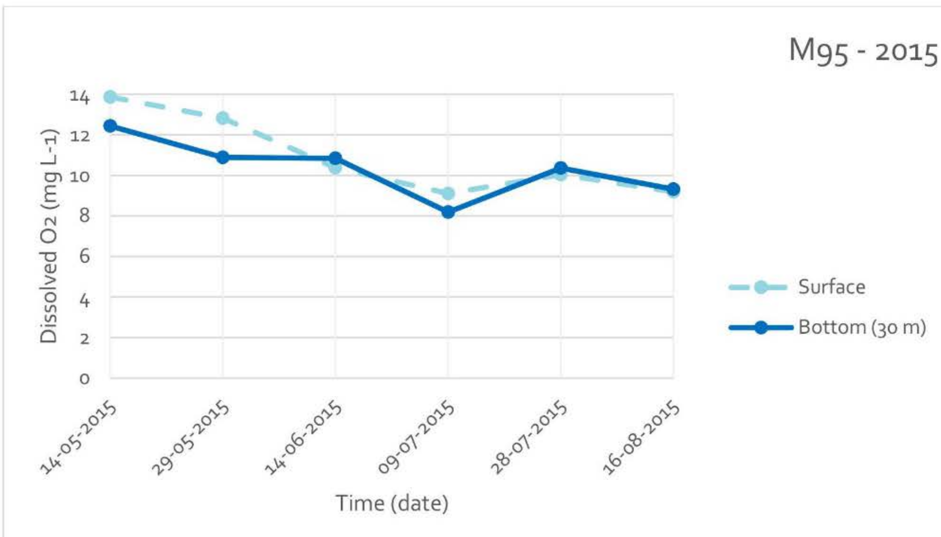

M94 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (9 m)


M94 - 2015
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (9 m)


M94 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (9 m)

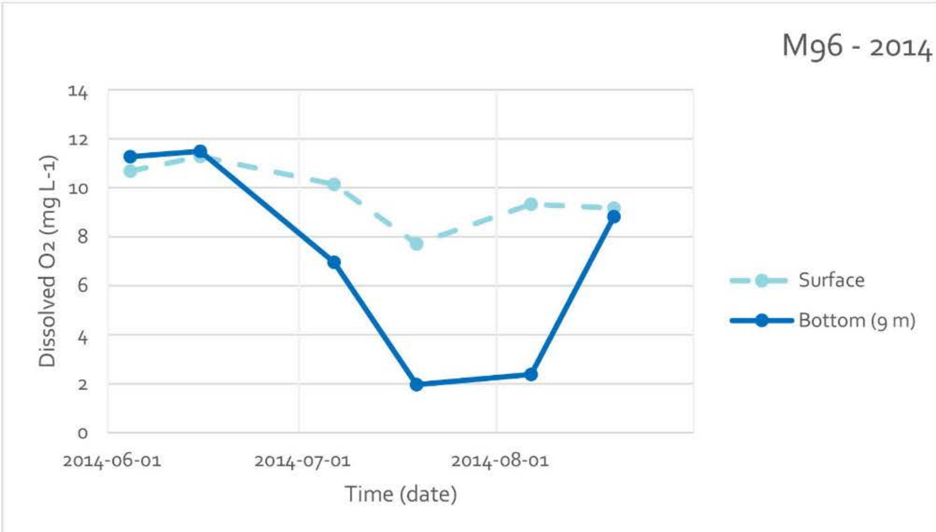


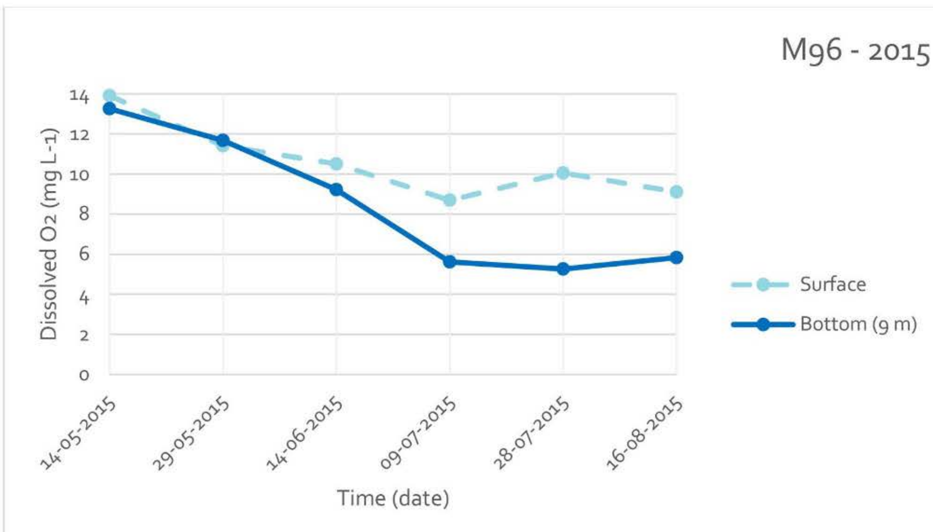
M95 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
Time (date)
Surface
Bottom (30 m)

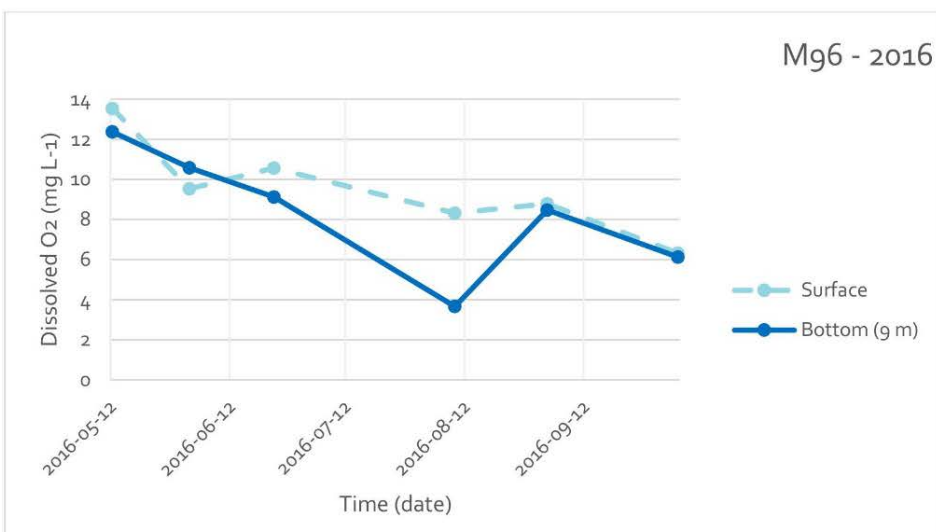


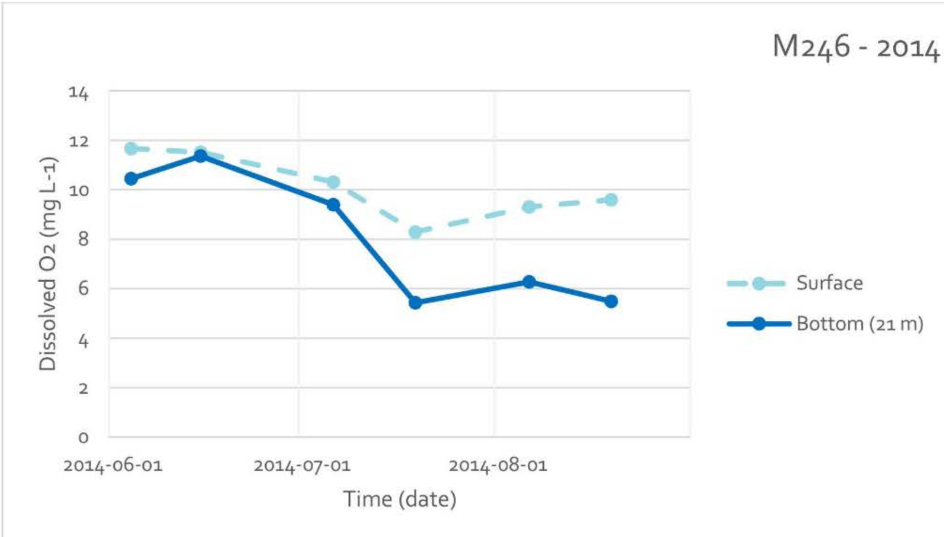
M95 - 2015
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (30 m)

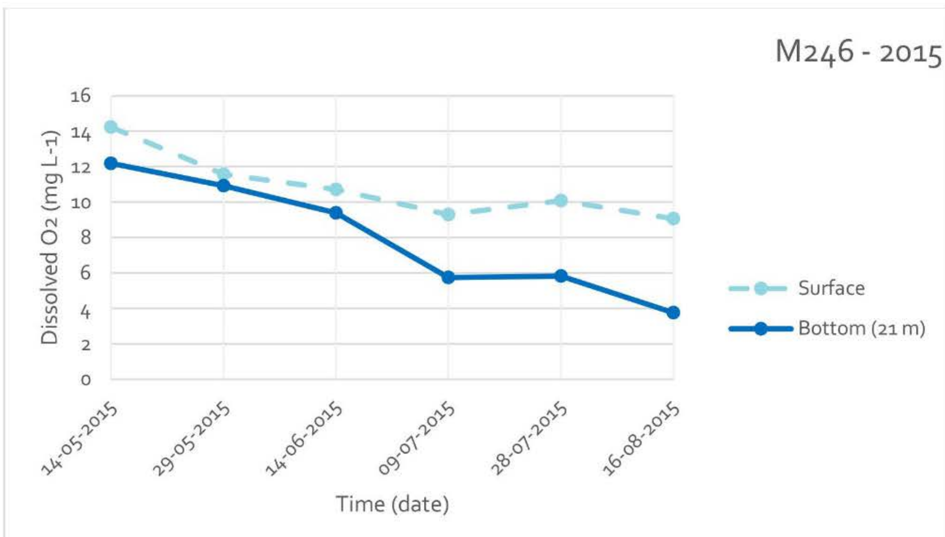
M95 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (30 m)

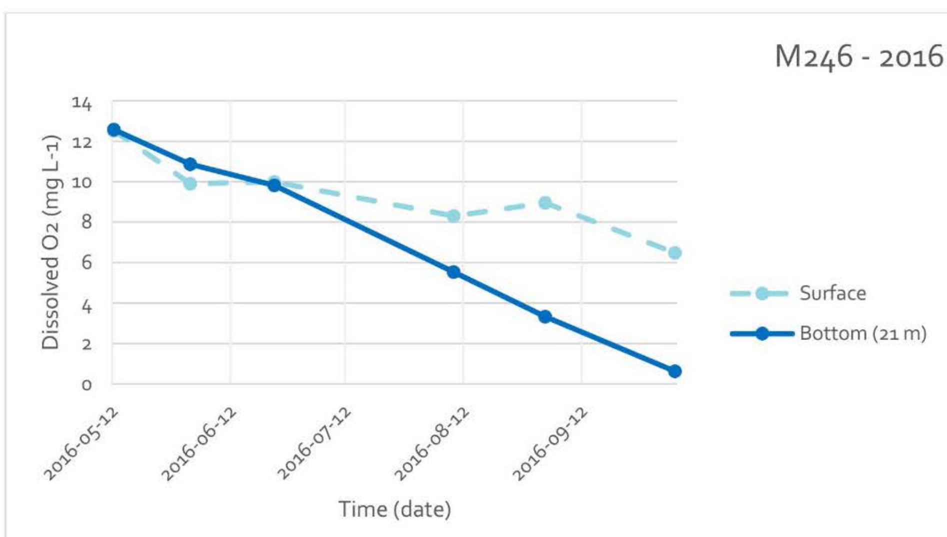

M96 - 2014
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (9 m)

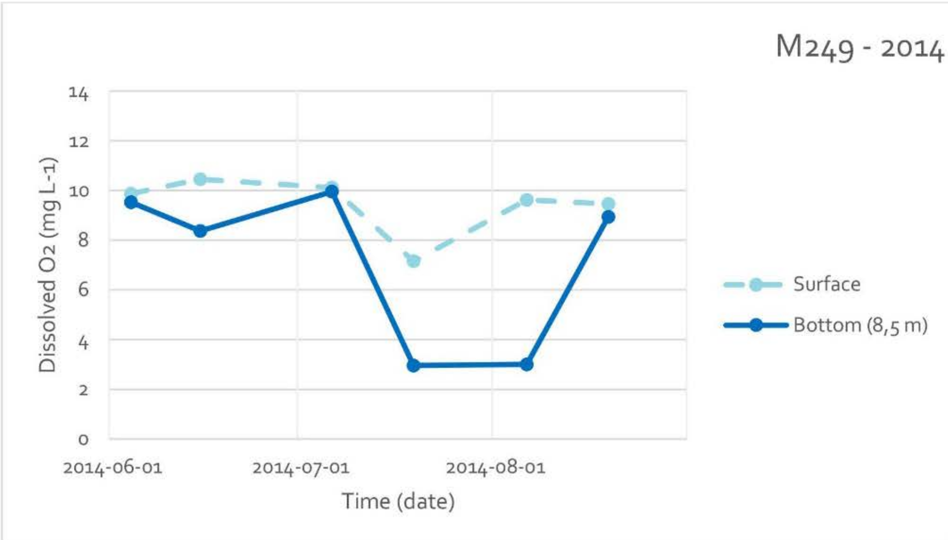

M96 - 2015
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (9 m)

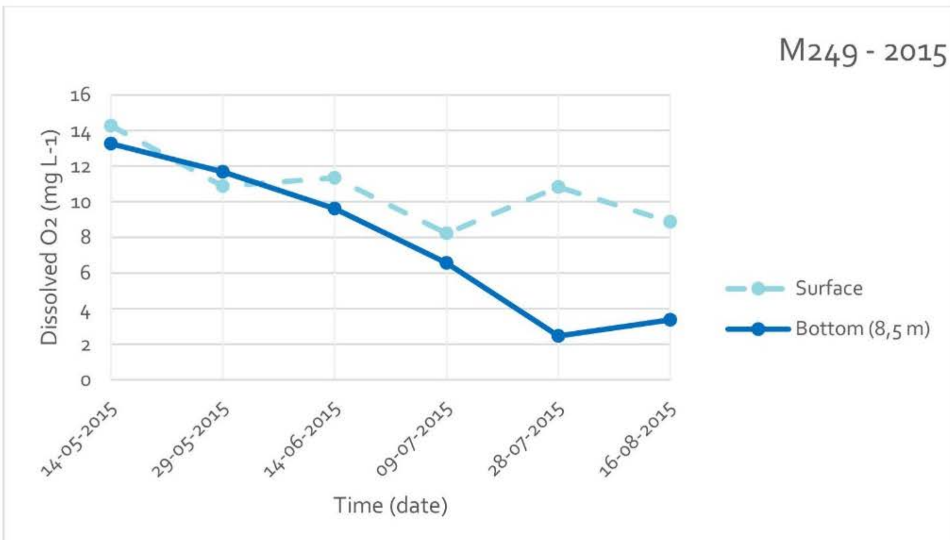

M96 - 2016
Dissolved O2 (mg L-1)
0
2
4
6
8
10
12
14
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (9 m)

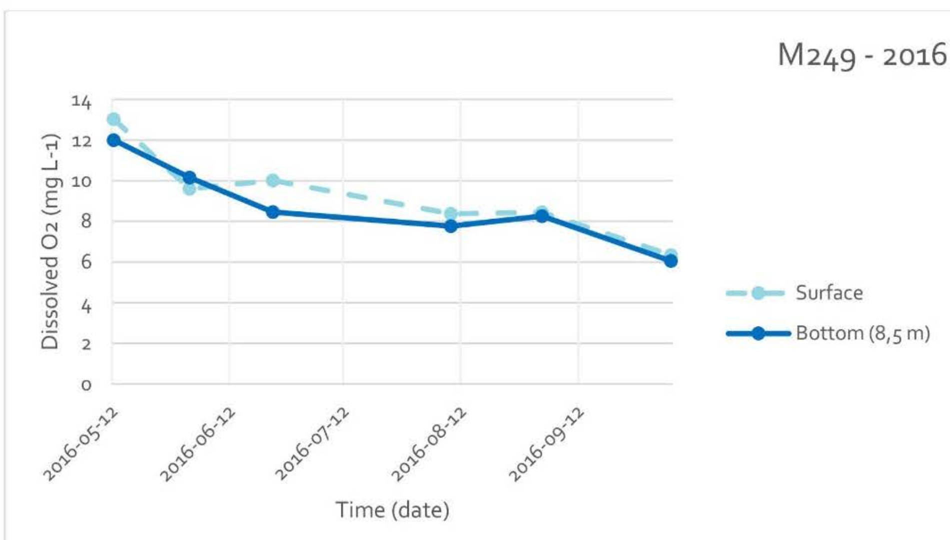

M246 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (21 m)


M246 - 2015
Dissolved O2 (mg L-1)
16
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (21 m)


M246 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (21 m)


M249 - 2014
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2014-06-01
2014-07-01
2014-08-01
Time (date)
Surface
Bottom (8,5 m)


M249 - 2015
Dissolved O2 (mg L-1)
16
14
12
10
8
6
4
2
0
14-05-2015
29-05-2015
14-06-2015
09-07-2015
28-07-2015
16-08-2015
Time (date)
Surface
Bottom (8,5 m)


M249 - 2016
Dissolved O2 (mg L-1)
14
12
10
8
6
4
2
0
2016-05-12
2016-06-12
2016-07-12
2016-08-12
2016-09-12
Time (date)
Surface
Bottom (8,5 m)

Chapter 3 Summary

Review of existing management efforts

Chapter 3 presents a review of the current efforts to reduce nutrient loading in the Memphremagog Watershed. This chapter includes details by country on stakeholders, laws and regulations, as well as current best management practices and programs to reduce nutrient loading.

Canada - Review of existing management efforts

Stakeholders working in Canada include federal, provincial, and municipal governments, non-governmental organizations, and private sector. For a list of stakeholders, please see Appendix 3-1.

The table below shows the major federal, provincial, and municipal laws and policies that regulate or affect nutrient loading in the Quebec portion of the Memphremagog Watershed.

Federal	**Provincial**	**Municipal**
Fisheries Act: 1985	Quebec Environment Quality Act (LQE, *Loi sur la qualité de l'environnement*): 1972	Memphremagog MRC Land Use Planning and Development Plan: 1999
Canada Water Act: 1985	Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (PPRLPI, *Politique de protection des rives, du littoral et des plaines inondables*): 1987	Zoning By-Laws
Canada Shipping Act: 1985, repealed 2001	Natural Heritage Conservation Act (LCPN, *Loi sur la conservation du patrimoine naturel*): 2002	Subdivision By-Laws
Canadian Environmental Protection Act: 1999	Quebec National Water Policy (PNE, *Politique nationale de l'eau*): 2002	By-Laws respecting septic systems management
	Act Affirming the Collective Nature of Water Resources and Promoting Better Governance of Water and Associated Environments (*Loi affirmant le caractère collectif des ressources en eau et visant à renforcer leur protection*): 2009	By-Laws on Comprehensive Development Plans
	Quebec Sustainable Forest Development Act (LADTF, *Loi sur l'aménagement durable du territoire forestier*): 2013	
	Quebec Wetland and Water Environments Conservation Act (LCMHH, *Loi concernant la conservation des milieux humides et hydriques*): 2017	
	Quebec Water Strategy (SQE, *Stratégie Québécoise de l'eau*): 2018	

The Quebec Water Strategy (SQE, *Stratégie Québécoise de l'eau*) announced by the government of Quebec in 2018 sets out seven policy priorities and 23 objectives to ensure the protection, use, and management of water and aquatic environments. The Strategy is developing several measures to reduce erosion and nutrient loading in the water bodies of Quebec. In 2019, the Quebec government programs to reduce erosion and nutrient loading include:

Programs	**Description**
Enhanced Drinking Water Source Protection Program (PPASEP, *Programme pour une protection accrue des sources d'eau potable*)	Analyzes the vulnerability of drinking water sources
Municipal support program for the establishment of sustainable storm water management infrastructures (PGDEP, *Programme de soutien aux municipalités dans la mise en place d'infrastructures de gestion durable des eaux de pluie à la source*)	Supports municipalities in their sustainable stormwater management initiatives
Assistance Program for the Development of a Regional Wetlands and Bodies of Water Plan	Supports the MRCs in the development of a Regional Wetlands and Bodies of Water Plan
Restoration and creation of wetlands and waterways Program	Supports the planning and the realization of a restoration or creation project of MHH
Prime-Vert	Increases the adoption of agri-environmental practices by agricultural enterprises to help improve the quality of the environment and human health.

The following table shows the current water quality monitoring programs, decision support tools, and Best Management Practices (BMP)s in the Quebec portion of the watershed. The table represents major actors and categories of BMPs. Elements of the table are arranged alphabetically, not in order of importance.

		Federal government	Provincial government	MRC	Municipalities	Non-governmental organizations		
						COGESAF	MCI	Other lake associations
	Monitoring and research							
	Cyanobacteria Monitoring Program in the lake		•	•	•	•	•	
	Lake Monitoring Program		•				•	
	Tributary Monitoring Program			•	•/$	•	•	
	River-Network Monitoring program (Cherry river and the outlet)		•					
	Other Lakes Monitoring Program		•					•
	Tributary Flow Monitoring (Castle Brook)				•			
	Littoral Habitat Characterization						•	
	Decision support tools							
	Land use phosphorus export model			$				
	Criteria for Surface Water Quality		•					
	Water Quality Data Convergence Project		$			•		
	Water Management Plans		•/$			•		
	Sub-watersheds Environmental Assessments	$	$		•/$		•	•
	Conservation Plans of Municipal Territories	$	$		$		•	
	Regional Wetlands and Bodies of Water Plan (planned for 2022)		•/$	•				
	BMPs							
Agriculture	Assistance to implement agricultural BMPs	$	•/$				•	
	Outreach	•/$	•/$				•	
	Shorelines protection		•/$	•	•			
Developed Lands	Municipal or province road assessment, upgrades		•/$		•/$		•	•
	Outreach		•	•	•	•	•	•
	Municipal Planning			•	•			
	Private septic system management				•/$			
	Reforestation on developed lands		•/$	•	•		•	
Natural Lands	Public protected areas		•					
	Voluntary conservation agreements	$	$		$		•	
	Municipal Planning to Protect Natural Lands		•	•	•			
	Shoreline Assessments and Stabilization				•		•	•
	Forestry BMP implementation, assistance, planning		•/$	•	•			
Point Sources	WWTF Phosphorus requirement		•/$		•			
Recreation & Tourism	Boating Best Practices Awareness			•	•		•	•
	Open-air industry		•		•			
	Ski and Gold industries		•					
	Corrective measures							
	Sediment trapping in tributaries				•			
	Aeration in bays							•

United States - Review of existing management efforts

Stakeholders working in the United States include federal, state, and municipal government, non-governmental sectors, and private sector. For a complete list of stakeholders, please see Appendix 3-2.

The table below shows the major federal, state, and municipal laws that regulate or affect nutrient loading.

Federal	State	Municipal
Clean Water Act: 1972	VT Act 250, Land Use and Development Act: 1970	Municipal Zoning
Endangered Species Act: 1973	VT Shoreland Protection Act: 2014	Municipal By-Laws
Farm Bill: Renewed 2018	VT Act 64, Clean Water Act: 2016	
	VT Act 185, Clean Water Revolving Fund: 2018	
	VT Act 76, Provision of Water Quality Service:2019	

Act 64, Vermont's Clean Water Act requires the updating or development of a number of regulatory programs and best management practices (BMPs) to reduce erosion and nutrient loading. These programs from Act 64 include:

Program	Description
Acceptable Management Practices (AMPs)	BMPs that reduce erosion from forestry operations
Municipal Roads General Permit	To inventory and reduce erosion from municipal roads
Operational Three-Acre Permit	To inventory and reduce stormwater runoff from sites with over 3 acres of impervious surface
Required Agricultural Practices (RAPs)	To plan and implement BMPs to reduce impacts of farming on waterways
Transportation Separate Storm Sewer System Permit (TS4)	To inventory and reduce stormwater runoff from state transportation network and state transportation facilities

The following table shows the current water quality monitoring programs, decision support tools, and BMPs in the Vermont portion of the watershed. The table represented major actors and categories of BMPs. Elements of the table are arranged alphabetically, not in order of importance.

		Federal Government	VT State Agencies/Departments				Municipalities	Non-governmental organizations						Private Sector	
			VAAFM	VANR	VDH	Vtrans		County Conservation	Lake Associations	MWA	NVDA	NorthWoods Stewardship Center	VLT	Business/ Consultants	Citizen Volunteers or Landowner
	Monitoring and research														
	Cyanobacteria Monitoring and Reporting			•	•				•	•					•
	Lake Monitoring Program- Lay program			•			•		•	•					•
	Tributary Monitoring Program- Volunteer			•/$				•		•		•		•	•
	TMDL Tributary and Lake Monitoring	•/$		•/$				•							
	Decision support tools														
	Lake Memphremagog TMDL Tracking	•	•	•		•	•								
	Land use phosphorus export model	•		•/$				•		•		•			
	Tactical Basin Planning	$	•	•/$		•	•	•			•				
	Stormwater Infrastructure Mapping			•/$			•								
	Stormwater Master Planning			•/$						•				•	
	Stream Geomorphic Assessments/ River Corridor Planning			•/$								•			
	BMPs														
Agriculture	On-farm implementation of BMPs	•/$	•/$	•				•/$					•		•/$
Agriculture	Direct assistance/outreach/planning	•	•/$					•					•		
Agriculture	Conservation easements, buffers, habitat restoration	•/$	•/$	•/$				•				•	•		•/$
Developed Lands	Municipal or state road assessment, upgrades			•/$		•/$	•/$	•		•	•/$	•			
Developed Lands	Lake Wise/ Shoreland Assessments			•/$			•		•	•		•		•	•
Developed Lands	Instillation and design small/large Green Stormwater Infrastructure (GSI)			•/$			•/$		•	•		•		•/$	•/$
Developed Lands	Municipal Planning/ Direct Assistance			•			•				•				
Natural Lands	Habitat/ streambank restoration, conservation easements	•/$		•/$				•				•	•		
Natural Lands	Forestry BMP implementation, assistance, planning- AMP program	•/$		•/$				•				•	•	•/$	•/$
Point Sources	WWTF Phosphorus- Optimization program			•/$			•/$								
Recreation & Tourism	Trail and water access erosion control			•/$		•/$	•		•			•			

Chapter 3

Review of existing management efforts

Chapter 3 presents a review of the current efforts to reduce nutrient loading in the Memphremagog Watershed. The chapter includes details by country on stakeholders, laws and regulations, as well as current best management practices (BMPs) and programs to reduce nutrient loading.

3.1. Description of watershed's key stakeholders

3.1.1. Description of the Canadian watershed's key stakeholders

For a list of Canadian stakeholders, please see Appendix 3-1.

3.1.1.1. *Federal government*

The Canadian federal government has jurisdiction related to fisheries, navigation, and international relations, including responsibilities related to the management of boundary waters shared with the United States and relations with the International Joint Commission (IJC). It also has responsibilities for agriculture, health and environment, and plays a role supporting aquatic research and technology, in addition to ensuring national policies and standards are in place on environmental and health-related issues (Government of Canada, 2017). The federal government has the authority to pass environmental regulation that may affect nutrient loading and may also direct funding to federal and provincial departments or fund local projects to reduce nutrient loading. Within the Canadian government, various departments and agencies have responsibilities for freshwater, including Environment and Climate Change Canada (ECCC), Agriculture and Agri-Food Canada, Natural Resources Canada, Fisheries and Oceans Canada, Transport Canada and Parks Canada. The main federal department responsible of water quality management is ECCC.

3.1.1.2. *Provincial government*

According to the Canadian Constitution, the management of natural resources including water is a provincial jurisdiction. The Government of Quebec has several departments that work directly or peripherally on water quality issues: the Ministry of Municipal Affairs and Housing (MAMH, *Ministère des Affaires municipales et de l'Habitation*), the Ministry of Agriculture, Fisheries and

Food of Quebec (MAPAQ, *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec*), the Ministry of Environment and Fight against Climate Change (MELCC, *Ministère de l'Environnement et de la Lutte contre les Changements climatiques*), the Ministry of Energy and Natural Resources (MERN, *Ministère de l'Énergie et des Ressources naturelles*), the Ministry of Forests, Wildlife and Parks (MFFP, *Ministère des Forêts, de la Faune et des Parcs*) and the Ministry of Transport (MTQ, *Ministère des Transports*). The provincial department responsible of the water management is the MELCC: devising and implementing policies, bills, draft regulations, and programs aimed at preventing and reducing water contamination; overseeing water protection law and regulation enforcement, through authorization and permit application analysis, inspections, inquiries; gathering knowledge about water ecosystems, among others.

3.1.1.3. *Municipalities*

The Regional County Municipality (MRC, *Municipalité régionale de comté*) Memphremagog was incorporated on January 1, 1982 by the Quebec Government. It is an administrative entity regrouping seventeen municipalities, including all the municipalities of Memphremagog Watershed, except the municipality of Stanstead-Est which has about 2 km^2 of its territory in the watershed. In Quebec, the MRCs are responsible of their territory management, and elaborating and updating a Land Use Planning and Development Plan (SAD, *Schéma d'aménagement et de développement*) that establishes guidelines for the physical organization of the MRC territory. The MRC Memphremagog also have responsibilities regarding environment, sustainable development, civil security and economic development. It provides outreach and education, research, and field work to meet environmental protection, including water quality.

In Quebec, there are 10 municipalities with at least 1 km^2 of their territory within the Memphremagog Watershed (section 2.1.6). Each municipality is responsible to elaborate and update an urban plan that establishes guidelines for the land use at local level. Each municipality has its own town by-laws, zoning laws, and urban plan with policies that may affect nutrient loading. They play an important role regarding water management, particularly in the management of municipal watercourses, the protection of lakeshores, riverbanks, littoral zones and floodplains, the sanitation of municipal wastewater discharges, the control of septic systems for isolated dwellings, and in the production and distribution of drinking water. Some municipalities provide outreach and education and have created green funds to support local associations for water quality improvement projects. Three Quebec municipalities in the watershed are operating wastewater treatment facilities. One municipality (the Town of Magog) is operating a hydroelectric power dam downstream of Lake Memphremagog outlet.

3.1.1.4. *Non-governmental organizations*

Non-governmental organizations include non-profit organizations, cooperatives, and universities. In Quebec, several non-profits engage in activities to provide outreach and education, research, and/or on-the-ground projects to improve water quality. In the Memphremagog Watershed, the Saint-Francis River Watershed Governance Committee (COGESAF, *Conseil de gouvernance de l'eau des bassins versants de la rivière Saint-François*) was founded by the Government of Quebec to implement integrated water management by watershed on St-Francis River zone. The non-profit organizations also include lake and river associations and conservation groups primarily funded through donations, membership fees, municipal contributions, and/or federal, provincial, municipal or foundation grants for specific projects. Memphremagog Conservation Inc. (MCI) is a lake association created in 1967 whose mission is the protection of Lake Memphremagog and its watershed. Several other lake and river associations exist in the watershed as the Association for the Protection and Management of Castle Brook (APARC, *Association pour la protection et l'aménagement du ruisseau Castle*), the Lake des Sitelles property owners Association (APLS, *Association des propriétaires du lac des Sitelles*) and the Lake Lovering Conservation Society (SCLL, *Société de conservation du lac Lovering*). Other non-profit organizations work to conserve natural lands in the watershed as Appalachian Corridor (ACA, *Corridor appalachien*), Memphremagog Wetlands Foundation (MWF) and the Association du Marais-de-la-Rivière-aux-Cerises (LAMRAC) who works to promote, preserve and enhance the Cherry River wetland.

The Regrouping of Associations for the Protection of Environment of Lakes and Watersheds (RAPPEL, Regroupement des Associations Pour la Protection de l'Environnement des Lacs et des bassins versants) is a solidarity cooperative specialized in environment and water management formed by more than 150 members, including 71 lake and river associations, individuals, and some private companies. RAPPEL has offered expert consulting services since 1997 and has done numerous projects in the Lake Memphremagog Watershed for different associations or municipalities with the objective of improving the water quality.

The following non-governmental organizations provide information and technical support to the agricultural producers and foresters of the watershed: the Agricultural Producers Union (UPA, *Union des producteurs agricoles*), through the Memphremagog local union, and the Forest Producer Union of the South of Quebec (*Le Syndicat des Producteurs forestiers du Sud du Québec*) represent the agricultural producers and foresters of the watershed; the Agroenvironmental Club of Estrie (CAEE, *Club agroenvironmental de l'Estrie*), which provides their clients with agri-environmental expertise and support them in implementing sustainable agricultural practices; and the Agency for the Enhancement of the Private Forest of Estrie (AMFP, *Agence de mise en valeur de la forêt privée de l'Estrie*) which guides the development of the private forest of the region.

Several universities have also done research in the Lake Memphremagog Watershed, including Concordia, McGill, Sherbrooke, and Quebec University in Montreal (UQAM, *Université du Québec à Montréal*).

3.1.1.5. *Private Sector*

The Quebec private sector includes businesses, industries, and forestry group ventures. The businesses or industries of the watershed might have impacts on water quality through runoff such as marinas, landscape businesses, golf and ski industries or through their discharge such as the cheese factory. Although these businesses may not be directly working on efforts to reduce nutrient loading, their activities are regulated to protect water quality or they may implement additional practices to reduce nutrient loading.

The two main forestry group ventures operating on the Quebec territory of Lake Memphremagog watershed are Forestry and Agricultural Management des Sommets inc. (AFA, *Aménagement forestier et agricole des sommets inc.*) and the Forestry Group Venture of the Haut-Yamaska inc. (GFHY; *Groupement forestier du Haut-Yamaska inc*.). These enterprises, specialize in the management of forest resources in a context of sustainable development and certified Forest Stewardship Council (FSC), offer forestry services to private forest owners and can help them to implement practices to reduce nutrient loading.

3.1.2. Description of the United States watershed's key stakeholders

For a complete list of United States stakeholders, please see Appendix 3-2.

3.1.2.1. *Federal government*

The United States federal government has the authority to pass environmental regulation that may affect nutrient loading. The federal government may also direct funding to federal and state agencies and support the direct dissemination of federal funding to local projects to reduce nutrient loading. The US federal government also oversees federal agencies, all of which have the authority to enforce federal policy and have grant making authority. This includes the US Environmental Protection Agency (EPA), US Fish and Wildlife Service, US Department of Agriculture (USDA), US Geological Survey (USGS), and US Army Corps of Engineers. The National Science Foundation was established in 1950 by the US Congress to support research and science, including environmental research and education. Further, EPA, under the Federal Clean Water Act, sets surface water quality standards and regulates discharges of pollutants into US waterways.

3.1.2.2. *State government*

The Vermont state government is responsible for passing state laws and supporting state agencies that work to improve water quality and reduce nutrient loading. The state also regulates, maintains, and oversees various funding sources for non-profits, universities, and municipalities for clean water projects. The state of Vermont has three major agencies that work on water quality issues: Vermont Agency of Natural Resources (VANR), Vermont Agency of Agriculture, Food, and Markets (VAAFM), and Vermont Agency of Transportation (VTrans). All state agencies have the authority to issue permits and monitor municipal and individual activities as it pertains to enforcing state policy. In some instances, the state has the authority to act for the federal government in permitting. For example, the state of Vermont has assumed authority to issue federal National Pollutant Discharge Elimination System (NPDES) permits to regulate point-source pollution discharge into Vermont surface waters (VDEC, 2018f).

3.1.2.3. *Municipalities*

In Vermont, there are 25 municipalities and gores within the Memphremagog Watershed (section 2.1.6). Each municipality has its own town by-laws, ordinances, zoning laws, and town plans with policies that may affect nutrient loading. Further, towns are responsible for maintaining town roads and infrastructure, as well as maintaining and operating wastewater treatment facilities in the watershed. There are three gores with land in the Memphremagog Watershed, which are unincorporated towns that have joined together for administrative purposes as the Unified Towns and Gores.

3.1.2.4. *Non-governmental organizations*

Non-government organizations in Vermont consist of universities and non-profit organizations. Universities engage in research, education, and on-the-ground projects. Non-profits range in their activities from providing outreach and education, to research, to direct assistance to meet water quality goals. Non-governmental organizations working in the Memphremagog watershed include lake and watershed associations, conservation districts, and recreational and conservation groups. Non-profits are funded primarily through donations, membership fees, and/or federal, state, or foundation grants.

3.1.2.5. *Private Sector*

The private sector stakeholders include businesses or industry that benefit from or impact water ways such as marinas, forestry, agriculture, development, and hydroelectric power generation. Although these businesses may not be directly working on efforts to reduce nutrient loading, their activities may be permitted and regulated by state agencies to protect water quality and business may implement stewardship practices along with business activities to reduce nutrient loading.

3.1.3. Quebec-Vermont Steering Committee

The Environmental Cooperation Agreement on Managing the Waters of Lake Memphremagog was signed by Vermont Governor James Douglas and Quebec Premier Jean Charest in 2003 (Gouvernement du Québec & Gouvernement du Vermont, 2003). This agreement recognized the earlier work done by the Quebec-Vermont Working Group since the agreement of 1989 and established the new Quebec-Vermont Steering Committee to continue assessment and protection work on the lake.

The Quebec Vermont Steering Committee has been meeting since 2004 and is comprised of Canadian and US Stakeholders including members from provincial/state governments, municipalities, and basin organizations from Vermont and Quebec. There are binational cochairs and meetings are held twice per year. At the meetings, stakeholders present scientific findings, emerging or resolved issues, management practices, current projects, and topics of general interest for the watershed. There is also a Quebec Vermont Technical Subcommittee, comprised of binational watershed science experts, and is a forum for deeper conversations into scientific considerations.

3.2. Inventory of nutrient management efforts

3.2.1. Inventory of Canadian nutrient management efforts

3.2.1.1. *Water quality protection Policies, Acts and Laws*

a) Federal legislative framework

When the management of natural resources including water is a provincial jurisdiction, the federal government is responsible for navigable and transboundary waters and the protection of fish habitat (Government of Quebec, 2017). Various Canadian Acts apply to the water domain: *Canadian Fisheries Act* (R.S.C., 1985, c. F-14), the *Canada Water Act* (R.S.C., 1985, c-11), the *Canada Shipping Act* (R.S.C., 1985, c. S-9, Repealed, 2001, c. 26, s. 332), the *Canadian Environmental Protection Act* (S.C. 1999, c. 33), the *International Boundary Waters Treaty Act* (R.S.C., 1985, c. I-17), the *Navigable Waters Protection Act* (R.S.C. 1985, c. N-22) and the *Canadian Environmental Assessment Act* (R.S.C. 1992, c. 37).

Fisheries Act: Effective 1868

The *Canadian Fisheries Act* (R.S.C., 1985, c. F-14) contains two key provisions on conservation and protection of fish habitat essential to sustaining freshwater fish species. The Department of Fisheries and Oceans administers section 35, prohibiting any work that would cause harmful alteration, disruption, or destruction of fish habitat. Environment and Climate Change Canada (ECCC) administers section 36, prohibiting the deposit of deleterious substances into waters inhabited by fish, unless authorized by regulations under federal legislation. Under this act, the *Wastewater Systems Effluent Regulations* regulates suspended solids concentration at the effluent of the wastewater systems (Government of Canada, 2019).

Canada Water Act: Effective 1970

The *Canada Water Act* (R.S.C., 1985, c. C-11) provides an enabling framework for collaboration among the federal, provincial and territorial governments in matters relating to water resources. According to this Act, the federal government can collaborate with a provincial government to establish intergovernmental committees to maintain consultation on water resource matters and to advise on priorities for research, planning, conservation, development and utilization; to advise on the formulation of water policies and programs; and to facilitate the coordination and implementation of water policies and programs. The federal government may collaborate with a provincial government providing for programs regarding water quality monitoring or projects implementation (Government of Canada, 2016).

Canada Shipping Act: Effective 1985

The Canadian federal government has exclusive jurisdiction over navigation through the *Canada Shipping Act* (R.S.C., 1985, c. S-9, Repealed, 2001, c. 26, s. 332). In Canada, any level of government who wants to restrict the use of pleasure craft on a body of water must ask the federal government (Transport Canada, 2014). In the Quebec portion of the lake, the speed limit is 70 km/h (43 mi/h) except within 100 m (328 ft) from the shore and other specific zones where the limit is reduced to 10 km/h (6 mi/h; (Government of Canada, SOR/2008-120). Motorboats are also prohibited near several public beaches (Government of Canada, SOR/2008-120).

Canadian Environmental Protection Act: Effective 2000

The *Canadian Environmental Protection Act* (CEPA, S.C. 1999, c. 33) is aims to prevent pollution by protecting the environment and human health. CEPA 1999 came into force on March 31, 2000 following a review of the former CEPA of 1988. This law makes prevention the cornerstone of national efforts to reduce toxic substances in the environment with, for example, the *Regulations respecting the concentration of phosphorus in laundry detergents* (Government of Canada, 2019).

b) Provincial legislative framework

Governance Framework

The management of natural resources including water is a provincial jurisdiction and the MELCC is responsible for coordinating water management in Quebec.

Quebec National Water Policy (PNE, Politique nationale de l'eau): Effective 2002

In 2002, Québec launched the National Water Policy to ensure the protection of this resource, to manage water with a sustainable development perspective and, in doing so, to better protect public and ecosystem health.

The directions of the PNE were:

- Implement integrated watershed management to reform water governance;
- Implement this form of management on the St. Lawrence by recognizing a special status for this important watercourse;
- Protect water quality and aquatic ecosystems;
- Continue water sanitation and improve the management of water services;
- Promote recreational tourism activities related to water.

The PNE has led to the recognition of 33 priority watersheds and the creation of a network of watershed organizations (OBVs, *Organismes de bassin versant*) for their integrated and collaborative management. The OBV is a round table that includes all types of water users from the same integrated water management zone. The PNE entrusted these watershed organizations with the mandate to carry out the first Water Master Plans (PDEs, *Plans directeurs de l'eau*) and suggested their implementation through the production of Watershed Contracts between the different stakeholders.

Act Affirming the Collective Nature of Water Resources and Promoting Better Governance of Water and Associated Environments (Loi affirmant le caractère collectif des ressources en eau et visant à renforcer leur protection): Effective 2009

Subsequently, the adoption in 2009, of the *Act Affirming the Collective Nature of Water Resources and Promoting Better Governance of Water and Associated Environments* (*Water Act*, C-6.2) confirmed the legal status of water resources as part of the collective heritage, clarified the responsibility of the Government of Quebec as the custodian of the resources on behalf of citizens and defined the rights and the obligations of the collectivity (Gouvernement du Québec, 2019b).

This act came to specify the mission of the watershed organizations, now numbering 40: " to develop and update a water master plan for its integrated management zone, facilitate and monitor its implementation ensuring balanced representation of users and of stakeholders, as the government, Native, municipal, economic, environmental, agricultural and community sectors " (Article 14).

As part of the implementation of integrated watershed management in Quebec, the Water Master Plan helps structure the process and decision-making. This planning process is intended to be adaptive, iterative, and prospective, and is carried out with consultation of stakeholders within a watershed. It is thus a mode of participative governance.

Quebec Water Strategy (SQE, Stratégie Québécoise de l'eau): 2018

In 2018, the Government of Quebec announced a new Quebec Water Strategy (SQE) for 2018-2030, which takes over from the National Water Policy launched in 2002. The Water Strategy is based on a series of consultations held with 140 organizations in the water sector throughout Quebec and will be implemented through three successive action plans. It sets out seven policy directions:

- Ensure quality water for the population;
- Protect and restore aquatic environments;
- Improve the prevention and manage water-related risks;
- Capitalize on the economic potential of water;
- Promote sustainable use of water;
- Acquire and share the best knowledge about water;
- Ensure and strengthen the integrated management of water resources.

The measures put forward in the first action plan (2018-2023) represent investments of over $552 million CAN ($409 million US). This action plan includes 63 measures carried out by eleven ministries and governmental organizations including:

- the inception of the Enhanced Drinking Water Source Protection Program (PPASEP, *Programme pour une protection accrue des sources d'eau potable*) which requires the municipalities to complete an analysis of the vulnerability of their drinking water source;
- to support the municipalities in conserving and restoring aquatic environments;
- to meet government objectives for protected areas;
- the inception of a *Municipal support program for the establishment of sustainable storm water management infrastructures* to encourage municipalities to adopt sustainable storm water management practices;
- to increase the knowledge on lakes;
- to strengthen integrated water resources management, including intergovernmental and international cooperation (MDDELCC, 2018a).

The follow up of the SQE is done by the MELCC. An annual progress report will be published, and a mid-term review is planned. The SQE aims to promote greater coherence of interventions related to water management.

Framework for the protection of water environments and wetlands

Water governance in Quebec is supported by a legal framework for the protection of water environment and wetlands; the main authority of this governance is the MELCC. The main legal bases are the *Quebec Environment Quality Act* (LQE, *Loi sur la qualité de l'environnement*), as well as the *Quebec Wetland and Water Environments Conservation Act* (LCMHH, *Loi concernant la conservation des milieux humides et hydriques*).

Quebec Environment Quality Act (LQE, Loi sur la qualité de l'environnement): Effective 1972

The *Quebec Environment Quality Act* (L.R.Q., c. Q-2) prohibits the release into the environment of a contaminant in a quantity or concentration greater than determined by this Act and requires the obtaining of an authorization for works located in water environments and wetlands.

Within this act, the MELCC has set Environmental Discharge Objectives (OER, *Objectifs environnementaux de rejets*) for each source of contamination to determine the concentrations and contaminant loads that may be released into an aquatic environment without compromising water use. These concentrations and loads are determined from the characteristics of the receiving environment and the level of quality required to maintain water use and may justify additional interventions or project modifications. OERs exist for total phosphorus, ammoniacal nitrogen, nitrates-nitrites, and nitrogen at the industrial effluents, among others, and are tailor made for each effluent which are controlled individually.

There are 68 regulations under the LQE. Among the regulations affecting the quality of water, there are:

- the *Regulation Respecting Wastewater Disposal Systems for Isolated Dwellings* (*Règlement sur l'évacuation et le traitement des eaux usées des résidences isolées;* Q-2, r.22) prohibits the release into the environment of toilet, wastewater or greywater waters unless these waters have been appropriately treated;
- the *Agricultural Operations Regulation* (REA, *Règlement sur les exploitations agricoles*; Q-2, r. 26; see box 3-1) prevents water contamination from agricultural operations;

- the *Regulation Respecting Municipal Wastewater Systems* (*Règlement sur les ouvrages municipaux d'assainissement des eaux usées*; Q-2, r. 34.1) presents municipal wastewater treatment plant effluent discharge standards and standards for municipal wastewater overflows;
- the *Water Withdrawal and Protection Regulation (Règlement sur le prélèvement des eaux et leur protection*, Q-2, r. 35.2*)* aims to provide for methods water withdrawals and protection;
- the *Regulations Respecting Water Protection Against Discharges of Pleasure Craft* (*Règlement sur la protection des eaux contre les rejets des embarcations de plaisance*; Q-2, r. 36) prohibits to discharge any wastewater from a pleasure craft (Gouvernement du Québec, 2019b).

The enforcement of many of these regulations is the responsibility of the municipalities.

Box 3-1: Agricultural Operations Regulation (REA, Règlement sur les exploitations agricoles; Q-2, r. 26)

Adopted in 2002 and revised several times since this time, the REA protect water and soils against pollution caused by certain agricultural activities. More specifically, it seeks to prevent the contamination of surface water, groundwater and soil by nutrients or pathogens contained in animal waste and other fertilizers stored or spread on agricultural land (MDDELCC, 2017a). It has three major components: livestock farming, plant cultivation, and fertilizer application. The REA includes standards and practices for:

- Livestock facilities
- Animal waste storage facilities
- Livestock Exclusion
- Buffers
- Manure and Nutrient Application
- Manure and Nutrient Storage
- Nutrient Management Plans
- Soil Health
- Discharges
- Farm size
- Ground water
- Animal mortality
- Water quality monitoring
- Farm structures

For farms with certain characteristics (e.g. with a cumulative area greater than 15 ha), the REA ensures the completion of an Agro-environmental Plan of Fertilization (PAEF, *Plan agroenvironnemental de fertilisation*) and a phosphorus balance signed by an agronomist (MDDELCC, 2017a).

Agro-environmental Plan of Fertilization (PAEF, Plan agroenvironnemental de fertilisation)
The PAEF determines, for each parcel of a farm and for each annual crop year (maximum of 5 years), the cultivation practiced and the limitation of the spreading of fertilizers. Signed by an agronomist, the PAEF must contain all the information necessary for its application, such as the fertilizer doses and the modes and periods of application. It ensures that any fertilizer application is done for the purpose of fertilizing the soil of a cultivated parcel.

Phosphorus balance

A phosphorus balance must also be submitted to the MAPAQ every year by farms with certain characteristics and be signed by an agronomist. The phosphorus balance is an inventory of phosphorus lo ads, produced or imported, and of the capacity of soils to receive these loads in accordance with the annual maximum phosphorus deposits set out in the REA. It makes it possible to check the balance between the phosphorus inputs and the maximum deposition capacity, in order to prevent a surplus from being found in the rivers and to impair their quality, notably by promoting the proliferation of blue-green algae (Gouvernement du Québec, 2019b).

Also, under the LQE, all interventions carried out in shorelines, floodplains, lakebeds, and riverbeds must obtain authorization from the MELCC, or from the local municipality, in accordance to the Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (PPRLPI, *Politique de protection des rives, du littoral et des plaines inondables*, see page 88). Some types of work carried out in a water environment, or affecting it, is subject to an impact assessment and a review process, which may include public hearings under the Public Environmental Auditing Office (BAPE, Bureau d'audiences publiques sur l'environnement).

Under the article 32 (22, 3°) of the LQE, the Government of Quebec requires stormwater management criteria in the authorization request for new development projects that need an aqueduct or a sewer network. The removal of suspended solids and total phosphorus is required for every project more than 2 ha (4.9 ac.) in size. Removal can be achieved by implementing one or more best management practices (MELCC, 2019b).

In 2018, a major reform of the LQE was completed, and more than 20 new regulations were produced. For example, clause 20 has been amended to add the ecosystem protection concept to the prohibition of environmental contamination. This has reinforced the compulsory power regarding a problematic concentration for an ecosystem. Also, the authority to refuse an authorization has been reinforced and the rejection is allowed in case of important apprehended impacts. The authority to impose conditions to better protect the environment has also be added to the authorization process.

Quebec Wetland and Water Environments Conservation Act (LCMHH, Loi concernant la conservation des milieux humides et hydriques): Effective 2017

In 2017, the *Quebec Wetland and Water Environments Conservation Act* (2017, ch. 14) set a new system to conserve wetland and water environments. The LCMHH amended the Water Act to recognize the ecological functions of wetlands and water environments, to clarify the role of watershed organizations and regional round tables, and entrusting MRCs and local municipalities with the responsibility of developing and implementing a *Regional Wetlands and Bodies of Water Plan* (PRMHH, *Plan régional des milieux humides et hydriques*) at the level of their respective territories, which has to be revised every 10 years. The MRC Memphremagog is now developing their PRMHH that must be ready before 2022 (Goulwen, *et al*., 2018). The LCMHH also gives the Minister the authority to develop and implement programs that promote the restoration and creation of wetlands and water environments. It also requires the production of reports in relation to the modifications in the situation of wetlands and water environments, particularly with regard to the objective of "no net loss".

Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains (PPRLPI, Politique de protection des rives, du littoral et des plaines inondables): Effective 1987

In addition to these acts, the Protection Policy for Lakeshores, Riverbanks, Littoral Zones, and Floodplains (PPRLPI; Q-2, r. 35) aims to provide adequate protection for lakeshores, riverbanks, littoral zones, and floodplains that are essential to the ecological integrity of water bodies. The PPRLPI requires a vegetated buffer strip to protect water bodies by reducing shoreline degradation and erosion. This strip of vegetation can be left in a natural state or managed and should be, in general, 10 to 15 meters wide depending on the slope of the terrain. In agricultural lands, producers are legally required to maintain a minimum shoreline protection strip of 3 meters wide and if the top of the slope is at less than 3 meters from the high-water mark, the buffer strip must include at least 1 meter on the ground plane.

The implementation of this policy was carried out in two steps: 1) the insertion of the policy in the *Land Use Planning and Development Plan* (SAD, *Schéma d'aménagement et de développement*) of the MRCs, and 2) its integration in all local municipalities Town Planning By-laws. Municipalities and MRCs are thus important players in the protection of water environments and wetlands. This policy provides a minimal prescriptive framework but does not prevent various government and municipal authorities from adopting additional protection measures in response to special circumstances and according to their respective jurisdictions. The policy binds the government and its departments and agencies, which must take it into account in their activities and in the application of their programs and authorisation schemes.

Natural Heritage Conservation Act (LCPN, Loi sur la conservation du patrimoine naturel): Effective 2002

The purpose of the *Natural Heritage Conservation Act* (C-61.01) is to establish protective measures for natural environments and to promote the creation of a network of protected areas. The Act can be used to create provincial parks, biodiversity and ecological reserves, as well as recognized endangered species habitats on public lands. It can also be used to create natural reserves on private land.

Quebec Sustainable Forest Development Act (LADTF, Loi sur l'aménagement durable du territoire forestier): Effective 2013

The *Quebec Sustainable Forest Development Act* (ch. A-18.1) aims to implement sustainable forest management to support the conservation of soil and water, among others. Under this act, the regional agencies for the enhancement of private forests have the mission to guide and develop the enhancement of private forests in their territory. In addition, the Ministry of Forests, Wildlife, and Parks (MFFP, *Ministère des Forêts, de la Faune et des Parcs*) develop programs to promote sustainable management of private forests.

In the province of Quebec, several other acts are applied to the water domain and address wildlife habitats, shoreline protection, forests, mining, agriculture, fisheries and food, including the *Conservation and Enhancement of Wildlife Act* (L.R.Q., c. C-61.1; la *Loi sur la conservation et la mise en valeur de la faune*); the *Forests Act* (L.R.Q., c. F-4.1; la *Loi sur les forêts*); the *Mines Act* (L.R.Q., c. M-13.1; la Loi sur les mines) and the *Protection of Agricultural Land Act* (L.R.Q., c. P-41.1; *la Loi sur la protection du territoire agricole*).

c) Municipal legislative framework

The *Land Use Planning and Development Act* (LAU, *Loi sur l'aménagement et l'urbanisme*) was passed in 1979 (Government of Quebec, 1979). The MAMH is responsible for the implementation of the LAU that led to the creation of the MRCs and entrusted them, as well as the local municipalities, with the coordination of land use planning. Under the LAU, every MRC is required to maintain a Land Use Planning and Development Plan (SAD, *Schéma d'aménagement et de développement*) applicable to its territory in which the main directions and the major designated land uses are described in the planning. The Government Planning Guidelines (OGAT, *Orientations gouvernementales en aménagement du territoire*) must be integrated in the MRC's SAD.

Memphremagog MRC Land Use Planning and Development Plan (SAD, Schéma d'aménagement et de développement; r. 8-98): Effective 1999

The Memphremagog MRC SAD coordinates the decisions that concern all the municipalities of the MRC and the Provincial government. The SAD is a document formulated to bring out a regional vision of sustainable development. It determines the major land uses (eg, urban, industrial, recreational, forestry, agricultural) and areas where land use is subject to special constraints for reasons of public safety or environmental protection of shorelines, littoral and floodplains (MAMH, 2019).

For example, as required by the Government of Quebec, the SAD of the MRC Memphremagog prohibits any work, construction, or septic system in a shoreline protection strip 10 to 15 meters wide, depending on the slope of the terrain with some exceptions (MRC de Memphrémagog, r. 8-98). However, the MRC adopted additional protection measures and prohibits any control of vegetation on 5 or 7.5 m width of riparian banks, according to the slope, and any tree cutting on 15 m width of riparian banks (MRC de Memphrémagog, r. 8-98). To naturalize, shoreline owners must follow guidelines elaborated by RAPPEL or MELCC (RAPPEL, 2005; MDDELCC, 2015b) or other equivalent techniques. The SAD of the MRC Memphremagog also presents regulations on tree-cutting that differ according to different types of forest operation sectors: sectors where forestry operations are banned, sectors with severe constraints on forestry operations, and sectors of forestry operations (MRC de Memphrémagog, r. 8-98).

The SAD contains minimal and general rules that need to be transposed in the local urban planning regulations; it does not prevent the municipal authorities concerned, according to their jurisdictions, from adopting additional protection measures. In 2019, the MRC Memphremagog began a process to review the SAD (MRC de Memphrémagog, 2019).

Municipalities by-laws

According to the *Quebec Municipal Powers Act* (Loi sur les compétences municipales, C-47.1), a local municipality has jurisdiction in water resource management regarding, for example, recreation, parks, local economic development, power development, environment, sanitation, nuisances, and transportation. They have an important role to play, particularly in the management of municipal watercourses, the protection of lakeshores, riverbanks, littoral zones and floodplains, the sanitation of municipal wastewater discharges, the control of septic systems for isolated dwellings, and the production and distribution of drinking water.

Integrating the SAD of the MRC Memphremagog, municipalities of the watershed are responsible for implementing urban planning bylaws that regulate land development and activities within municipal boundaries through permits and regulations. They can also adopt additional protection measures to limit pollution, control erosion, conserve forest cover, and protect wetlands.

In the Memphremagog Watershed, some municipalities have adopted additional measures to direct residential expansion and passed discretionary urban planning by-laws in areas of the watershed. Some of them also adopted a by-law on *Comprehensive Development Plans* (PAE, Plans d'aménagement d'ensemble) for areas of ecological interest for which it defines specific criteria governing their development (Austin, r.16-430; Potton, r.2001-290). PAEs can, among other things, provide measures to control soil erosion and sediment transport, limit surface sealing of the soil, retain forest cover, or conserve natural lands during a development project (Austin, 16-435).

Regarding tree-cutting, some municipalities adopted additional measures and have extended the areas where the forest operations are banned. For example, the municipality of Austin does not allow tree cutting on their territory with some exceptions, including new construction or for forestry operations in some sectors (Austin, r. 16-430). Also, tree cutting is prohibited in the Town of Magog within 300 m (984 ft) width of main waterbodies (Magog, 2019, r. 2368-2010). The municipalities of the watershed have different maximum percentage of deforestation according to different property areas.

Regarding erosion control, in some municipalities residents must use erosion control measures during soil manipulation works in specific situations, dependent on the area of the soil manipulation work, the distance from a water body, or the inclination of the slopes (Austin, r. 16-430; Magog, r. 2368-2010; Ogden, r. 2000-3; Orford, r. 800; Stanstead Township, r. 212-2001). Also, to reduce the risk of erosion and overflow of rivers caused by heavy rainwater runoff, some municipalities regulate gutters, and the water coming from a roof must necessarily be poured on a permeable surface far from the building (Magog, 2019, r. 2368-2010). Some municipal by-laws also concern erosion control measures along private roads during the construction of bridges and culverts (Bolton-Est, r. n°2014-278; Potton, 2001-291) or during the construction of all roads (Orford, no 789). Municipal by-laws also exist for road slopes (Austin, r.16-431) and minimal distance between a road and a waterbody (Austin, r.16-431).

Regarding fertilizers on residential properties, several municipalities of the watershed have regulations to limit their application: some prohibit the application of fertilizers within 15 m width of a waterbody, and others prohibit the application of fertilizers on all lawns of their territory (Austin, r.16-430; Bolton-Est, r. n°2014-278; Magog, r. 2368-2010; Ogden, r. 2000-3, Stanstead Township, r. 212-2001).

Regarding lakeshore and riverbank protection, some municipalities do not allow any work, construction, or septic systems within a riparian buffer strip of 20 or 30 meters wide in some areas (Austin, r.16-430; Bolton-Est, r. n°2014-278). Other municipalities do not allow any control of vegetation within a 10, 15 or 20 m riparian buffer strip in some areas or in all their territory (Austin, r.16-430; Bolton-Est, r. n°2014-278; Magog, r. 2368-2010; Ogden, r. 2000-3). Some municipalities also have a regulation requiring the prevention of shoreline erosion and the stabilization of the bank (Austin, r.16-430, Bolton-Est, 2018, r. n°2014-278; Stanstead Township, r. 212-2001). Finally, to ensure the conformity of private septic systems, some municipalities of the watershed systematically inspect older private septic systems (Austin, r. 18-461).

3.2.1.2. *Monitoring and research*

Water Quality Monitoring in Lake Memphremagog

Since the early 2000s, the MELCC, in collaboration with MCI, has monitored the open waters of the lake to determine the trophic level and to track its evolution. The number of samples taken annually is generally four, in the months of June, July and August. However, as many as seven samples have been taken in some years and have included the month of May, and the period from September to November. This sampling protocol is used at nine sites on the lake (MDDELCC, 2018b; Figure 2-6 in section 2.2.2).

These water samples are taken following the MELCC's standard operating procedures for lake water quality monitoring (MDDELCC & CRE Laurentides, 2017). Water quality analyses include total phosphorus, chlorophyll-a, dissolved organic carbon and Secchi transparency. Total phosphorus and chlorophyll-a concentration trends are presented in section 2.2.2.1.

From 2013 to 2017, water temperature and dissolved oxygen concentration profiles were also measured at the nine monitoring sites in the lake and at the outlet, at 1-meter increments from the surface, to a maximum depth of 30 m with a multi-parameter monitor. These data are available online at: https://www.memphremagog.org/en/documents-studies

River Monitoring Network

In 1979, the MELCC set up a water quality monitoring network in the main rivers of the province, the River-Network (Réseau-rivières), which includes 260 stations distributed among the 40 drainage basins of the St. Lawrence's tributary rivers. The water quality is monitored monthly throughout the year. One station is located in the Memphremagog Watershed, at the mouth of Cherry River, and one station is located at the outlet of Lake Memphremagog, on the Magog River. Analyses completed at these stations include fecal coliform, conductivity, pH, ammonia nitrogen, nitrates-nitrites nitrogen, total nitrogen, total phosphorus, suspended solids and turbidity (MELCC, 2019c).

Water Quality Monitoring of the other lakes of the watershed

In 2004, the MELCC established a Volunteer Lake Monitoring Network (RSVL, Réseau de surveillance volontaire des lacs) including 700 lakes registered as of 2012 for the entire province of Quebec (MDDEFP, 2012). In collaboration with local associations, the MELCC assesses the water quality of the following lakes of the watershed: Cherries Pond, George Pond, Lake Gilbert, Lake Lovering, Lake Malaga, McKey Pond, Lake Nick, O'Malley Pond, Peasley Pond, and Lake des Sittelles. Since 2010, the program is based on a cycle of 2-3 years of sampling, three times each summer, followed by a 4 year break in sampling (Gouvernement du Québec, 2019c).

Water quality data from the RSVL is available online at:
http://www.environnement.gouv.qc.ca/eau/rsvl/relais/rsvl_liste.asp

Cyanobacteria Monitoring Program

Since 2004, the MELCC and the Ministry of Health and Social Services (MSSS, *Ministère de la Santé et des Services Sociaux*) established a management plan for cyanobacteria blooms to ensure the protection of public health. Since then, the MELCC and the MSSS have provided information about the cyanobacteria blooms and invited the public to report their observations and send photographs to the MELCC website. Depending of the characteristics of the cyanobacteria bloom, the MELCC may go on site to make their own observation, inform the municipality, and recommend that specific areas (such as swimming areas) be closed for recreational activities. The MELCC can also analyze the presence of cyanotoxins in the blooms in some cases. Data collected by the MELCC between 2004 and 2018 are available by contacting them directly. An annual report is published every year to present a review of the situation at a provincial scale.

COGESAF and MCI provide training for Lake Keeper volunteers and municipal employees to visually assess surface waters for the presence of cyanobacteria. When a volunteer sees a bloom, they can directly contact the MELCC to report their observation. For Lake Memphremagog, the volunteer can also call MCI patrol who can assist in logging an observation and send photographs to the MELCC website. The MCI and the MRC patrollers are also visually assessing surface waters during the summer between May and September, and report their observations to the MELCC. The data of the bloom episodes that have been reported by the public and that have been registered by the MELCC in the Quebec portion of the Lake since 2004 are presented in Chapter 2, Section 2.4.1.

Similar to Vermont, when a bloom in Quebec is identified, a photograph is sufficient evidence for the closure of a recreational area. Samples of the bloom are not necessary to enforce public land closures.

Tributary Water Quality Monitoring Program

The MRC de Memphremagog coordinates a tributary monitoring program that has sampled over 40 sites throughout the Quebec portion of the Memphremagog Watershed since 1998. Every year, around 20 tributaries of Lake Memphremagog and other lakes of the watershed are monitored, generally at their mouth, and sometimes upstream to identify sources of pollutants. Sites are chosen in collaboration with the municipalities at the beginning of the year. Sites are monitored the same day, five times between the beginning of May and the beginning of September: twice after rainy days and three times after dry weather. Sampling is conducted through the collaborative efforts of the municipalities and MCI under the supervision of the MRC (Roy, 2018). Total phosphorus, fecal coliforms, and suspended solids are tested for every site, while total organic carbon is tested at some sites (Roy, 2018). The analysis of the water samples is done by a private laboratory (EurofinsEnvironeX Sherbrooke) and methods are accredited by the MELCC. Sampling is financially supported by municipalities of the watershed and the City of Sherbrooke.

Data from this sampling program are compared to the Government of Quebec's criteria which are used to assess surface water quality entering Lake Memphremagog and to identify areas of concern. The sampling program has led to efforts to work with municipalities, specific landowners and some agricultural producers to implement BMPs and track their effect on water quality.

Water quality data from the tributaries monitoring program from 2008 to 2017 are available online: www.mrcmemphremagog.com/gestion-du-territoire/environnement/programme-dechantillonnage-des-tributaires/. Figure 2-4 in section 2.2.1 shows the median concentrations of total phosphorus monitored between 1998 and 2018 in the tributaries of the Quebec portion of the watershed.

Some years, non-profit organizations (APLS, the COGESAF, MCI and SCLL) also sample sites to increase the monitoring efforts in some key areas or to monitor following spring rain events (COGESAF, 2019). These data, including the data from the MRC tributary monitoring program, are available online: http://cogesaf.sigmont.org/cogesaf/cogesaf.php. The Appendix 3-3 presents all the sampling site monitored since 2006 in the tributaries of the Quebec portion of the watershed.

Tributary Flow Monitoring

In 2018, the first permanent hydrometric station was installed in the Quebec portion of the watershed to continuously measure stream flow and turbidity near the Castle Brook mouth in Magog (Magog, 2019).

Littoral Habitat and Riparian Buffer Strip Characterization

In the summer of 2004, MCI commissioned RAPPEL to execute a study called *Operation Healthy Lake* to examine the health of the Quebec littoral and shoreline of Lake Memphremagog. Vermont's Agency of Natural Resources then asked MCI to do an identical study on the Vermont portion of the lake. Data related to the condition of the shoreline and littoral habitat (sediments, aquatic plants, green algae, shoreline alterations) were gathered and corrective actions to improve lake health were recommended (RAPPEL & MCI, 2005; 2006). In 2015, a follow-up to that study was done in Fitch Bay to characterize the changes in the aquatic vegetation and the accumulation of sediments on the bottom of the bay (MCI, 2016b). Other littoral characterizations were done in Lake Memphremagog by associations and RAPPEL in Aulnes Bay and Anse Bay in 2015.

In 2007, MELCC published a riparian buffer strip characterization protocol for lake associations and municipalities (MDDEP & CRE Laurentides, 2007). To be able to compare Lake Memphremagog to the other lakes of the Province, a new riparian buffer strip characterization has been done by MCI for the Quebec portion of the lake between 2014 and 2016 using MELCC protocol (MCI, 2014b; 2015b; 2016c). An inventory of the Canadian shoreline properties by photography was also done in 2011 to evaluate modifications of the riparian buffer strips and an update was initiated in 2018 (MCI, 2011b). Also, shoreline erosion has been characterized along Castle Brook and Cherry River in 2012 and 2013 (GENIVAR, 2013; WSP, 2014), and along Fitch Bay tributaries in 2015 (Bissonnette *et al.*, 2015) to recommend corrective actions to the municipalities.

In 2015, a study done by UQAM in collaboration with SCLL and MCI concluded that wakeboats were creating more shoreline erosion than natural waves when the sports generating oversized waves are done at less than 300m from the shore (Mercier-Blais & Prairie, 2014). Also, in 2018 Everblue Massawippi coordinated a project financed by Transports Canada to measure shoreline erosion in areas frequented by wakeboats in four lakes of Estrie, including Lake Lovering and Lake Memphremagog (Gérin, M., Everblue Massawippi, 2018, pers. comm.).

Littoral and/or riparian buffer strip characterization were also done by RAPPEL in other lakes of the watershed: Lake Lovering (RAPPEL, 2006), Peasley Pond (2005; 2017), Lake Nick (2006), Castle Brook (2008), Lake Gilbert (2010; 2017), O'Malley Pond (2011), Lake des Sittelles (2015), Lake à la Truite (2015) and Lake Malaga (2018; Martel, J.-F., RAPPEL, 2018, pers. comm.). These studies were generally financed by local associations and/or municipalities.

3.2.1.3. *Decision support tools*

Phosphorus export model

As detailed in the section 3.2.2.2c., a land use phosphorus export model was originally developed in 2009 by a private consultant, SMi Amenatech Inc., in collaboration with the Quebec Vermont Steering Committee's Technical Committee on Lake Memphremagog. The model development was funded by the MRC Memphremagog to estimate phosphorus loading from sub-watershed areas and to attribute loading to land uses across the watershed. This model was updated by VDEC with input from the Quebec Vermont Steering Committee. Current estimated loading is presented in Chapter 2 in Section 2.3. Since the development of this model, a TMDL was set in the Vermont portion of the watershed to establish the maximum amount of phosphorus that can enter in Lake Memphremagog to meet clean water goals.

Quebec criteria for surface water quality

The Quebec government has defined water quality criteria for 300 contaminants for different types of surface water uses. The following criteria can be used to assess the deterioration of a lake but should not be used to evaluate the phosphorus loads that could be released. The Quebec government has defined criteria for total phosphorus for the protection of the aquatic life (chronic effect) and for the protection of the recreational activities and aesthetics of water bodies. For oligotrophic lakes with a natural concentration of less than or equal to 0.01 mg/L, the quality criterion is defined as a maximum increase of 50% over the natural concentration without exceeding 0.01 mg/L. To limit the eutrophication of lakes whose natural concentration is between 0.01 and 0.02 mg/L, the quality criterion is defined by a maximum increase of 50% compared to the natural concentration, without exceeding 0.02 mg/L. Finally, the Quebec criteria for surface water quality is 0.3 mg/L for streams and rivers (Gouvernement du Québec, 2019b).

Water Quality Data Convergence Project

Since 2010, COGESAF is coordinating a project to compile all the water quality data collected in St Francis Watershed by different stakeholders (MELCC, municipalities, lake associations, etc.). This cartographic tool allows the public to follow the evolution of the water quality and to identify areas of concern. It is available on the web: http://cogesaf.sigmont.org/cogesaf/cogesaf.php.

Water Management Plans

In 2002, Quebec established an integrated management of water in the meridional Quebec watersheds at the local and regional state level. This includes 40 watershed organizations that integrate water management through voluntary participation and consultation of water users. Since then, COGESAF coordinates the implementation of a water management plan for the St-Francis River Watershed to improve water quality. A portrait and a diagnosis of the St-Francis River Watershed was published in 2006 (COGESAF, 2006). COGESAF has since coordinated specific water management plans for all the St-Francis subwatersheds, including the Lake Memphremagog Watershed. A Memphremagog Local Watershed Committee has met annually since 2007 to follow the implementation of the actions (Grenier, J., COGESAF, 2019, pers. comm.).

Sub-watershed Environmental Assessment

Several sub-watershed environmental assessments were done in Lake Memphremagog watershed to recommend corrective actions to improve water quality:

- Lake à la Truite Watershed (RAPPEL in 2005);
- Fitch Bay Watershed (MCI and RAPPEL in 2006);
- Lake Nick Watershed (RAPPEL in 2007 and 2009);
- Peasley Pond Watershed (RAPPEL in 2009);
- Lake Gilbert Watershed (RAPPEL in 2014);
- O'Malley Pond Watershed (RAPPEL in 2010);
- Lake Sittelles Watershed (MCI and l'Association des propriétaires du lac des Sittelles in 2013);
- Castle Brook Watershed (Magog in 2019).

Sources: MCI & RAPPEL, 2006; Lafrenière *et al*., 2013; Martel, J.-F., RAPPEL, 2019, pers. comm.; Magog, 2019).

These environmental assessments were generally done with the contribution of volunteers from lake associations and financed by lake associations, municipalities, the Regional Conference of Elected Officials (CRÉ, Conférence régionale des élus), and/or by the federal program EcoAction.

Natural Land Conservation Plans

Natural land conservation plans were completed for four municipalities around the lake (Austin, Magog, Stanstead Township, and Ogden) to identify the natural lands of ecological interest on their territory and to recommend actions to conserve them (MCI & ACA, 2011; 2015; 2017; MCI

& GENIVAR, 2014). These conservation plans were generally done by MCI with the collaboration of ACA or GENIVAR and financed by municipal, provincial, federal programs, or by the Quebec Wildlife Foundation (FFQ, Fondation de la Faune du Québec). Plans are used by the municipalities to integrate the conservation of natural lands in their town by-laws, zoning laws, and town plan. A mapping portrait of the natural lands of ecological interest was also completed for the territory of the municipality of Potton, by ACA (Thibault, V., ACA, 2018, pers. comm.).

Regional Wetlands and Bodies of Water Plan

Since 2017, following the adoption of the Quebec Wetland and Water Environments Conservation Act (*LCMHH*, Loi concernant la conservation des milieux humides et hydriques) which modified the *Water Act* (C-6.2; see section 3.2.1.1), the MRC Memphremagog has been developing a *Regional Wetlands and Bodies of Water Plan* (PRMHH, Plan régional des milieux humides et hydriques) for its territory to integrate the conservation of wetlands and water environment into its planning. The PRMHH must be completed before 2022 (Goulwen *et al*., 2018).

3.2.1.4. *Current Implementation of Best Management Practices (BMPs) in the watershed*

In addition to the policies, acts and by-laws, BMPs are implemented in the Quebec portion of the watershed to ensure the protection of water quality of Lake Memphremagog and its tributaries.

a) Multi-sector

The following global action plans are implemented to adopt BMPs in specific areas of the watershed to reduce nutrient loading in Lake Memphremagog and its tributaries.

Healthy Fitch Bay project

Since 2014, the *Healthy Fitch Bay Project: From diagnosis to solutions!* aims to improve the water quality in Fitch Bay and to conserve the biodiversity of the watershed. Coordinated by MCI, various stakeholders are working together to implement a 2015-2020 action plan regarding the activities that have an impact on the health of Fitch Bay and its watershed. This includes boating, residential and farming practices, as well as the protection of natural lands (MCI, 2015c).

Committee on Castle Brook

In 2015, an action plan (2016-2021) to reduce sedimentation in Castle Brook was initiated. Coordinated by the City of Magog, a committee of several stakeholders including the MELCC, the MFFP, COGESAF, the MRC, MCI, the municipality of Austin, the municipality of Orford Township, the Castle Brook Protection and Management Association (APARC, l'Association pour la protection et l'aménagement du ruisseau Castle), and the Association for the revitalization of the Lake Memphremagog delta and bays (ARDBLM, Association pour la revitalisation du delta et des Baies du lac Memphrémagog) meets once or twice a year to follow the implementation of the action plan. This action plan includes water quality monitoring, a watershed assessment, shoreline stabilization, and the management of a sediment trap designed to collect sediment coming from the Castle sub-watershed (Magog, 2016).

b) Agricultural sector

The following programs and stakeholders are working to assist agricultural producers with the continued and increased adoption of BMPs in the Quebec portion of the Memphremagog Watershed through awareness, and technical and financial assistance.

Prime-Vert program

The Prime-Vert program from MAPAQ aims to increase the adoption of agro-environmental practices by agricultural enterprises to help improve the quality of the environment and human health. It can finance between 70% and 90% of the expenses to implement best management practices. An important part of the program is co-financed by the Federal and the Provincial Governments under the Canadian Agricultural Partnership (Gouvernement du Québec, 2018b). Through this program between 2009 and 2018, 17 agricultural producers of the 53 located on the Quebec portion of Lake Memphremagog watershed received $316,924 CAN ($241,000 US) for construction of manure storage (67.5%), alternative installations for beef cattle production (14.5%), soil and water conservation practices and reduction of non-point source pollution (9%), and pesticide application equipment (1%; MAPAQ, 2019, unpublished data).

Agro-environmental support plan (PAA, Plan d'accompagnement agroenvironnemental)

MAPAQ and Agriculture and Agri-Food Canada propose an agro-environmental approach to assist agricultural producers in the implementation of BMPs. Done on a voluntary basis, the PAA is a tool for planning interventions to be carried out within the agricultural enterprises according to the intervention priorities established by an agro-environment advisor. For a PAA to be eligible for funding, the agricultural producer must commit within a given period to carry out actions included in the PAA action plan. These actions may be funded under the Prime-Vert or Consulting Services programs. Five PAA have been done between 2013 and 2018 in the Quebec portion of the watershed (9.4% of the agricultural producers; MAPAQ, 2019, unpublished data).

Other information and technical support to the agricultural producers

In the Lake Memphremagog Watershed, the Agricultural Producers Union (UPA, Union des producteurs agricoles), through the Memphremagog local union, provides expertise to producers through information tools and farmland visits where watercourse protection actions have been done (UPA, 2019; Dame, G., UPA, 2018, comm. pers.). In 2020, UPA-Estrie, in collaboration with the MRC Memphremagog, will offer workshops to agricultural producers regarding BMPs to implement to reduce erosion during interventions in shorelines, for example during the installation of bridges and culverts (UPA-Estrie & SPFSQ, 2019). Also, to reduce nutrient loading in Lake Memphremagog, the Agroenvironmental Club of Estrie (CAEE, Club agroenvironnemental de l'Estrie) agronomists visit croplands and propose soil conservation practices to agricultural producers to limit soil and nutrient losses, while helping them implement best management practices. In 2018-2019, 11 agricultural enterprises used the MAPAQ Advisory Services Program or CAEE's services (21%). This limited proportion may partially explain the small number of PAAs achieved.

Fitch Bay soil conservation project

MCI and the CAEE undertook a soil conservation project between 2016 and 2019 in agricultural areas of the Fitch Bay watershed with financial support from the Prime-Vert Program from the MAPAQ. The aim was to help agricultural producers in the adoption of soil conservation practices, prioritizing annual crops. Information on erosion reduction and water management techniques, erosion and water management analysis, and help in implementing soil conservation practices have been offered to 12 agricultural producers of the 31 located in the Fitch Bay watershed.

Agricultural riparian buffer characterization

In 2008, the MRC Memphremagog conducted, in collaboration with CAEE and financially supported by Prime-Vert, an agricultural riparian buffer characterization for all the Quebec portion of Lake Memphremagog watershed. 66 agricultural properties where visited in the municipalities of Magog, Stanstead Township, Ogden, Potton, Saint-Benoît-du-Lac and Austin. The main observed problems were minor shoreline erosion problems and animal access to the streams (MRC de Memphrémagog, 2008). Landowners were invited to contact MAPAQ to submit mitigation measure proposals and receive funding (Roy, A., Memphremagog MRC, 2019, pers. comm.).

c) Developed Lands

The following programs and stakeholders are working to assist municipalities and citizens with the continued and increased adoption of BMPs in the Quebec portion of the Memphremagog Watershed through awareness, and technical and financial assistance.

Stormwater Runoff Management

Several organizations work to inform municipalities and citizens about sustainable stormwater management. COGESAF gives training to municipal employees in order to help the municipalities of the watershed assess sustainable management of their territory (Grenier, J., COGESAF, 2019, comm. pers.). Some municipalities also give training to contractors on soil management and stormwater runoff on construction sites (Austin, 2019). The MRC Memphremagog, the municipalities and the non-governmental organizations also have different information tools to support the population in the management of stormwater on their property. To raise awareness and to maintain and increase the forest cover, MCI, LAMRAC, and the Forest Research Trust of Eastern Townships (FRFCE, *Fiducie de recherche sur la forêt des Cantons-de-l'Est*) give thousands of trees every year to the population of the watershed, with the collaboration of the MFFP and the Southern Quebec Forestry Association (AFSQ, *Association forestière du sud du Québec*). Finally, some municipalities also offer funding for the owners who purchase rainwater tanks (Pouliot, J., Magog, 2018, comm. pers.).

Road Management

In the Quebec portion of the watershed, 121 km (15 %) of roads are managed by the Government of Quebec and 634.5 km (79 %) are managed by municipalities. There are also 45 km (6 %) of private roads, many of which are adjacent to waterways and are subject to municipal regulations (MTQ, 2019, unpublished data). The provincial transportation infrastructure is managed by the MTQ who builds and maintains the provincial roads following standards to prevent the release of contaminants into the environment.

Regarding the municipal road network, some mapping of municipal road problems and road practice characterization had been done in different areas of the Quebec portion of the watershed. RAPPEL offers training to municipal employees on environmental management of ditches and diagnosis of municipal road networks for municipalities (Martel, J.F., RAPPEL, 2018, comm. pers.). MCI has also supported the municipality of Ogden in the characterization of their road network and practices, and the Town of Magog in the erosion characterization where roads crossed Castle Brook or Cherry River (Aubé *et al.*, 2017; WSP, 2014). Several problematic sites along the roads, ditches, and culverts have been observed in some areas (Aubé *et al.*, 2017).

Several municipalities are presently working to reduce erosion along their municipal road network (Desroches-Pichette, J., Orford, 2019, comm. pers. ; Déturche, F., Bolton-Est, 2018, comm. pers.; Maillé, L., Austin, 2018, comm. pers.; Simard, P. Canton de Stanstead, 2018, comm. pers.). The Government of Quebec currently has a funding program for municipal road networks (Programme d'aide à la voirie locale) that give annually $225 million CAN ($167 million US) to improve municipal road networks, that can be used to reduce runoff (MTQ, 2019).

Private Septic Management

All the municipalities of the Quebec portion of Memphremagog Watershed ensure private septic systems are pumped. This is done according to a certain frequency (every 2 years for a permanently occupied residence or every 4 years for a seasonal residence), or according to the accumulated quantity of sludge measured by the municipality every year and is the responsibility of the owner. To improve compliance, some municipalities have developed a funding program to help owners to upgrade substandard septic systems, including Austin and Stanstead Township (Austin, 2019; Stanstead Township, 2019). In 2010, the MRC Memphremagog, with founding from the

Government of Quebec, did an inventory of 839 private septic systems located near water bodies, which 184 were located in Lake Memphremagog watershed at less than 300 m of the lake, to characterize their performance and prioritize interventions (MRC de Memphrémagog, 2010). The MELCC, all the municipalities of the Watershed, the MRC, MCI and other lake associations produce and/or distribute information to owners of isolated residences about a proper management of their septic system through their web site, pamphlets, newsletters or conferences.

d) Point sources

In Quebec, there are approximately 30 industries whose wastewater is treated in the Lake Memphremagog watershed, either by a Wastewater Treatment Facilities (WWTF), or on site by the industry itself (Cloutier, J.-F., MELCC, 2020, pers. comm.). There are currently four WWTF located in the Quebec portion of Lake Memphremagog Watershed. The Environmental Discharge Objectives (OER, *Objectifs environnementaux de rejets*) at the effluent of the WWTF is an annual average of 0.3 mg/L for the total phosphorus (Gouvernement du Québec, 2019b). The WWTFs of the Quebec portion of the watershed had until January 2017 to meet this requirement. After this date, the MELCC does not authorize an extension of the municipal sewer system if the municipality does not comply with the phosphorus requirement in domestic wastewater discharges. The requirements for ammonia nitrogen at the effluent of the WWTFs depend on temperature and pH (e.g. 3mg/L in summer and 5 mg/L in winter). Nitrates-nitrites nitrogen and total nitrogen concentrations can also be required depending on the types of wastewater received at the facility. Medium and large sized WWTFs are also required to conduct Whole Effluent Toxicity (WET) tests on a regular basis.

e) Natural lands

The Lake Memphremagog watershed is mostly natural lands and several Quebec stakeholders are involved in the conservation and the protection of this territory through awareness campaigns, technical and financial assistance, and the creation of protected areas.

Conservation of public lands

In the Lake Memphremagog watershed, there are two public protected areas owned by the Government of Quebec under the Natural Heritage Conservation Act for a total of 36.2 km^2 (8,933 ac.; Appendix 2-4): the Mount Orford National Park, managed by the Société des établissements de plein air du Québec (Sépaq), and the projected biodiversity reserve Michael-Dunn. Some lands are also owned and protected by municipalities or foundations: for example, the Town of Magog and the FFQ own a part of the Cherry river wetland, a natural land protected, managed and enhanced by LAMRAC.

Voluntary conservation agreements

There are also several private protected areas owned by individuals, conservation organizations or municipalities for a total of 10.1 km^2 (2,496 ac.; Appendix 2-4). These private protected areas are created by landowners who take the initiative to conserve the natural lands on their property. Since most of the watershed is in private ownership, MCI works to inform and support landowners, and obtain funds to protect lands in perpetuity through voluntary conservation agreements. Appalachian Corridor (ACA), Memphremagog Wetlands Foundation (MWF), Nature Conservancy Canada and the Association du Marais-de-la-Rivière-aux-Cerises (LAMRAC, the Association who promotes, preserves and enhances the marsh of the Cherry River) are MCI's main partners in the implementation of conservation actions, and municipalities, federal and provincial government agencies such as ECCC and the MELCC are also collaborators. The conservation projects are generally funded by government agencies and foundations such as FFQ. The Government of Quebec, with its Act respecting municipal taxation (Loi sur la fiscalité municipale; ch. F-2.1), also gives an incentive to the landowners who create a private nature reserve with a total or partial municipal and scholar tax exemption.

Natural land mapping and assessment

The SAD of the MRC Memphremagog identifies areas of ecological interest that require special protection such as wildlife habitat, waterbodies and wetlands. To improve the accuracy of wetland mapping, the MRC de Memphremagog acquired LiDAR (Light Detection and Ranging) data and new mapping is planned for 2019. The SAD contains minimum and general rules to protect natural lands that must be adopted by the municipalities and that concern, among others, wetlands, tree cutting, and shorelines. Also, some non-profit organizations such as MCI and ACA support municipalities in the delineation and the characterization of wetlands in the field to improve the accuracy of the wetlands mapping and to formulate recommendations to protect them.

Forest lands

Municipalities of the territory of the MRC Memphremagog enforce their tree-cutting by-law through an inter-municipal inspection agreement. The purpose of the agreement is to provide the municipalities with the services of a forest engineer to assist municipal inspectors with the application of municipal tree cutting by-laws and any other matter relating to forestry. The MRC Memphremagog also distributes an awareness document to the foresters to inform them about the regulations and the good practices to adopt (MRC de Memphrémagog, 2011). To inform and raise awareness about sustainable stormwater management, RAPPEL give training to foresters about best management practices to implement along forest roads (Martel, J.-F., RAPPEL, 2018, comm. pers.).

The forestry group ventures covering the Quebec portion of Lake Memphremagog watershed support private forest owners in the adoption of additional measures regarding forestry operations. Within the Forest Producers Union of the South of Québec, several of their clients are certified Forest Stewardship Council (FSC), which requires the implementation of best management practices. The Ministry of Forests, Wildlife and Parks (MFFP, Ministère des Forêts, de la Faune et des Parcs) gives financial support to private forest owners through its Private Forest Enhancement Program and through a regulation allowing the owner to get a property tax refund, for forestry works that protect and enhance the private forests and protect water resources. The Private Forest Development Program is managed in Estrie by the Agency for the Enhancement of the Private Forest of Estrie (AMFP, Agence de mise en valeur de la forêt privée de l'Estrie) who also offers technical support and training to the forestry group ventures.

Shorelines and Riparian Habitat

To help the municipalitiesenforce the riparian buffer regulations around Lake Memphremagog, the MCI lake patrol patrols the lake by boat and sends pictures of problems to municipalities. To support shoreline revegetation, each year, the MRC Memphremagog coordinates a program that distributes shrubs in the municipalities around the lake. More than 60 000 shrubs were distributed over the last twelve years (Roy, A., MRC de Memphrémagog, 2019, pers. comm.). The MELCC, the municipalities of the watershed, the MRC, MCI and other lake associations also distribute information to shoreline owners through their web site, pamphlets, newsletters or conferences.

Also, some municipalities and MCI have financially supported citizens to revegetate their shorelines (Maillé, L., Austin, 2018; Orjikh, A., MCI, 2018; Simard, P., Stanstead Township, 2018, pers. comm.). For the agricultural sector, the Agricultural Producers Union (UPA, Union des producteurs agricoles) has a Shoreline Operation Campaign and a website specifically to distribute information and sensitize farmers about shoreline protection, with the financial support of the FFQ. The Prime-Vert program from MAPAQ also gives financial support to create wide and mixed riparian buffers on agricultural lands (UPA, 2019).

f) Recreational tourism sector

Lake Memphremagog and its watershed have an active outdoor recreation sector in Quebec: boating, fisheries, ski, golf, hiking and swimming are all important activities for both tourists and residents of the region. This section addresses the actions to limit the impacts of recreational activities that involve significant transformation of natural habitats, such as golf courses and ski resorts, or other activities that have a potential impact on the water quality, such as boating.

Boating practices

The Memphremagog MRC, the Quebec Provincial Police (SQ, Sûreté du Québec) and the Memphremagog Regional Police (Régie de police de Memphrémagog) are responsible to enforce the federal regulation regarding boating on Lake Memphremagog. Several buoys are installed between June and September at 100 m (328ft) from the shore where the speed limit is reduced to 10 km/h (6 mi/h). A pamphlet presenting the existing regulation is made every year and distributed to boaters. Since 1989, the MRC lake patrol made up of police students applies regulations regarding boating on Lake Memphremagog and Lake Lovering.

Since 2016, the Memphremagog MRC, in collaboration with the municipalities and MCI, implements the awareness campaign *Follow the wave* in Lake Memphremagog, asking boaters to practice sports generating oversized waves at least 250 m (820 ft) from the shore (MRC Memphremagog, 2016). Every summer, buoys are installed near three sensitive zones as a reminder for the boaters to stay at least 250 m (820 ft) from shore when practicing these sports. A short video and a pamphlet were created and have been distributed to the population. Since 1974, the MCI lake patrol has also distributed a pamphlet on best practices for boaters.

Open-air industry

In Quebec, some public and private owners protect natural lands for recreation, such as walking, hiking, biking, snowmobiles and/or all-terrain vehicles. While some recreational activities may export nutrients into watercourses because of erosion along dirt roads for example, they also can prevent the conversion of natural lands into another type of land use with a greater nutrient export coefficient.

Ski and Golf industries

The ski and golf industries are considered intensive recreational activities by the MRC and must be implemented in specific areas of the SAD. Their management is regulated by the *Quebec Environment Quality Act.*

3.2.1.5. *Implementation of restoration measures in the lake and its tributaries*

Sediment trap in Castle Brook, Magog

In 2000, in Castle Brook, the Town of Magog installed a sediment pit to collect sediment coming from the Castle sub-watershed before entering in Lake Memphremagog. The pit was upgraded in 2017. More than 1600 m^3 of sediment was dug out from the water course to install the pit (Magog, 2019, unpublished data). The pit and trap built in 2000 and upgraded in 2017 were designed and are effective for sediments larger than 0.1 mm (MENV, 2000; MDDELCC, 2017b; Polytech, 2009). On the other hand, the efficiency for sediments of less than 0.1 mm is limited and high concentrations of suspended matter are observed in the water column downstream of the pit during heavy rain events which contributes to the silting of Magog Bay (JFSA, 2016; Gagnon, 2019).

Installation of Aerators in Aunes Bay, Magog

In 2017, the Association for the revitalization of the Lake Memphremagog delta and bays (ARDBLM, Association pour la revitalisation du delta et des Baies du lac Memphrémagog) began a pilot project and installed aerators in Aunes Bay, near the mouth of Castle Brook to reduce the thickness of sediments in the area (Magog, 2018b). When, in theory, the internal phosphorus load of a lake can be reduced by the artificial circulation of water in cases where the release of phosphorus by sediments is the main mechanism for water enrichment, the installation of aerators can have the opposite effect and increase the internal phosphorus load by increasing the aerobic decomposition of organic matter (Ministère de l'Environnement, 2003). The impact of the aerators on the concentration of nutrients in Aunes Bay and Lake Memphremagog is not yet known.

3.2.2. Inventory of United States nutrient management efforts

3.2.2.1. United States water quality protection policies, acts, and laws

a) United States federal acts and laws

Federal Clean Water Act: Effective October 18th, 1972

The Clean Water Act (CWA) is the federal law governing water pollution in the United States with the purpose of maintaining and restoring the nation's waters addressing chemical, physical, and biological conditions. This act lays the foundation for the basic regulations of discharged pollutants. Under the clean water act pollution control programs have also been implemented, such as wastewater standards and the Total Maximum Daily Load (TMDL) requirements (EPA, 2019a).

Federal Endangered Species Act: Effective December 27th, 1973

The Endangered Species Act serves to conserve both flora and fauna in the ecological niches in which they are found. The federal agencies that oversee enforcing this act are the U.S. Fish and Wildlife Service and the U.S. National Oceanic and Atmospheric Administration Fisheries Service (EPA. 2019b). The US Endangered Species Act could be used to regulate nutrient loading if these activities or nutrient concentrations were found to pose a threat to an endangered species.

Federal Farm Bill: Effective 1981, Renewed in 2018

The Farm Bill is designed to provide stability for farmers, develops trade opportunities, helps Americans with access to nutritious food for their family's health and protects resources and land (UCSUSA, 2019). Programs and funding included in the US Farm Bill directly support the implementation of Best Management Practices (BMPs) on farms to reduce nutrient loading.

b) Vermont state acts and laws

VT Act 250, Land Use and Development Act: Effective in 1970

Act 250 is Vermont's Land Use and Development Act. This was designed to address the community and environmental impacts potentially caused by development. There are 10 different criteria that must be followed in order for the District Environmental Commissions to approve every development, including water pollution (VDEC, 2019a). The full list of criteria is available on the Natural Resources Board website: https://nrb.vermont.gov/act250-permit/criteria .

Vermont Shoreland Protection Act: Effective July 1st, 2014

The Shoreland Protection Act regulates activities that occur within 250 ft (76.2 m) of the mean water level of a lake that is 10 ac. (approx. 4 ha) or larger in size. VDEC administers the Shoreland Protection Act through shoreland permitting program to ensure that any development within the shore area is in compliance with the act. The act is intended to ensure that reasonable development continues while also protecting the shoreline, aquatic habitat, and water quality (VDEC, 2015b).

VT Act 64, Vermont Clean Water Act: Effective November 18, 2016

Act 64 is Vermont's Clean Water Act and serves to address water quality issues and provisions relating to agriculture, stormwater and basin planning, as well as use value appraisal. This act also increased funding for the implementation of water quality programs and improvements (VLEG, 2019a). In Act 64, the regulation of stormwater runoff was updated to include discharges from existing impervious surfaces such as municipal roads and any impervious surface of three acres (1.2 ha) or more in size. This act requires VANR to update the basin plans for the 15 watersheds (VDEC, 2019a).

Act 64 required the updating or development of a number of regulatory programs and required best management practices (BMPs) to reduce erosion and nutrient loading. These programs from Act 64 include (VDEC, 2017c):

Program	**Description**
Acceptable Management Practices (AMPs)	BMPs that reduce erosion from forestry operations
Municipal Roads General Permit	To inventory and reduce erosion from municipal roads

Operational Three-Acre Permit	To inventory and reduce stormwater runoff from sites with over 3 acres of impervious surface
Required Agricultural Practices (RAPs)	To plan and implement BMPs to reduce impacts of farming on waterways
Transportation Separate Storm Sewer System Permit (TS4)	To inventory and reduce stormwater runoff from state transportation network and state transportation facilities

VT Act 185, Clean Water Revolving Fund: Effective May 28, 2018

Is an act relating to the clean water state revolving loan fund. This law amended statutory provisions for the clean water state revolving loan fund (CWSRF) to expand project eligibility. Act 185 made natural resource projects that are sponsored by a municipality and paired with a traditional project eligible for CWSRF funding and made private borrows eligible for loans from the CWSRF for water quality projects (VDEC, 2019a).

VT Act 76: An act relating to the provision of water quality service: Signed by Governor, June 19, 2019

Act 76 provides a long-term funding source for water quality programs in the state of Vermont by allocating 6% of the revenue from the rooms and meals tax to this fund. It also sets up a new funding distribution model for water quality projects by requiring VANR to establish regional clean water service providers who are responsible for water quality projects in their region along with a basin water quality council to make decisions on projects. The act also establishes four new grant programs and requires VANR to develop clean-up plans for impaired waters (VLEG, 2019b)

c) Municipal laws

Municipal zoning and by-laws

Municipalities in Vermont can pass bylaws that regulate land development within municipal boundaries through permits, prohibitions, restrictions, and regulations. Municipalities can regulate uses of land and shoreland, construction and uses of structures, timing and/or sequence of growth, and uses of river corridors. Municipalities may adopt bylaws to protect river corridors and buffers by regulating development and use of river buffer and corridor. Municipalities can choose to implement these bylaws for a number of reasons, including pollution, sediment, and/or erosion control, reduction of stormwater runoff, or protection/preservation of wetlands and/or natural habitat.

3.2.2.2. Lake Memphremagog Total Maximum Daily Load for Phosphorus

Section 303(d) of the US federal CWA authorizes EPA to work with states to list waters as impaired and develop Total Maximum Daily Loads (TMDL). A TMDL establishes the maximum amount of a specific pollutant that can enter a waterbody to meet clean water goals (USEPA, 2018). Additional information on the federal TMDL process and impaired waters is available at: https://www.epa.gov/tmdl

Through water quality testing, it was established that phosphorus concentrations for the Vermont portion of Lake Memphremagog averaged 18 µg/L which exceed the water quality criteria of 14 µg/L. Due to the exceedance of the water quality standard, the CWA requires that a TMDL for phosphorus be set to limit the amount of phosphorus entering Lake Memphremagog from its watershed. This was completed by VDEC and approved by EPA in November of 2017 (VDEC, 2017a).

VDEC was tasked with developing the TMDL for the Lake Memphremagog Watershed. The development of the TMDL was done using three related but distinct modeling tools which are: a land use phosphorus export model, an in lake "bathtub" model, and a BMP scenario tool (VDEC, 2017b). The monitoring and modeling processes are described briefly below, but conceptually, the TMDL process included:

1. Water quality monitoring.
2. Development of phosphorus reduction targets by land use type through the:
    a. Development of land use export model to understand phosphorus loading by land use type.
    b. Development of "Bath Tub"` Model for Lake Memphremagog to establish the percent reduction of phosphorus needed to meet the water quality criteria.
    c. Use of BMP scenario tool to determine loading reductions achievable from phosphorus source sectors based on combinations of implemented BMPs.
3. Development of a final TMDL report to reduce phosphorus loading to reach clean water goals which will be implemented though increased regulations of phosphorus generating sectors and voluntary actions. Voluntary actions are targeted based on tactical basin plans that are updated every five years to allow for an iterative process to identify, and then implement

targeted phosphorus reduction actions. See section 3.2.2.4 for information on tactical basin plans.

a) *TMDL phosphorus reduction targets*

The TMDL is a legally binding document for Vermont only, as such, phosphorus reduction targets and the plan to meet those targets were developed for Vermont only and assumed that phosphorus loading from Quebec would remain constant. The TMDL indicated that an overall 29% reduction in phosphorus loading is needed from the Vermont portion of the watershed to meet the clean water goals of a phosphorus concentration of 14 µg/L in the Vermont portion of Lake Memphremagog. Table 3-1 shows reduction percentages by land use as included in the TMDL to meet Vermont's load reduction target.

Table 3-1. Reduction percentages by land use

Land use	**Percent Phosphorus Load Reduction**
Agricultural Lands	46%
Agricultural Production Areas	64%
Developed Lands	18%
Other (Forest, shrub, wetland, water)	3.5%
Streambank	23%
Wastewater Treatment Facilities	33% of current permitted load

As a part of the TMDL and TBP, VDEC developed an action plan for phosphorus reduction that included necessary phosphorus reduction by land use type and outlines best management practices to reach those goals (VDEC, 2017c).

For more information, all TMDL related documents are available online:

- Lake Memphremagog TMDL (2017): http://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Memph%20TMDL%20Final%20EPA%20approved.pdf

- Modeling Documentation for Lake Memphremagog TMDL (2017): https://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Memph%20TMDL%20documentation%208-2-17.pdf

The Basin 17 Tactical Basin Plan includes the TMDL as a section and in context of broader initiatives for the Basin and includes an expanded action plan for the Lake Memphremagog Watershed and Basin. It is available online at:

http://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Basin17_TBP_Signed.pdf *b) TMDL water quality monitoring programs*

Vermont TMDL Lake Memphremagog Monitoring Program - Vermont Department of Environmental Conservation

Water Quality samples were taken on Lake Memphremagog from 2005 through 2012 through the Vermont Lake Assessment program including samples of total phosphorus, total nitrogen, chloride and metals. Samples were taken by VDEC biweekly from May through October or November at 0.2 meters depth and then every two meters depth to one meter above the bottom. In addition to this, a hydrolab was used to measure pH, turbidity, and chlorophyll every one-meter of depth and measurements of Secchi depth were taken at each site. These samples were taken at the same locations as the Lay Monitoring Program, in South Bay and off Whipple Point (Memph 03), with an additional site sampled on Lake Memphremagog (Station 249/Memph 04) which is located one kilometer southwest of Bell Island in the middle portion of Lake Memphremagog and which is also sampled by MELCC (See Figure 2-6 in section 2.2.2).

TMDL tributary phosphorus loading monitoring program-Vermont Department of Environmental Conservation

The VDEC has led a sampling program since annually 2005 on the Black River, Barton River, Clyde River at the lowest bridge above the lake taking water samples using a depth integrated sampler. VDEC in coordination with the volunteer monitoring program have also taken samples on the smaller Johns River several miles upstream from the outlet at Beebe Plain as grab samples. Sampling frequency is roughly monthly with 8-13 high flow samples taken per year when flows were above the 90th percentile of flows as measured at the Black River.

The Flux Program (Walker, 1999) has been used to estimate annual phosphorus loading for each tributary using a methodology that segregates sample dates into strata based on rising, falling or stable portions of the hydrograph which results in a relatively low coefficient of variation for each tributary. VDEC is evaluating the use of the Weighted Regression on Time Discharge and Season as an alternative approach to estimate phosphorus loading.

c) *TMDL models*

Land use phosphorus export model

In order to set a TMDL for Lake Memphremagog, a land use phosphorus export model was developed to estimate phosphorus loading from watersheds areas where these data were not already available based on stream monitoring and to attribute loading to land uses across the watershed. The land use phosphorus export model was originally developed in 2009 by a private consultant, SMi Amenatech Inc., in collaboration with the Quebec Vermont Steering Committee's Technical Committee on Lake Memphremagog and funded by the Regional County Municipality (MRC, Municipalité Régionale de Comté) Memphremagog (Vezina & Desilets, 2009). This model uses literature phosphorus export values to estimate loading from land uses, estimates of septic system loading, and then estimates of retention in lakes larger than 4 ha (9.88 ac.) to approximate phosphorus loss in the watershed.

This model was updated by VDEC with input from the Quebec Vermont Steering Committee to add land use classifications for dirt roads, paved roads and farmstead areas, and to add estimated loading from stream channel erosion from the larger rivers in Vermont. VDEC calibrated the land use export coefficients for the model based on loading estimates for the four major tributaries and 24 minor tributaries that were available in Vermont. At the time the model was developed, phosphorus loading estimates were not available for Quebec tributaries which increases the uncertainty of loading estimates from this model in Quebec.

Current estimated loading from the TMDL is presented in section 2.3. The TMDL document as supplementary material is available online at: https://dec.vermont.gov/watershed/map/basin-planning/basin17

Lake Memphremagog "bathtub" model

To support the development of the Lake Memphremagog phosphorus TMDL, a "bathtub" model was developed to estimate the exchange between lake segments and the sedimentation of phosphorus in each lake segment. This model is described in detail in the modeling documentation for the Lake Memphremagog TMDL (VDEC, 2017c.) The Bathtub model estimates a 29% reduction in phosphorus loading in Vermont is needed for Lake Memphremagog to meet Vermont clean water goals assuming that phosphorus loading remains the same in Quebec.

Memphremagog BMP scenario tool (M-BMP)

The Memphremagog BMP Scenario Tool, or M-BMP, is a spreadsheet-based modeling tool designed to estimate how much phosphorus reduction could potentially be achieved by various mixes of BMPs across the Lake Memphremagog Watershed. This is a modified version of the Lake Champlain Phosphorus Scenario Tool built for the Lake Champlain TMDL (Tetra Tech, 2015b) and is described in the modeling documentation for the Lake Memphremagog TMDL (VDEC, 2017c.) This scenario tool uses land use phosphorus model-generated baseline loading coefficient for each land use together with BMP efficiency information generated through a Lake Champlain SWAT model, or literature values, to estimate the amount of phosphorus reduction potentially achievable from a wide variety of user-selected BMP scenarios in each lake segment sub-watershed. Through this tool, BMPs can be applied across a set acreage or percentage of a given land use across a sub-watershed draining to a lake segment in either Vermont or Quebec. The tool then estimates the load reduction achieved. The load reduction estimates are then input into the bathtub model (described in the previous section) which estimates the resulting change in lake phosphorus concentration for each lake segment.

3.2.2.3. Monitoring and research

United States Geological Survey (USGS)- Flow Monitoring

The USGS maintains three flow gages in the Vermont portions of the Lake Memphremagog watershed in addition to a water level gage on Lake Memphremagog itself which was established in 1931. The Black River gage has been in operation since 1951, the Barton River gage since in 2010, and the Clyde River gage was established in 1909 with a few years break in the record around 1927.

Vermont Lay Monitoring Program - Vermont Department of Environmental Conservation

The Vermont Lay Monitoring Program (VLMP) provides training and equipment for local volunteers or lay monitors to sample surface waters in Vermont. The program began in 1979 and has three main goals: 1) to establish baseline water quality data; 2) to track trends in nutrient enrichment; 3) to provide education and outreach. Lay monitors sample surface waters every week to ten-days throughout the season from Memorial Day (last Monday in May) to Labor Day (first

Monday in September) for phosphorus, secchi depth, and chlorophyll a. A minimum of eight samples must be taken over the season to calculate average values (VDEC, 2018b).

The lay monitoring program has been active in the Memphremagog Watershed since 1985. There are two sampling sites on Lake Memphremagog, one in the center of South Bay and one located in center of lake off Whipple Point (Station 294/Memph 03) (See Figure 2-6 in section 2.2.2).

Additionally, lay monitors sample Salem Lake, Seymour Lake, Shadow Lake, Great Hosmer Pond, Long Pond, Lake Willoughby, Lake Parker, and Echo Lake in the Vermont portion of the watershed.

Water quality data from the lay monitoring program is available online at https://dec.vermont.gov/watershed/lakes-ponds/data-maps/lay-monitoring

Cyanobacteria Monitoring Program - Vermont Department of Environmental Conservation and Vermont Department of Health (VDH)

The VDEC and VDH currently provide training for volunteers to visually assess surface waters for the presence of cyanobacteria. Volunteers log their (weekly) observations with the online cyanobacteria tracker. If a bloom is present, the VDH advises that all contact be avoided and may recommend that specific areas, such as swimming beaches, be closed for recreational activities. Jurisdiction to close beaches resides with the local town health officer and VDH works closely with local officials to develop an appropriate response and communication plan. At the end of each year, VDEC releases a report on the cyanobacteria observations for the season. All data is available online at http://www.healthvermont.gov/tracking/cyanobacteria-tracker.

Since 2013, the Memphremagog Watershed Association (MWA) has recruited and coordinated cyanobacteria monitors on the Vermont portion of Lake Memphremagog and has helped facilitate trainings for volunteers to recognize cyanobacteria. Prior to 2013, no formal monitoring program existed and blooms were reported by residents and VDEC staff. In 2013, routine summer monitoring under the guidance of the Lake Champlain Committee, VDEC, and the Vermont Department of Health (VDH) was initiated at selected locations following protocols used on Lake Champlain (Shambaugh, 2018).

If a bloom is identified on the Vermont portion of Lake Memphremagog, samples of cyanobacteria are not required, as visual observations and photograph documentation are sufficient to close an area for recreation following VDH guidelines even if the presence of cyanotoxins is not confirmed. This allows for rapid response to cyanobacteria bloom conditions, which can change rapidly. Water testing and taxonomic samples require several days before results are available. The visual assessment protocol used in Vermont was developed specifically to facilitate rapid response by local authorities.

Voluntary Tributary Water Quality Monitoring Program

Since 2005, the voluntary tributary monitoring program has sampled over 153 sites throughout the Vermont portion of the Memphremagog Watershed. This program is supported by the LaRosa Partnership Program through the VDEC which supports the processing of the water sample at Vermont State Laboratories. A wide array of funding sources has provided organizational support to collect and analyze data since 2005.

Sampling of tributaries has been conducted through the collaborative efforts of the Orleans County Natural Resources Conservation District, NorthWoods Stewardship Center, and the Memphremagog Watershed Association under the lead of Fritz Gerhardt of Beck Pond LLC through 2018.

The LaRosa program includes testing for nitrogen, phosphorus, and before 2017 turbidity eight times per year with two sample dates targeting active runoff events.

Data from this sampling program have been used to assess areas of concern for nutrient loading as shown in Figure 2-5 in section 2.2.1 and has led to efforts to work with specific landowners and agricultural producers to implement best management practices and track the effect of those BMPs on water quality (VDEC, 2017a). Annual reports are available online at: https://dec.vermont.gov/watershed/map/monitor/larosa .

3.2.2.4. Decision support tools

Stream Geomorphic Assessments (SGA)

Three stream geomorphic assessments have been completed for the Memphremagog Watershed by the NorthWoods Stewardship Center with guidance of VDEC. In 2008, an assessment for the Barton and Johns River, and the Clyde River were completed, and in 2011, the Black River. These reports are available online: https://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment

The purpose of an SGA is to provide guidance on how to balance human activities, development, and water use with stream corridor protection and restoration. The reports are used as watershed planning and educational tools, to ensure that development and projects are planned and implemented in such a way that is consistent with current stream geomorphic features as well as the expected stream channel evolution (VDEC, 2018c).

Stormwater Master Planning and Stormwater Infrastructure Mapping

In 2016, a Stormwater Master Plan was produced for the Vermont portion of the Memphremagog Watershed by Watershed Consulting Associates (WCA). WCA was hired by the Memphremagog Watershed Association (MWA) using funding from a Vermont Ecosystems Restoration Program grant from VDEC. The plan uses the Stormwater Mastering Planning Guidelines set out by the VDEC to identify twenty priority projects across the towns of Barton, Coventry, Derby, Glover, Irasburg, Newport City, and Orleans Village. These priority projects where chosen as high impact locations for stormwater retrofits to reduce the amount of phosphorus entering waterways. In the report, four of these priority projects were accompanied by a 30% design for a stormwater retrofit (WCA, 2016). This report is being used as a planning tool for MWA and municipalities to apply for additional funding to design and implement stormwater retrofits around the watershed to reduce phosphorus from developed lands to help meet the TMDL phosphorus reduction targets.

Stormwater Infrastructure Mapping has also been completed for multiple municipalities in the watershed. This mapping was done by VANR and is used as a decision-making tool for the towns to maintain existing stormwater infrastructure and plan for future upgrades. Stormwater Infrastructure Mapping has been completed for the municipalities of Albany, Barton, Brighton, Craftsbury, Derby, Glover, Irasburg, Newport Center, and Orleans Village.

Tactical Basin Planning

Tactical Basin Plans (TBP) are produced every five years by Watershed Planners at VDEC in close coordination with basin partners. TBPs provide an evaluation of surface water quality, identify problems and threats, and recommend watershed projects and funding sources to bring waters into compliance with current state water quality standards (VDEC, 2018a). According to Act 64, or Vermont's Clean Water Act, actions that improve water quality undertaken by the state must be included in the TBPs and the state must establish relationships with local actors to carry out these actions (VDEC, 2017c). As such, TBPs are an important planning tool and project prioritization document.

Vermont is broken up into fifteen basins. The Vermont portion of the Memphremagog Watershed is in Basin 17, the Memphremagog, Tomifobia, and Coaticook Basin. The TBP for Basin 17 was completed in 2017 and had, as a primary focus, the implementation of phosphorus reductions as required to meet the Lake Memphremagog TMDL. The TBP includes recommendations for actions to be taken on each type of land use to reduce phosphorus loading in proportion to the percent loading from each type of land (VDEC, 2017c). These recommended actions and projects are compiled on VDEC's Watershed Project Database, which serves to assist in the prioritization of water quality projects, guide state funding, and watershed organizations and municipalities in their water quality projects. Future basin planning cycles will make use of additional monitoring and modeling information to develop priorities for implementation at five-year intervals allowing for an iterative process to implement the TMDL over time. The TMDL calls for a 29% reduction in phosphorus loading.

3.2.2.5. Current implementation of best management practices (BMPs) in the United States watershed

a) Agricultural sector

Required Agricultural Practices

Act 64 required that Secretary of the Vermont Agency of Agriculture, Food and Markets (VAAFM) amend Vermont's Accepted Agricultural Practice (AAPs) Rule to strengthen practices to reduce the impact of agriculture on water quality and implement the small farm certification program. The AAPs became effective in 1995 and were revised in 2006. In 2016, an updated series of practices and management strategies for all Vermont farmers was approved, known as the Required Agricultural Practices (RAPs). These new RAPs were amended again in 2018 (VAAFM, 2018). According to the Required Agricultural Practice Rule (2016) the purpose of the updated standards and practices is to reduce or eliminate sediment and nutrient losses, including cropland erosion, through improved farm management techniques, technical support, and when needed, enforcement, all to protect Vermont's waterways.

RAPs include standards and practices for:

- Farm size classification
- Water Quality Training
- Nutrient Management Plans
- Discharges
- Soil Health
- Manure and Nutrient Storage
- Manure and Nutrient Application
- Buffers
- Animal Mortalities
- Livestock Exclusion
- Ground Water
- Farm Structures

Between 2012-2016, agricultural producers in the Memphremagog Watershed adopted BMPs to reduce runoff on over 7,000 ac. (2,833 ha) costing a total of $1.5 million US ($1.96 CAN) (VTDEC, 2017c). These figures on BMP adoption were produced by the Orleans County NRCD and represent the combination of Natural Resources Conservation Service (NRCS) and VAAFM financial assistance program data. For the TMDL, an analysis of the impact of BMPs since 2012 suggests a phosphorus reduction of 250 kg/year (550 lbs/year) due to the installation of those practices (VDEC, 2017c).

The following programs and organizations are working to assist farmers with the continued and increased adoption of BMPs in the Memphremagog Watershed in Vermont through technical and financial assistance.

VAAFM Best Management Practice Program

The Best Management Practice program is a voluntary program to assist farmers with implementing conservation practices to improve water quality. From 2012-2016 over $217,000 US ($293,000 CAN) in funding was spent on barnyard improvement projects in the Lake Memphremagog watershed (VDEC, 2017c).

VAAFM Farm Agronomics Program

The Farm Agronomics Program (FAP) is a voluntary program that provides financial assistance to help farms implement soil based agronomic practices that improve soil quality, increase crop production, and reduce erosion and field runoff. This program funded over 4,000 ac. (1619 ha) of cover crop and conservation tillage in the Lake Memphremagog watershed from 2012-2016 (VDEC, 2017c).

United States Department of Agriculture/ Natural Resources Conservation Service (USDA/NRCS)

USDA/NRCS provides resources and BMPs guidance for farmers across the United States. In the Memphremagog Watershed, the USDA/NRCS office is located in Newport, VT. USDA/NRCS employees provide direct assistance to farmers and can assist with the development of conservation plans. Further, USDA/NRCS offers a cost sharing program called the Environmental Quality Incentives Program (EQIP) which provides direct financial assistance to farmers for BMP implementation. USDA also has other grant making programs and is currently funding the Memphremagog RCPP (see below).

Conservation Districts

The Orleans County and Essex County Natural Resources Conservation Districts are two of fourteen conservation districts in state of Vermont. Conservation Districts exists by state statue, are subdivision of local government with municipal legal status and function like nonprofits. The Orleans County Conservation District covers 95% of the Vermont portion of the Memphremagog Watershed and provides direct technical assistance and financial assistance to municipalities and landowners including agricultural producers. Current agricultural program offerings include implementing farmstead and field BMPs including riparian restoration, Nutrient Management Plan (NMP) development and implementation, education and outreach offerings, project coordination, grant sourcing assistance, agricultural BMP water quality monitoring and promotion of agricultural water quality success stories. Funding for the Conservation District programs and the pass through for financial assistance to farmers comes from USDA, State of Vermont and private funding sources. Outreach and educational opportunities for farmers also include the development and distribution of materials and workshops. The Orleans County NRCD created an online RAP quiz (https://www.vacd.org/rapquiz/) which provides farmers, service providers and interested community members with information on the RAPs and Farm BMP practices, and counts towards the RAP required water quality training hours for all certified and permitted farms. The Orleans County NRCD also offers agricultural conservation equipment rental programs including soil probes, portable skidder bridges, portable truck scales, no-till drills, and soil aeration equipment. Lastly, Conservation District staff organize the Memphremagog Agricultural Workgroup that is made up of conservation district, state and federal agency staff and other partner staff working with farmers in the watershed. The workgroup meets biannually to discuss current programs, coordination efforts and other relevant topics of importance.

USDA Regional Conservation Partnership Program (RCPP)- Memphremagog Long-Term Water Quality Partnership or "Memphremagog RCPP"

The Memphremagog RCPP is a 5-year project that began in 2016 and is led by the Orleans County NRCD. The program has pulled together twelve regional partners with a focus on reducing nutrient runoff from agricultural lands in targeted subwatersheds of the Memphremagog watershed. The subwatersheds were chosen as priorities based on high phosphorus concentrations recorded by a decade of water sampling.

Through this program, there is approximately $400,000 US ($540,00 CAN) available as financial assistance for farmers to develop Nutrient Management Plans (NMPs) and implement BMPs. There is also $275,000 US ($ 371,000 CAN) for direct technical assistance to farmers participating in the project. Additionally, the twelve partners committed additional support for technical and financial assistance in the amount of $674,000 US ($910,000 CAN) for water quality improvements. This program incorporates volunteer water quality sampling described in section 3.2.2.3 into technical assistance provided to farmers to guide BMP projects to areas of the farm where water sampling identifies the most critical source areas. The program also includes follow up water quality monitoring after BMPs have been installed to evaluate the effectiveness of projects at addressing water quality issues and the publication of success stories to encourage greater participation in these programs.

Vermont Land Trust (VLT)

VLT is a nonprofit that works to conserve Vermont farmland, as well as forest lands, through conservation easements. When working with farmland and landowners, VLT connects the landowner with financial and technical resources to reduce nutrient loading and improve land management, such as USDA/NRCS staff and resources. VLT also establishes riparian buffers on conserved farm and forest land to protect river corridors, provide habitat, and reduce nutrient loading.

b) Developed Lands

Memphremagog Stormwater Collaborative

In 2017, fourteen Vermont regional partners came together as the Memphremagog Stormwater Collaborative (SWC). The purpose of the group was to inventory current projects underway to reduce stormwater runoff, to identify areas of collaboration, and to write a strategic plan to guide stormwater work for the next three years. In June of 2018, the Memphremagog Stormwater Strategic Plan was released which outlines three years of priority projects with potential funding sources and collaborative approaches (MWA, 2018). Projects span all sectors including large and small scale Green Stormwater Infrastructure (GSI), roads, agriculture, outreach/education, and town planning. The SWC continues to meet biannually to assess progress on the goals laid out in the strategic plan, as well as collaborate on projects.

Roads

In the Vermont portion of the watershed, 60% of the paved roads are managed by the state of Vermont, while the majority of dirt roads are managed by the towns (VDEC, 2017c; VDEC 2018d). There are also private roads and driveways throughout the watershed, many of which are adjacent to waterways and are not subject to any regulation. Erosion from roadways, especially dirt roads, is a significant source of sediment and phosphorus in the watershed. The TMDL model estimates that 1.2% of the phosphorus comes from paved roads and another 8.2% coming from dirt roads (VDEC, 2017c). Throughout the entire state of Vermont there are 15,840 total road miles

(Class 1-4 roads) (25,492 km), 13,131 total road miles (21,132 km) are municipal roads (VDEC, 2018d). This means that towns in Vermont managed approximately 83% of the road ways, with the state managing 17%.

Vermont currently has two programs to reduce runoff from roadways, both of which are being implemented in the Memphremagog watershed, one for municipal roads and one for state transportation infrastructure.

As required by Act 64, the Municipal Roads General Permit (MRGP) was finalized in 2018. The MRGP requires that all municipalities in Vermont conduct a Road Erosion Inventory (REI) to assess all hydrologically connected road segments to determine if the segments meet the MRGP standards. Initial REIs must be completed by December 31st, 2020. Municipalities must then develop implementation plans and bring all hydrologically connected road segments up to standard by 2037. There is state funding available for municipalities to pay for the REI and to apply for municipal roads projects through VDEC's Municipal Grant-in-Aid program and other water quality grants (VDEC, 2018d).

Most municipalities in the Memphremagog Watershed have recently completed or are working on completing the REI. Local organizations such as NVDA, Orleans and Essex County NRCD, NorthWoods Stewardship, and MWA have been hired to collect the data and produce REI reports. Municipalities have also begun applying for funding to implement road upgrades.

State transportation infrastructure is managed under a separate permit throughout the state known as the Transportation Separate Storm Sewer System General Permit or TS4 which was released in 2016. Currently, VDEC is working with VTrans to develop a Phosphorus Control Plan which will incorporate Memphremagog TMDL phosphorus reductions and guide VTrans in required upgrades and projects for state transportation infrastructure. The Phosphorus Control Plan will outline BMPs with a design, construction, and financial plan for VTrans controlled infrastructure (VDEC, 2017c). In their annual operations, VTrans maintains state roads and annually replaces and upgrades culverts.

Lake Wise

The Lake Wise initiative from the VANR is a program that awards landowners for having lake-friendly property. The program seeks to change the way landowners develop and live on the lakeshores by working with landowners and awarding those who implement BMPs for shorelands that both reduce runoff, reduce impervious surfaces, and provide shoreline habitat to improve the quality of the lake littoral zone (VDEC, 2018e).

The program is voluntary for landowners. Landowner invite a Lake Wise assessor to their property to evaluate their land based on the Lake Wise Criteria in the categories of shore, recreational area, septic, driveway, and structure. If all the BMPs are already in place, the landowner will receive the Lake Wise Award. If there are projects a landowner needs to implement, then the assessor gives the landowner project suggestions and there is technical assistance available through the Lake Wise Program. Landowners have three years to implement practices and be reassessed to receive the Lake Wise award (VDEC, 2018e).

If 15% of the landowners around a lake are certified Lake Wise, then that lake receives Gold Lake Wise Award. The social science behind this suggests that the 15% is the critical threshold over which others will follow the example (VDEC, 2018e).

In the Memphremagog Watershed, lake associations and NorthWoods Stewardship Center have been working to provide assessments to landowners and implement projects to certify properties. In 2017, both Seymour and Echo Lake Associations worked with landowners to achieve the Gold Lake Wise Award for their lakes. Assessments, certifications, and project implementations continue annually.

In addition to assessments and implementation, area Lake Associations and MWA also host educational workshops for landowners on BMPs for shoreland owners and lake shore management, pulling from the Lake Wise program and materials.

Large Scale Stormwater Retrofits

In 2016, the Memphremagog Stormwater Master Plan was completed as described in section 3.2.2.4. There are 20 priority retrofit projects listed in the Stormwater Master Plan that are ready for design to lead to implementation to reduce phosphorus entering into the Vermont portion of the watershed (WCA, 2016).

Currently, MWA has two ecosystem restoration program grants from the VDEC to complete 100% designs on the Newport City Turnout Project and Numia Medical Facility (as named in the Stormwater Master Plan). These designs are anticipated to be completed in 2019, followed by implementation.

Two of the projects in the Stormwater Master Plan are on VTrans facilities and would collectively remove 57kg (124 lbs) of phosphorus a year (WCA, 2016). Design and completion of these projects could be included in the Phosphorus Control Plan which is currently being developed.

Municipal Planning and Projects

Northeastern Vermont Development Association (NVDA) is the Regional Planning Commission that covers the 50 towns and gores in Essex, Caledonia, and Orleans Counties, which covers all the towns and gores in the Memphremagog watershed. NVDA works directly with municipalities to provide planning assistance for transportation and natural resource projects, as well as town planning and regulation. NVDA also administers grants directly to organizations and municipalities. The partnerships between NVDA, municipalities, and organizations results in the development and implementation of projects to reach sustainable development goals.

In 2017 and 2018, through two grants from VDEC, NVDA worked closely with the Conservation Districts to coordinate activities that support the goals in the Tactical Basin Plans. The grants supported the Conservation Districts in outreach, coordinated monitoring programs, develop water quality projects, and organize local working groups.

Private Septic

VDEC is the permitting agency for alterations to existing or installation of new private wastewater facilities and has regional offices with permit specialists to assist landowners. In 2007, the Vermont Wastewater System and Potable Water Supply Rule came into effect which removed permit some of the exemptions for new construction, alternation, additional connections, or repair or replacement of existing private wastewater systems. Amendments to these rules were proposed in 2018 and a series of public meetings were held. The final new rules have not yet been released (VDEC, 2019).

c) *Natural lands*

Unstable Streambanks and Riparian Habitat

Significant efforts have been made in the Memphremagog Watershed to restore floodplain forest and to plant riparian buffers. From 2005 to 2016, through the combined efforts of the Nature Conservancy, Vermont Fish and Wildlife, Conservation Reserve Enhancement Program, NorthWoods Stewardship Center, and the Orleans County NRCD over 24 ha (60 ac.) of buffers were planted; this covers 21 km (13 mi) of streambank (VDEC, 2017c).

As of 2019, Vermont Fish and Wildlife Department (VFWD) owns over 105 km (65 mi) of streambank on the major tributaries of the Memphremagog Watershed. Most of these streambank parcels are 5 m (16.5 ft) wide floating ownership, meaning that the ownership moves with the river. VFWD is currently managing and protecting that land to provide access for anglers, as well as to protect and conserve the land; a) to better enable it to function as a "filter" for nutrients and contaminants before they reach the water; b) to function as wildlife corridors; c) to shade and cool the water which leads to water temperatures more conducive to our native fish (like brook trout) and; d) to grow mature floodplain forests whose trees and root systems will protect against erosion of soils and which will add to large wood deposition into the streams and onto the floodplain where they provide habitat for both aquatic and terrestrial species. VFWD holds an Ecosystems Restoration Program grant from the Vermont Department of Environmental Conservation to survey their riparian lands in 2019 and to prioritize projects which will reduce nutrient loading and improve riparian habitat. Additionally, VFWD has received funding from the Great Lakes Fisheries Commission (GLFC) to complete a binational angler survey of Lake Memphremagog on both sides of the International border to be conducted from December 2018 to November 2020. Long term, continued GLFC funding could support the implementation of projects to acquire and improve riparian habitat.

Lastly, VFWD is experimenting with methods to best convert former agricultural fields with abundant and robust invasive exotic plant species back to floodplain forest at South Bay and Willoughby Falls Wildlife Management Areas.

The Conservation Corps at NorthWoods Stewardship Center (NWSC) is an education and employment opportunity for youth, ages 15-25. Through the program, participants learn about conservation practices through hands-on installation of projects. During each field season, crews of Conservation Corps work in the Memphremagog Watershed (and throughout all six New England states) on trail maintenance, streambank restoration, stormwater best management practice installation, invasive species manual removal, and wildlife habitat restoration projects. The NWSC crews have also installed stormwater management practices on VT Fish and Wildlife Department access ramps. It is through this program that NWSC has installed Lake Wise practices, riparian buffers, and other shoreline BMPs in the Memphremagog Watershed. The Conservation Corps Watershed Crew program has been funded through VDEC Clean Water Initiative Work Crew grants, Ecosystem Restoration Program grants, and a few private contracts. In 2018, the Watershed Crew installed stormwater best management practices on five lakeshore properties on Seymour and Echo Lakes. Practices installed included driveway open-top culverts, infiltration steps, vegetated swales, vegetated infiltration areas, dry wells, parking area delineations, and rain gardens, among various others. Practices are designed to redirect stormwater to areas where it can infiltrate rather than flow over erodible surfaces, and to encourage biofiltration of runoff before it reaches the surface waters.

Forest Lands

Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont or AMPs were first established in 1987. Act 64 required that the Commissioner of Vermont Forest Parks and Recreation update and revise AMPs. The revised AMPs were released in 2016-2017, only to be revised again and finalized in August of 2018. According to the AMPs, “the purpose of the acceptable management practices is to provide measures for loggers, foresters, and landowners to utilize, before, during, and after logging operations to comply with the Vermont Water Quality Standards and minimize the potential for a discharge from logging operations in Vermont.”

The Orleans County NRCD also offers portable skidder bridge rentals for logging operations allowing. This practice reduces both streambank and stream bed disturbance. The portable bridges reduce disturbance of aquatic habitat as well as sedimentation and are considered a best management practice for stream crossing according to AMPs. The Orleans County NRCD rental program allows for affordable access to this equipment.

The NorthWoods Stewardship Center has a Forest Stewardship Institute program that is designed to educate and consult landowners and forestry professionals on advancing sustainable land management practices. NorthWoods staff will provide direct assistance to forest owners through site visits, land management plans, forestry services, low impact timber harvest, invasive species control, and mapping (Northwoods, 2019).

d) Point Sources: Wastewater Treatment Facilities

There are currently 4 wastewater treatment facilities in the Vermont portion of the Memphremagog Watershed. As of 2019, new permits are being issued from VDEC for all four facilities which include reducing the wasteload allocation for each facility by 33.2% from current permitted levels to reach TMDL phosphorus targets. In addition to this, permits will include a requirement for the development of a Phosphorus Optimization Plan (POP) to increase the WWTF's phosphorus removal efficiency by implementing optimization techniques that achieve phosphorus reductions using primarily existing facilities and equipment. To ease the financial burden of these new requirements, VDEC will be working with the municipalities to provide flexibility in meeting these goals, including a period of facility optimization, allowing for municipalities to reduce loading using their current technologies (VDEC, 2017c). WWTF are also required to have a Nitrogen Optimization Plan in their permits.

e) Recreational tourism sector

The Memphremagog watershed has an active outdoor recreation sector for both tourists and residents. Walking, hiking, or biking trails within 76 m (250 feet) of mean water level are regulated under the Vermont Shoreland Protection Act, with any new construction or expansion subject to permitting processes. Boating within 61 m (200 feet) of the shoreline is also regulated, requiring that boats operate at "no wake speed" which is defined as the speed at which the vessel does not create a wake, not to exceed 8 km/h (5 mi/h) (Vermont Boat Course, 2019).

In 2018, the Vermont Land Trust secured funding to build a recreational trail on the Bluff Side Farm in Newport that connect the bike path in Newport to the Beebe Spur trails which continues into Quebec. This path will include a bridge that crosses over Scott's Cove and along Lake Memphremagog (VLT, 2019). Newport City is also working on plans to expand the bike path along Prouty Beach to give better access to the water and recreational opportunities, a project that if permitted and funded would be installed in 2019 (Lambert, K., MWA, pers. Comm., 2019). In late 2017, a walking path continuation of the Newport Bike Path with stormwater management practices was installed behind the Waterfront Plaza shopping center. This project was an example of a public/private partnership that provided recreational opportunities and increased aesthetic value of the area, while also mitigating stormwater runoff from a shopping center plaza.

3.2.3. Inventory of binational nutrient management efforts

Over the past decades, binational committees have been joining their efforts to protect and improve the water quality of Lake Memphremagog Watershed. Following an increasing incidence of cyanobacteria blooms in 1968, the Governments of Canada, United-States, Québec and Vermont has created a first intergovernmental committee to improve the water quality of Lake Memphremagog whom then created a working group to formulate recommendations (Quebec-Vermont Working Group, 1993). After the publication of a report in 1975, the intergovernmental committee did not continue to meet until 1989, but efforts have been made by the governments to address the recommendations contained in the report (Quebec-Vermont Working Group, 1993).

Following the agreement signed between the Governments of Quebec and Vermont in 1989, a Quebec-Vermont Working Group was created, and a report have been published in 1993 containing 47 recommendations to improve the water quality of Lake Memphremagog (Quebec-Vermont Working Group, 1993). In 2005, it was determined by the Quebec/Vermont Steering Committee that progress had been made on 37 of these recommendations, and, of these 27 were completed (Quebec/Vermont Steering Committee, 2008).

In 2008, following another sequence of cyanobacteria blooms, a new report was done by the Monitoring and Assessment Work Group of the Quebec/Vermont Steering Committee (Quebec/Vermont Steering Committee, 2008). The recommendations provided in this last report are an extension of the recommendations listed in the 1993 report, modified to omit actions that have been accomplished, and include new activities as well. In 2008, the Quebec/Vermont Steering and Technical Committees also facilitated the collaborative effort to develop a watershed phosphorus export model (Copans, B., VDEC, comm. pers. 2019).

Appendix 3-1

List of Canadian Stakeholders

Municipalities

Austin
Website: www.municipalite.austin.qc.ca

Bolton-Est
Website: www.boltonest.ca

Ogden
Website: http://www.munogden.ca/

Orford Township
Website: www.canton.orford.qc.ca

MRC Memphremagog
Website: www.mrcmemphremagog.com

Potton Township
Website: www.potton.ca

St-Benoît-du-Lac
Website: www.abbaye.ca

Stanstead Township
Website: www.cantonstanstead.ca

Town of Magog
Website: www.ville.magog.qc.ca

Town of Sherbrooke
Website: www.ville.sherbrooke.qc.ca

Quebec Provincial Government

Orford County - Gilles Bélanger
Website:
https://coalitionavenirquebec.org/fr/blog/equipe/gilles-belanger/

Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)
Website: www.environnement.gouv.qc.ca

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ)
Website: www.mapaq.gouv.qc.ca

Ministère des Forêts, Faune et Parcs (MFFP)
Website: mffp.gouv.qc.ca/

Canadian Federal Government

Compton-Stanstead County - Hon. Marie-Claude Bibeau
Website: http://mcbibeau.liberal.ca/

Brome-Missisquoi County - Hon. Denis Paradis
Website: http://dparadis.liberal.ca/

Environment and Climate Change Canada (ECCC)
Website: www.ec.gc.ca

First nations

Conseil des Abénakis d’Odanak
Website: https://caodanak.com/

Regional organizations

Agence de mise en valeur des forêts privées de l’Estrie (AMFE)
Website: www.agenceestrie.qc.ca

Association forestière du sud du Québec (AFSQ)
Website: https://afsq.org

Aménagement forestier et agricole des Sommets inc.
Website: http://www.afasommets.qc.ca/

Club agroenvironnemental de l’Estrie (CAEE)
Website: www.caeestrie.com

Conseil de gouvernance de l'eau des bassins versants de la rivière Saint-François (COGESAF)
Website: www.cogesaf.qc.ca

Conseil régional de l'environnement de l'Estrie
Website: www.environnementestrie.ca

Appalachien Corridor appalachien

Website: www.corridorappalachien.ca

Fédération Québécoise des chasseurs et pêcheurs de l’Estrie :
Website: http://fedecp.com/communaute-evenements/05-estrie/conseil-d-administration

Union des producteurs agricoles (UPA) – Estrie
Website: https://www.estrie.upa.qc.ca

Local organizations and lake associations

Association du Marais-de-la-Rivière-aux-Cerises (LAMRAC)
Website:
https://maraisauxcerises.com/lamrac/general/association-du-marais-de-la-riviere-aux-cerises.php

Association pour la protection et l’aménagement du ruisseau Castle (APARC)

Association de protection du lac Gilbert

Association des propriétaires de la baie des Aulnes

Association des propriétaires du lac Malaga

Association des propriétaires du lac Miller

Association des propriétaires du lac Nick

Association des propriétaires de la Pointe-Gibraltar

Association des propriétaires de Southière-sur-le-Lac

Association des propriétaires du lac des Sitelles

Association des propriétaires des Villas de l'Anse

Association des riverains du lac à la truite

Memphremagog Wetlands Foundation (MWF)

Memphremagog Conservation Inc. (MCI)
Website: www.memphremagog.org

Mont-Orford Park
Website:
www.sepaq.com/pq/mor/index.dot?language_id=2

RAPPEL – Coop
Website: www.rappel.qc.ca/

Société de conservation du lac Lovering (SCLL)
Website: www.laclovering.org

Appendix 3-2

List of US Stakeholders

Municipalities

Town of Albany

Averys Gore

Town of Barton
Website: https://bartonvt.com/

Town of Brighton
Website: http://brightonvt.org/

Town of Brownington

Town of Charleston
Website: http://charlestonvt.org/town-office/

Town of Coventry
Website: http://www.coventryvt.org/

Town of Craftsbury
Website:
https://www.townofcraftsbury.com/

Town of Derby
Website: https://derbyvt.org/

Town of Eden
Website: https://www.edenvt.org/

Town of Glover
Website: http://townofglover.com/

Town of Greensboro
Website: http://www.greensborovt.org/

Town of Holland

Town of Irasburg

Town of Lowell
Website: http://www.townoflowell.org/

Newport City
Website: https://www.newportvermont.org/

Newport Town

Town of Morgan
Website: http://townofmorgan.com/

Town of Newark

Town of Sheffield
Website: http://www.sheffieldvt.org/

Town of Sutton
Website: http://suttonvt.org/

Town of Westmore
Website: http://www.wolcottvt.org/

Warners Grant

Warrens Gore

Town of Wolcott

Vermont State Government

Vermont Fish and Wildlife
Website: http://www.vtfishandwildlife.com/

Vermont Agency of Natural Resources
Website: https://anr.vermont.gov/

Vermont Department of Environmental Conservation
Website: http://dec.vermont.gov/

Vermont Agency of Transportation
Website: http://vtrans.vermont.gov/

Vermont Department of Health
Website: http://www.healthvermont.gov/

Vermont Agency of Agriculture Food and Markets
Website: http://agriculture.vermont.gov/

Vermont Department of Forests Parks and Recreation
Website: https://fpr.vermont.gov

Lake, River, and Watershed Associations

Echo Lake Protection Association
Website:
http://www.echolakeassociation.net/

Lake Parker Association
Website: http://lakeparker.org/contact-us/

Memphremagog Watershed Association
Website: www.mwavt.org

Salem Lakes Association
Website: http://www.salemlakesvt.org/

Seymour Lake Association
Website: http://seymourlake.org/

Shadow Lake Association
Website: http://shadowlakeassociation.org/

Westmore Association
Website: https://westmoreassociation.org/

Non-Governmental Organizations

Essex County Natural Resources Conservation District
Website: http://essexcountynrcd.org/

Federation of Vermont Lakes and Ponds
Website: http://vermontlakes.org/

Northern River Land Trust
Website:
http://www.northernriverslandtrust.org/index.html

NorthWoods Stewardship Center
Website:
https://www.northwoodscenter.org/wordpress/

Orleans County Natural Resources Conservation District
Website:
https://www.vacd.org/conservation-districts/orleans-county/

Vermont Land Trust
Website: www.vlt.org

Vermont Forests Products Association
Website: http://www.vtfpa.org/

Vermont Reptile and Amphibian Atlas
Website: https://www.vtherpatlas.org/

Watersheds United Vermont
Website: https://watershedsunitedvt.org/

Colleges and Universities

Community College of Vermont
Website: http://ccv.edu/location/ccv-newport/

Sterling College
Website: sterlingcollege.edu

University of Vermont, Rubenstein School of Environment and Natural Resources
Website: https://www.uvm.edu/rsenr

Federal Agencies

National Science Foundation
Website: https://www.nsf.gov/

US Army Corps of Engineers
Website: http://www.wolcottvt.org/

US Environmental Protection Agency Region 1
Website: https://www.epa.gov/aboutepa/epa-region-1-new-england

United States Department of Agriculture Natural Resource Conservation Service
Website: https://www.rd.usda.gov/vt

US Fish and Wildlife Services
Website: https://www.fws.gov/

US Geological Survey
Website: https://www.usgs.gov/

Private Industry

Beck Pond LLC

Casella Waste Management
Website: https://www.casella.com/locations/waste-usa-landfill-coventry-landfill

Newport Marine Service

Other

Northeastern Vermont Development Association
Website: http://www.nvda.net/

Appendix 3-3

Sampling sites monitored since 2006 in the tributaries of the Quebec portion of the watershed

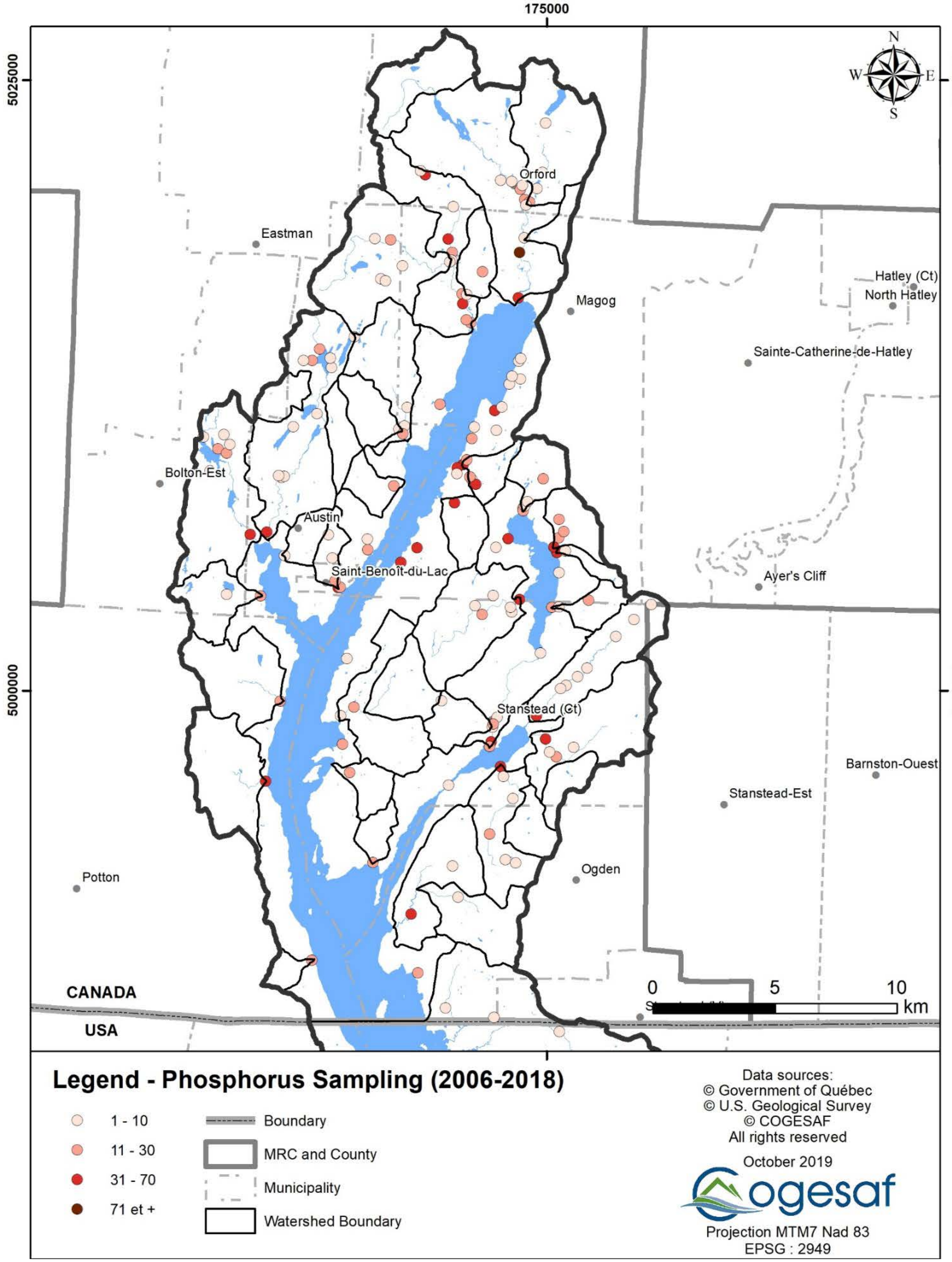


Figure 3-1 Sampling sites monitored since 2006 in the tributaries of the Quebec portion of the watershed

Chapter 4 Summary

Science and Policy Analysis

Chapter 4 is an analysis based on a literature review presented in Chapter 2 and 3, an online survey, local working group meetings, and meetings of the Memphremagog Study Advisory Group (MSAG), in order to better understand the needs and opportunities for scientific research and policy in the Memphremagog Watershed.

Canada Science and Policy Analysis

Context

Lake Memphremagog is the largest body of water in the region of Estrie, an important drinking reservoir for more than 175,000 people mostly from the City of Sherbrooke and the City of Magog and a major tourist draw and fishing destination. Despite the development pressure, the Quebec portion of Lake Memphremagog watershed is still mainly natural: the natural lands represent about 82% of the land use, followed by 10% of agricultural lands and 8% of developed land both representing respectively 33% and 42% of the Quebec phosphorus loading estimate.

In general, the phosphorus concentration in Lake Memphremagog has been either stable or has slightly decreased since the early 2000s, when the chlorophyll concentration indicated stability. The lake is globally at an oligo-mesotrophic level according to the total phosphorus concentration. However, according to the indicator of algal biomass, it is situated at the mesotrophic level in the southern half of the lake and at the oligo-mesotrophic level in the northern half of the lake. Fitch Bay and South Bay, which are isolated and distinct sections of the lake, show a more advanced state of eutrophication.

These water quality data can indicate that interventions have, to some extent, prevented degradation of the water quality despite pressures (eg climate change, population increase in the watershed). Because it is predicted that the population of the Regional County Municipality (MRC, Municipalité régionale de comté) Memphremagog will continue to grow, which will likely continue to convert natural lands into developed lands, that climate change will increase future nutrient loading and the frequency of cyanobacteria blooms in the lakes of the region, that some areas of the lake show a more advanced state of eutrophication, and because of the importance of Lake Memphremagog as a regional drinking reservoir, it is important to prevent is degradation.

Canada Science Analysis

The literature review showed that additional science is needed in the Quebec portion of the watershed regarding water quality to identify the nutrient sources, to evaluate the effectiveness of BMPs and to measure the evolution of water quality in the watershed.

- A lake water quality monitoring program and a tributary water quality monitoring program exist for many years and the distribution of the monitoring stations has a good spatial coverage. The measurement of the water flow in the tributaries would increase the precision regarding phosphorus loading estimates, water quality hotspot, effectiveness of BMPs and tendencies in the water quality of the tributaries. A global analysis of the water quality datasets would be necessary to identify the limits of these and to propose a sampling strategy at a great temporal scope.

- A great number of cyanobacteria blooms have been reported by several stakeholders around the lake. Because the monitoring efforts can largely differ between years, it is not possible to make a portrait of the evolution of cyanobacteria blooms. An improvement in the cyanobacteria monitoring program would be necessary to be able to follow the evolution of the issue.
- In the networking survey, Canadian stakeholders mentioned different research needed, such as the potential for climate change to increase nutrient loading in Lake Memphremagog, the impact of the Coventry landfill and leachate on water quality, the impacts of boats on lake Memphremagog and on the localization of the phosphorus sources.

Canada Policy Analysis

Water Quality Target Discussion

- The *Quebec Environment Quality Act* targets individual effluents that can be tied to specific citizens and industries. The Quebec portion of the watershed does not have a water quality target for the lake included in a regulatory approach, a process by which to measure progress towards these water quality goals and a current project implementation plan to prioritize projects to reduce nutrient loading in Lake Memphremagog. The implementation of a water quality target for the lake and a strategy of water quality monitoring to follow the impact of the BMPs would support the implementation of an action plan to prioritize action and funding to reduce nutrient loading.

Agricultural Lands Discussion

- Only about 10% of the Quebec portion of the watershed is used for agriculture. The annual crops represent about 1% of the land use, with an estimated contribution of phosphorus loading of 11%, and the perennial crops represent about 9% of the land use with an estimated contribution of phosphorus loading of 20%. While the dominance of perennial crops limits phosphorus export linked to erosion, steep slopes causes high rates of erosion of annual crops in some areas. However, little information exists about erosion problems among annual crops or perennial crops in critical zones, such as steep slopes. Therefore, erosion among agricultural field must be assessed. Incentives given to agricultural producers to keep perennial crops would prevent an increase in nutrient loading in Lake Memphremagog.
- The erosion along the water courses of the agricultural producers of the watershed has been characterized. Little information exists on whether the producers have implemented BMPs since this characterization and the issue must be assessed. Incentives for agricultural producers who restore wider buffers along shorelines larger shorelines, are needed to increase the ecological services provided by these natural lands.

- The manure storage and spreading practices can cause significant phosphorus exports. Because of the relatively high proportion of livestock farming in the agricultural sector, it is important to assess manure management to ensure that the *Agricultural Operations Regulation* (REA, Règlement sur les exploitations agricoles) is implemented.
- Assistance and incentives to improve manure management among small farms not targeted by the REA could prevent issues, such as the field stacking of manure. Some incentives already exist among the Prime-Vert program, but they are not commonly used by the agricultural producers in the watershed. Manure management among small farms must be assessed.

Developed Lands Discussion

- Developed lands, including paved roads, dirt roads and septic systems, have been estimated to be the largest source of phosphorus in the Quebec portion of the watershed.
- No stormwater runoff portrait has been done at a watershed scale and a global portrait would be necessary to implement an action plan to identify priorities, and priorities for funding.
- Roads represent 15% of the phosphorus loading estimate for the Quebec portion of the watershed. Municipal road network characterizations have been done in some areas and several erosion problematics have been observed. As in Vermont, regulations about the characterization of stormwater infrastructures in the watershed would help to assess this issue. The new *Quebec Water Strategy* announced in 2018 developed a program to support the municipalities in the implementation of sustainable rainwater management infrastructure.
- There are differences between municipal policy to reduce nutrient loading in Lake Memphremagog and its tributaries from new developments, existing developed parcels and roadways. Some municipalities have adopted strong measures to control development in steep slopes, erosion during soil manipulation works, tree cutting, and application of fertilizers on residential properties, among others. An opportunity would be to expand the stronger municipal regulations throughout the other municipalities, ensuring assistance for bylaws updates and resources for by-laws implementation. The *Land Use Planning and Development Plan* (SAD, Schéma d'aménagement et de développement) of the MRC, which began review in 2019, would be an opportunity to adopt a stronger regulatory framework.
- Some municipal regulations systematically ensure the compliance of old private septic systems and fund the improvement of substandard septic systems. An opportunity would be to expand these by-laws throughout other municipalities ensuring that assistance for bylaw updates and resources for by-law implementation are provided.

Natural Lands Discussion

- The watershed is still mainly natural: the natural lands provide critical ecological services as water purification and erosion control. Only 9.2% of the Quebec portion of the watershed is protected, when the provincial and federal objectives are to conserve at least 17% of the terrestrial lands and interior water bodies before 2020. Because of the services given by the Lake Memphremagog Watershed regarding the filtration of potable water for more than 175 000 people, the watershed must be a priority zone for the Governments.

- Several conservation plans have been done at the municipal scale. Due to the importance of maintaining natural lands to prevent nutrient loading, a conservation plan at a watershed scale would be necessary to establish collaborative conservation and restoration goals for the watershed. The *Regional Wetlands and Bodies of Water Plan (*PRMHH, Plan régional des milieux humides et hydriques) planned for 2022 is an opportunity to plan the protection of wetlands and Lake Memphremagog in the Quebec portion of the watershed.
- There are different strengths of municipal regulations to direct residential expansion and control development in natural areas. The SAD of the MRC, which began review in 2019, is an opportunity to expand municipal regulations to control development in sensitive areas and ensure the protection of natural areas, such as wetlands, forests and riparian buffers.
- The properties around Lake Memphremagog, particularly located in the municipalities with low populations, have high monetary values. Voluntary conservation programs and conservation organizations can reach conservation goals by conserving natural lands with lower costs, and the incentives given to owners to create a nature reserve can be relatively low. To conserve lands in perpetuity in Lake Memphremagog watershed, conservation programs would have to target the Lake Memphremagog watershed and the incentives to create nature reserves must be increased.
- In the Networking report, regarding the forest sector, the need to increase incentives to support foresters to implement and improve bridges and culverts, to apply the FSC certification and to implement Forest Management Plans (PAF, Plan d'aménagement forestier) integrating best management practices were mentioned.

Recreational Sector Discussion

- Golf courses and ski resorts can have impacts on Lake Memphremagog through stormwater runoff and erosion and these impacts must be assessed.
- Boating in some sensitive areas of Lake Memphremagog is an issue that can cause shoreline erosion and resuspension of the bottom sediment. Awareness campaigns were done, but they need constant financial and human resources. A stronger regulatory approach would be needed in sensitive areas.
- In the Quebec portion of the lake, more than 1000 boats have a toilet and the public pump-out stations are only located in Magog and Newport. The possibility of adding a pump out service in Quebec in the southern part of the lake must be assessed.

Collaborations Discussion

- Numerous management practices are done by several stakeholders, and a central challenge is to ensure that these efforts are developed in a complementary way. The implementation of a joint action plan at a watershed scale would allow to coordinate the efforts.

Funding Discussion

- Sub-watershed assessments and on-the-ground projects are generally financed by municipalities and local associations. The new *Quebec Water Strategy* announced in 2018 which includes funding at a provincial scale of $552 million CAN for 5 years and several measures to supports local stakeholders in watershed assessments and on-the-ground projects, is an opportunity to reduce nutrient loading in Lake Memphremagog.
- The federal government may also provide programs to support initiatives to reduce nutrient loading in Lake Memphremagog and its tributaries.

United States Science and Policy Analysis

Background

The Lake Memphremagog Watershed, located in the Northeast Kingdom of Vermont, is composed of land uses that include natural lands (77.5%), agricultural lands (17.5%) and developed lands (5.4%) as well as three tributaries (Clyde, Barton, Black and John's Rivers) that flow into Lake Memphremagog.

In 2017, VDEC established a Total Maximum Daily Load (TMDL) for phosphorus for the Lake Memphremagog Watershed, due to elevated concentrations of phosphorus recorded in the Vermont portion of Lake Memphremagog. After extensive research, including water quality sampling and monitoring, the Tactical Basin Plan (TBP; https://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/Basin17_TBP_Signed.pdf) was developed, which recommends a 29% phosphorus reduction. Additional information about the process and results can be found here: https://dec.vermont.gov/watershed/map/basin-planning/basin17.

The TMDL is a legally binding document that requires Vermont to invest in clean water projects in the Memphremagog Watershed and the policy and science analysis in this report is geared towards identifying successes and gaps which will further assist with reaching clean water goals.

United States Science Analysis

In stakeholder surveys, additional water quality monitory for phosphorus, other nutrients, and pollutants was identified as the primary need to support the science analysis.

- ❖ The lack of consistency of the current funding cycle was noted as a challenge.
- ❖ Technical assistance for data interpretation, particularly in relation to BMP efficacy determination was also noted as a challenge.
- ❖ Stream Geomorphic Assessment throughout the entire watershed have not yet been completed, although many have been done.
- ❖ Analysis of the stakeholder responses indicated that while research was deemed important for project implementation, additional research was not recommended. A focus on

implementation of current plans and regulatory support to implement the on-the-ground projects was supported.

United States Policy Analysis

- ❖ Nutrient impairment is addressed through both the federal TMDL process (through the Clean Water Act) and the State of Vermont basin planning process.
- ❖ Project implementation and other regulated activities are covered by additional policies and regulations, such as VT Act 250 and the Shoreland Protection Act.
- ❖ Responses from United States stakeholders indicated that on a state level, VT has strong regulations, but enforcement, education and dedicated resources were not consistent. This suggests that Vermont needs to close gaps in regulatory implementation with funding, staff, and resources to implement the on-the-ground projects, BMPs, and regulatory requirements already enumerated in Vermont state laws like Act 64 and Shoreland Protection Act. Responses indicated that the top three barriers to project implementation in the Memphremagog Watershed were financial resources, human resources, and political will (mostly local) but that these could be addressed by the following:
  - ➢ **Funding Gaps:** Act 76 should provide more consistent funding, beginning in October, 2019. Projects that could be addressed through the Act 76 process include: 1) Human resources/capacity building and collaborative groups, for holistic solutions (several such groups currently exist); 2) Project development, which would include outreach to landowners, municipalities and other stakeholders and would include site visits, initial scoping, and preliminary design work; 3) Continued funding for design and full implementation of projects; 4) Operations/Maintenance/Monitoring/Follow Up.
  - ➢ **Enforcement** of state laws, specifically regarding the permitting process and restriction on new development from the Shoreland Protection Act, were identified by stakeholders as not being strongly enforced, and without enforcement, the laws and regulations are not effective. VDEC only has three regional lake and shoreland permitting analysts and seven regional enforcement officers for the state. Additional funding for this is needed.
  - ➢ **Lack of Political Will** on the local, state, and federal level. More outreach to the public, local officials, and state government officials is necessary to promote project successes.

Agricultural Lands Discussion

TMDL estimates indicate that phosphorus loading from agricultural lands needs to be reduced by 46% to meet our clean water goals.

- ❖ Many programs are already in place such as those through the USDA/NRCS and VAAFM, which have set guidelines for agricultural BMPs, provide funding for implementation and technical service providers, as well as government employee staff who provide direct assistance.
- ❖ Challenges to BMP implementation include: 1) The large number of individual operations and number of practices needed per operation; 2) Limited financial resources of agricultural producers to provide matching funds for BMPs and the financial strain involved in taking land out of production for conservation or BMPs; 3) Limited time agricultural producers have to

interface with complicated program requirements, applications, and reporting; 4) Limited capacity for technical service providers to provide direct assistance or financial assistance for planning, applications, and BMP implementation.

- ❖ Implementation efforts are also limited by: 1) Uncertainty in long-term funding for implementation and planning projects; 2) Gaps in programmatic support for follow-up, operations, and maintenance; 3) Gaps in collaboration among service providers; 4) Gaps in the dissemination of information to agricultural producers and private sector agricultural product representatives; 5) Gaps in the understanding of the impact, limiting factors, and effectiveness of BMPs for Lake Memphremagog Watershed producers.

Developed Lands Discussion

According to TMDL estimates, phosphorus loading from developed lands needs to be reduced by 18% to reach Vermont's clean water goals. Dirt roads and developed parcels contribute the most nutrient loading in the developed land category.

- ❖ Under Act 64, VDEC set standards to reduce erosion from all hydrologically connected road segments, requiring the development of the Municipal Roads General Permit (MRGP).
  - ➢ The implementation of this permit can be challenging for smaller municipalities due to limited personnel and budgets.
  - ➢ Funding is uncertain and the implementation of permit requirements can be expensive.
- ❖ Vermont's Shoreland Protection Act and Act 250 also regulates land development.
  - ➢ Dissemination of information and enforcement were the greatest hurdles to the implementation of the Protection Act (per stakeholder survey)
  - ➢ VDEC's Lake Wise is an existing voluntary program, which assesses and retrofits shorelands. Expansion of this program was mentioned as a method to increase stakeholder involvement.

Natural Lands Discussion

TMDL estimates indicated that a reduction in loading from natural lands includes 2.3% from "other" category, which includes wetlands, water, and forest, and 23% reduction from stream channels.

- ❖ Municipalities can pass zoning by-laws or river-corridor by-laws; however, there are municipalities in the watershed that currently have no zoning by-laws, making getting citizen and municipal buy-in for adopting zoning laws for environmental protection difficult.
- ❖ There are currently no regulatory requirements in Vermont to restore riparian buffers or streambanks.
- ❖ Maintaining access to funding and support from state and federal agencies for streambank and habitat restoration is necessary to continue and expand programs.

Quebec and Vermont Science and Policy Analysis

Background

- The Quebec Vermont Steering Committee has provided a successful and valuable space for international collaboration.

Quebec and Vermont Science Analysis

- While there are several similarities between monitoring done by Vermont and Quebec, some differences make it difficult to compare water quality between both parts of the lake. A sampling strategy allowing the comparison of the results would facilitate an overall understanding of water quality.
- Impacts of climate change are already noticeable, but little information exists on the potential impact on future nutrient loading in Lake Memphremagog. Studies must be done to take climate change into account when developing management plans and recommendations to reduce nutrient loading in the Memphremagog watershed.
- When the Bathtub model developed for the TMDL did not suggest substantial internal phosphorus loading from any lake segments, there is a need to better characterize the potential for internal phosphorus loading particularly with considerations for changes in the length of stratification which may occur with climate change.
- Staying current with emerging technologies, methods, and best management practices to reduce nutrient loading would lead to increased project efficiency and cost savings.
- It is difficult to access to the scientific data and research and a common portal would lead to increased sharing of scientific data and project efficiency.

Quebec and Vermont Policy Analysis

- Given that there is an opportunity to strengthen scientific and political connections between Quebec and Vermont, as well as an existing committee to support that process, a need for additional support to coordinate Steering Committee meetings, presentations, initiatives, and provide a public face for the Steering Committee in the local community and at the provincial/state and federal levels was identified as a priority recommendation.

Chapter 4
Science and Policy Analysis

Chapter 4 is an analysis based on a literature review presented in Chapter 2 and 3, networking with local stakeholders, and meetings of the Memphremagog Study Advisory Group (MSAG), in order to better understand the needs and opportunities for scientific research and policy in the Memphremagog Watershed. After the science and policy analysis by country, a binational analysis is also presented.

4.1. Canadian Science and Policy Analysis

Located in the south of the Province of Quebec, Lake Memphremagog is the largest body of water in the region of Estrie. It is an important drinking reservoir for more than 175,000 people living mostly in the City of Sherbrooke and the City of Magog and it is a major tourist draw and fishing destination in Eastern Townships. The Regional County Municipality (MRC, Municipalité régionale de comté) Memphremagog experienced constant growth, with an increase of 20 % of the population between 2001 and 2016 alone. Despite this development pressure, the Quebec portion of Lake Memphremagog watershed is still mainly natural: the natural lands represent about 82% of the land use, followed by 10% of agricultural lands and 8% of developed land both representing respectively 33% and 42% of the Quebec phosphorus loading estimate (Sections 2.1 and 2.3).

In general, water quality indicators suggest nutrient levels in the lake have been stable for the last 20 years. According to the trophic status classification chart used by the Ministry of Environment and Fight against Climate Change (MELCC, Ministère de l'Environnement et de la Lutte contre les Changements climatiques), the lake is globally at an oligo-mesotrophic level according to the total phosphorus concentration. However, according to the indicator of algal biomass (the chlorophyll-a concentration), it is situated at the mesotrophic level in the southern half of the lake and at the oligo-mesotrophic level in the northern half of the lake. On the Canadian side, Fitch Bay, which is an isolated and distinct section of the lake, shows a more advanced state of eutrophication (Section 2.2.2.1).

These water quality data can indicate that interventions have, to some extent, prevented degradation of the water quality of tributaries despite pressures (eg climate change, population increase in the watershed). Studies have shown phosphorus load reductions in several large watersheds in Quebec, which can be attributed in part to a reduction in agricultural loading and the treatment of municipal and industrial wastewater. (Patoine, 2017; Simoneau, 2018). Because it is predicted that the population of the MRC Memphremagog will continue to grow, which will likely continue to convert natural lands into developed lands, and that climate change will increase future nutrient loading and algal blooms in the lakes of the region, because some areas of the lake show a more advanced state of eutrophication, and of the importance of Lake Memphremagog as a regional drinking reservoir, it is important to prevent is degradation. In that respect, different science and policy challenges must be addressed regarding nutrient loading of the Lake Memphremagog watershed.

> Because it is predicted that the development pressure will continue, and that climate change will increase future nutrient loading, because some areas of the lake show a more advanced state of eutrophication and the lake is an important drinking reservoir and tourist draw, it is important to prevent is degradation.

4.1.1. Canadian Science Analysis

The literature review showed that additional science is needed regarding water quality to identify the nutrient sources, to evaluate the effectiveness of Best Management Practices (BMPs) and to measure its evolution in the watershed.

The lake water quality monitoring program has existed for many years. The long-term stability in phosphorus and chlorophyll data permits the use of these variables to highlight changes in the lake productivity, while transparency data are not sufficient to characterize the water quality of the lake. The distribution of the water quality stations has a relatively good spatial coverage of the various areas of the lake (Section 2.2.2.1). Regarding the tributary water quality monitoring program, while phosphorus concentration data are available for several years, the lack of tributary flow and of spring storm event data increase the uncertainty regarding nutrient loading from the tributaries which makes the evaluation of water quality

> The lake and the tributary water quality monitoring programs exist for many years. An analysis of the water quality datasets would be necessary to propose a sampling strategy to increase the precision regarding water quality hotspots, effectiveness of BMPs and tendencies in the water quality.

hotspots difficult, the effectiveness of BMPs and the tendencies in the water quality of the tributaries of the Quebec portion of the watershed (Section 2.2.1.1). While it is possible to estimate phosphorus loads with modeled flows, data from measured water flow would increase the precision of loading estimates. An analysis of the water quality datasets is necessary to identify the limits of these programs and to propose a revised sampling strategy (see Sections 5.1.6 and 6.1).

> When a great number of cyanobacteria blooms are reported every year, an improvement of the cyanobacteria monitoring program is needed to follow the evolution of the issue.

A great number of cyanobacteria blooms have been reported by several different stakeholders and volunteers on the Quebec side of Lake Memphremagog. However, because the monitoring efforts can largely differ between years, it is not possible to make a portrait of the evolution of cyanobacteria blooms. An improvement in the cyanobacteria monitoring program would be necessary to be able to follow the evolution of the issue (Section 2.4.1; see Sections 5.1.6 and 6.1). While the eutrophication of Lake Memphremagog can have important socio-economic impacts affecting, for example, drinkable sources, property values, recreation and tourism industries of the region, little information exists about this issue. A better understanding of these impacts would help mobilize stakeholders.

During networking, Canadian stakeholders mentioned different research needed, such as the threats of climate change on the increase of nutrient loading in Lake Memphremagog, the impact of the Coventry landfill and leachate on the water quality, the impacts of boats on lake Memphremagog, and the improvement of the knowledge on phosphorus sources.

4.1.2. Canadian Policy Analysis

The province of Quebec is responsible for the water resources within its boundaries (Section 3.2.1.1). Municipalities in Quebec have an important role to play, particularly in the protection of lakeshores, riverbanks, littoral zones and floodplains, in the sanitation of municipal wastewater discharges, in the control of septic systems for isolated dwellings, and in the production and distribution of drinking water. They can act in several jurisdictions regarding water management and regulate land development and activities through permits and regulations, integrating Provincial Acts and the MRC’s Land Use Planning and Development Plan (SAD, Schéma d'aménagement et de développement). They can also adopt non-regulatory measures and on-the-ground projects depending on their political will. Most of the programs, BMPs, and initiatives currently underway in the Quebec portion of the Lake Memphremagog watershed as listed in chapter 3 are supported or mandated by provincial and municipal policies, or are initiatives taken by non-profit organizations and municipalities (Section 3.2.1.4).

4.1.2.1. Water quality target

> The implementation of water quality targets for the lake and a process by which to measure progress towards clean water goals would support the implementation of an action plan to prioritize projects and funding to reduce nutrient loading in Lake Memphremagog.

The *Quebec Environment Quality Act* targets individual effluents that can be tied to specific citizens and industries (Section 3.2.1.1). Quebec does not have a water quality target for the lake included in a regulatory approach, a process by which to measure progress towards these clean water goals and a current project implementation plan to prioritize projects to reduce nutrient loading in Lake Memphremagog (Section 3.2.1.1). Several local action plans are made in different parts of the watershed, but different local organizations have mentioned needing resources to coordinate the implementation of the existed action plans and to implement BMPs in different sectors, as stormwater management and conservation of natural lands (Section 3.2.1.3; Networking report). While COGESAF is mandated by the government to implement a water management plan (PDE, Plan directeur de l'eau) for the St-Francis River Watershed, the scale of the PDE limits the actions that can be included (Section 3.2.1.3). In United States, nutrient concentration targets for Lake Memphremagog have been included in the regulatory approaches which imply strategies and a set of agreed upon priorities for all parties involved (Section 3.2.2.2). The implementation of water quality targets for the lake and a strategy of water quality monitoring to follow the impact of the BMPs on the water quality in Quebec would support the implementation of an action plan for the Quebec portion of the watershed (see Sections 5.1.6 and 6.1). A general implementation plan would prioritize actions, guide grant programs and priorities for funding and a long-term investment would be needed to achieve the implementation of this plan (see Sections 5.1.6 and 6.1).

4.1.2.2. Agricultural Lands

While, the agricultural crops are mostly perennial, the relief of the Quebec portion of the watershed may submit annual crops and some perennial crops to high rates of erosion. Because little information exists about the erosion within these crops, this issue must be assessed and concerned agricultural producers must be supported to reduce erosion within crops. Provideing incentives to avoid the conversion of perennial crops in annual crops would prevent nutrient loading.

Regarding agriculture land use, the Quebec portion of the watershed is less suitable for intensive agriculture than the Vermont portion because of the types of soils and the steep slopes: only 10% of the territory in Quebec is estimated to be used for agriculture (Sections 2.1.8 and 2.3.1). There is only a small proportion of annual crops, which have high estimated phosphorus export coefficients. These crops represent about 1% of the land use or 5 km^2, with an estimated contribution of phosphorus loading of 11% in the Quebec portion of the watershed, while the perennial crops represent about 9% of the land use, or 44 km^2, with an estimated contribution of phosphorus loading of 20% (Sections 2.1.8 and 2.3.1). While the dominance of perennial crops limits phosphorus export linked to water erosion, the high erosivity of steep slopes may submit some areas to high rates of erosion in annual crops (Michaud & Deslandes, 2003). However, little information exists about erosion problems among annual crops or perennial crops in critical zones, as steep slopes, because, among others, there is a limited use of specialized advisory services by the agricultural producers and a low participation in financial assistance programs (Section 3.2.1.4). A project has been done between 2016 and 2019 to assess soil erosion among fields in the Fitch Bay Watershed and help agricultural producers in implementing soil conservation practices (Section 3.2.1.4). However, erosion in fields located in other parts of the Quebec portion of the watershed has not been assessed (see Sections 5.1.1 and 6.2.1). Also, because perennial crops have lower nutrient export coefficients than annual crops, incentives given to agricultural producers to keep perennial crops, particularly in risk areas as steep slopes, would prevent an increase of nutrient loading in Lake Memphremagog (Section 2.1.8, see Sections 5.1.1 and 6.2.1).

Regarding the shorelines management within agricultural lands, while a project has been done to characterize erosion along the water courses of 66 agricultural producers in the Quebec portion of the watershed (Section 3.2.1.4), little information exists on if the producers have implemented BMPs to limit erosion along water courses (see Sections 5.1.1 and 6.2.1). A reinforcement of the *Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains* (PPRLPI, Politique de protection des rives, du littoral et des plaines inondables) to protect widened riparian buffers, for example providing incentives to agricultural producers who restore larger riparian buffers, may be necessary to increase the ecological services provided by these natural lands (see Sections 5.1.1 and 6.2.1).

> Erosion has been characterized along the agricultural water courses and the implementation of BMPs in the Quebec portion of the watershed must now be ensured. A reinforcement of the PPRLPI may be needed in order for shorelines to carry out their ecological services.

Also, significant loads of phosphorus can be exported if the mode and time of manure applications lead to surface runoff. Because 53% or the agricultural producers of the Quebec portion of the watershed operate livestock farms, for an animal density of 0.97 AU/ha in annual and perennial crops, manure storage and spreading practices, as well as the date of the spreading, the mode of supply, and the spreading setbacks from the water bodies, are issues that must be assessed (Section 2.1.8; see Sections 5.1.1 and 6.2.1). Because of the relatively high proportion of livestock farming in the agricultural sector, it is important to assess manure management in the Quebec portion of Lake Memphremagog Watershed. The improvement of manure management could be necessary and be done ensuring that the REA is implemented regarding manure applications, such as fall spraying and setback distances from streams. Additional human resources to support agricultural producers may be necessary to achieve the implementation of the REA as well as BMPs (Networking report). Also, incentives to improve storage of organic fertilizer among small farms not targeted by the REA could prevent issues regarding storage on the ground (Section 2.1.8, see Sections 5.1.1 and 6.2.1). However, because some incentives already exist among the Prime-Vert program and because they are not commonly used by the agricultural

> The manure storage and spreading practices can cause significant phosphorus exports. Because of the relatively high proportion of livestock farming in the agricultural sector, it is important to assess manure management to ensure that the REA is implemented and that assistance for small farms not targeted by the REA is sufficient.

producers in the watershed, an increase of the assistance given to agricultural producers of the watershed may be needed (Section 3.2.1.1, see Sections 5.1.1 and 6.2.1).

4.1.2.3. Developed Lands

The developed lands, including paved roads, dirt roads and septic systems, have been estimated to be the largest source of phosphorus in the Quebec portion of the watershed (Section 2.1.8).

Some inventories of stormwater runoff have been done in some areas of the Quebec portion of the watershed (Section 3.2.1.4). However, unlike the Vermont portion of the watershed, no stormwater runoff portrait has been done at a watershed scale and a global portrait would be necessary to develop and implement an action plan to identify priorities, guide grant programs and priorities for funding (Section 3.2.2.4; see Sections 5.1.2 and 6.2.2).

> In Quebec, no stormwater runoff portrait has been done at a watershed scale which would be necessary to develop an action plan to identify priorities and priorities for funding.

Regarding roads, which represent 15% of the phosphorus loading estimate for the Quebec portion of the watershed, 79 % are managed by municipalities and 6 % are private roads, subjected to municipal regulations and that many of which are adjacent to water bodies. Municipal road network characterizations have been done in some areas of the Quebec portion of the watershed and several erosion problems have been observed (Section 3.2.1.4). In Vermont, a state regulation requires that all municipalities conduct a road erosion inventory to assess the hydrologically connected road segments (Section 3.2.2.1). A provincial or a municipal regulation about the characterization of stormwater infrastructures in the watershed could help to address this issue. In the Networking report, the municipal stakeholders mentioned the need to have more resources to improve their road network. The new *Quebec Water Strategy* develops a program to support the municipalities in the implementation of sustainable rainwater management infrastructures (Section 3.2.1.1, see Sections 5.1.2 and 6.2.2).

> It is estimated that roads cause significant phosphorus loading. A regulatory approach, accompanied by financial support for municipalities, may support the upgrading of stormwater infrastructure in the watershed.

There are differences between municipal policy to reduce nutrient loading in Lake Memphremagog and its tributaries from new developments, existing developed parcels and roadways. These are reflected in the different strengths of municipal regulations and in non-regulatory efforts to reduce nutrient loading (Section 3.2.1.4). Some municipalities in the watershed adopted strong measures to control development on steep slopes, erosion during construction, tree cutting, application of fertilizers on residential properties or regarding gutters management, among others (Section 3.2.1.4). In the Networking report, after funding and human resources, regulatory support was mentioned as being the greatest need for Canadian municipalities to reduce nutrient loading and municipal political will was mentioned being the greatest barrier (Networking report). It was also mentioned that human resources were missing to apply regulations throughout the watershed at municipal levels regarding developed lands (Networking report). An opportunity in the watershed would be to expand the stronger municipal regulations throughout the other municipalities, ensuring that assistance for bylaws updates and resources for by-laws implementation are provided (see Sections 5.1.2; 5.1.4; 6.2.2). Some MRCs adopted strong regulatory frameworks to manage stormwaters and control erosion on their territory (MRC de Brome-Missisquoi, 2014). The SAD of the MRC Memphremagog, which the review began in 2019, would give the opportunity to adopt a stronger regulatory framework in Lake Memphremagog Watershed.

> Municipalities act at various degrees to reduce nutrient loading from new developments, existing developed parcels and roadways. An opportunity would be to expand by-laws throughout other municipalities ensuring that assistance for bylaws updates and resources for their implementation are provided. The SAD of the MRC, which the review began in 2019, gives the opportunity to adopt a stronger regulatory framework.

Also, while some municipalities have a regulation to ensure compliance of older private septic systems, the compliance of private septic systems in other municipalities of the Quebec portion of the watershed is not systematically assessed and some municipalities mentioned the need to improve the inspection of private septic systems to verify their compliance (Section 3.2.1.4, Networking report, see Section 5.1.2). Other municipalities also developed a funding program to help the owners to improve their substandard septic systems. Other types of regulations also exist in North America where septic

> Some municipal regulations systematically ensure the compliance of old private septic systems and fund the improvement of substandard septic systems. An opportunity would be to expand these by-laws throughout other municipalities ensuring that assistance for bylaws updates and resources for by-laws implementation are provided.

system regulations require, for example, retrofitting when renovations are carried out or properties are sold (Foulon & Rousseau, 2019; see Section 5.1.2). An opportunity in the watershed would be to expand some municipal regulations throughout the other municipalities, ensuring that assistance for bylaws updates and resources for by-law implementation are provided (see Sections 5.1.2; 5.1.4). In 2010, the MRC Memphremagog, with funding from the Government of Quebec, inspected 184 septic systems located within 300 m of Lake Memphremagog in two municipalities (Section 3.2.1.4). This type of program expanded to other municipalities would support the assessment and the compliance of the private septic systems in the watershed.

4.1.2.4. Natural Lands

82% of the Quebec portion of the Lake Memphremagog watershed is natural lands. These natural lands, including forest and wetlands, provide critical ecological services, such as water purification and erosion control. In Ontario, it has been estimated that the annual value of wetlands is between CAN$ 2,660 and 3,168 per hectare per year only for the water purification service (Troy & Bagstad, 2009). To prevent an increase in nutrient loading in Lake Memphremagog in a climate change context, it is essential to conserve these ecological services and maximize the protection of natural lands in the watershed. Only 9.0% of the Quebec portion of the watershed is protected, when the Governments of Quebec and of Canada objectives are to conserve at least 17% of the terrestrial lands and interior water bodies, including zones particularly important for the biodiversity and services given by ecosystems, before 2020 (Section 2.1.9; MELCC, 2019d; En route, 2019). Because of the services given by the Lake Memphremagog Watershed regarding the filtration of potable water for more than 175,000 people, the watershed must be a priority zone for the Governments (see Section 5.1.4).

> The watershed is still mainly natural: the natural lands provide critical ecological services as water purification and erosion control. Only 9.2% of the Quebec portion of the watershed is protected, when the provincial and federal objectives are to conserve at least 17% of the terrestrial lands and interior water bodies before 2020. Because of the services given by the Lake Memphremagog Watershed regarding the filtration of potable water, it must be a priority zone for the Governments.

While several municipalities have done a conservation plan to protect natural lands of ecological interest, no portrait of the natural lands at the watershed scale to plan their conservation and avoid the conversion to other types of land use with higher rates of nutrient export has been done (Section 3.2.1.4). The new modification to the Water Act gives to the MRCs the responsibility for developing and implementing a *Regional Wetlands and Bodies of Water Plan* (PRMHH, Plan régional des milieux humides et hydriques) in their respective territories which has to be revised every 10 years. This new plan will make a portrait of a portion of the natural lands (wetlands and water bodies) in Quebec at the watershed scale, will plan their conservation and then limit their conversion to other types of land use with higher rates of nutrient export (Section 3.2.1.1; see Section 6.2.3). Also, to improve the accuracy of the wetland mapping, new mapping of the wetlands, done with LiDAR (Light Detection and Ranging) data, is planned for 2020 by MRC Memphremagog (Section 3.2.1.4). A targeted percentage of natural lands of ecological interest to be protected to perpetuity in the watershed may support the implementation of an action plan to avoid the conversion of natural land of ecological interest into other types of land use with higher rates of nutrient export (see Section 5.1.4).

> Several conservation plans have been done at municipal scales. Due to the importance of maintaining natural lands to prevent nutrient loading a conservation plan at a watershed scale would be necessary to establish collaborative conservation and restoration goals for the watershed. The PRMHH planned for 2022 is an opportunity to plan the protection of wetlands and Lake Memphremagog in the Quebec portion of the watershed.

There are differences between municipal policy to protect natural lands reflected in different strengths of municipal regulations (Section 3.2.1.4). Some municipalities of the watershed have adopted strong measures to direct residential expansion in natural lands and to control development in some sensitive areas, such as strong regulations on tree cutting and shoreline protection (Section 3.2.1.4). In the Networking report, after funding and human resources to reduce nutrient loading, regulatory support was mentioned being the greatest need for Canadian municipalities and political will was mentioned being the greatest barrier for some municipalities (Networking report). To protect the natural areas of the watershed, an opportunity is to expand some municipal regulations throughout the other municipalities of the watershed (see Sections 5.1.2; 5.1.4). A way to expand some municipal regulations to other municipalities would be through the SAD of the MRC. Because in 2019, the MRC begins the review of the SAD, this

> There are different strengths of municipal regulations to direct residential expansion and control development in natural areas. The SAD of the MRC, which the review began in 2019, is an opportunity to control development in sensitive areas and ensure the protection of natural areas, as wetlands, forests and riparian buffers.

provides an opportunity to use the SAD to direct residential expansion in natural lands and to control development in some sensitive areas of the watershed (see Sections 5.1.2; 6.2.3).

> Voluntary conservation programs and organizations of conservation can reach conservation goals by conserving natural lands with lower costs, and the incentives to create a nature reserve can be very low. To conserve lands in perpetuity in Lake Memphremagog watershed, conservation programs would have to target Lake Memphremagog watershed and the incentives to create nature reserves must be increased.

Another way to conserve natural lands in the watershed that are almost entirely private lands, is to give incentives to private owners to conserve natural lands. Federal and provincial programs give funds to conservation organizations to purchase conservation servitude or lands and to protect natural lands to perpetuity (Section 3.2.1.4). These funding programs are designed to reward philanthropy at a percentage of market value. However, the properties around Lake Memphremagog, particularly located in the municipalities with lower populations, have high monetary values and the conservation organizations need to find more funding to buy a land or a servitude in the area (Section 2.1.6). With a limited funding, the existing programs and the conservation organizations can reach conservation goals by conserving natural lands that have lower costs. Also, the municipal and scholar tax exemption for landowners who create a nature reserve can be very low: the property value of properties recognized as a nature reserve may decrease significantly because of limitations on the uses of the property, affecting the impact of the benefits of the tax reduction; the property value of the parts of the property that are not recognized as a nature reserve may also increase due to the contiguous presence of a nature reserve and thus greatly reduce the benefits associated with the tax reduction; and the municipalities are entitled to a "municipal discretion" and can decide not to apply the entire tax exemption (Networking report, see Section 5.1.4). To conserve lands in perpetuity in the watershed, conservation programs would have to target Lake Memphremagog watershed and the incentives to create nature reserves must be increased (see Section 6.2.3).

In the Networking report, regarding the forest sector, it has been mentioned that there is a need to increase financial incentives to support foresters to implement some specific BMPs: to implement and improve bridges and culverts, to apply the FSC certification and to implement Forest Management Plans (PAF, Plan d’aménagement forestier) integrating best management practices (see Section 5.1.4).

4.1.2.5.Recreational sector

Golf courses and ski resorts can have impacts on Lake Memphremagog through storm water runoff and erosion and these impacts must be assessed.

Regarding the recreational sector, little is known about the impacts of the six golf courses and the two ski resorts on nutrient loading in the Quebec portion of Lake Memphremagog (see Section 3.2.1.4). Those sites present large unforested areas and can have impacts through storm water runoff and erosion. Artificial snow made by the ski resorts can also have different pressure than natural snow on waterbodies. Stormwater runoff and erosion from golf and ski resorts must be assessed (see Section 5.1.5).

Boating in some sensitive areas of Lake Memphremagog is an issue that can cause shoreline erosion and the resuspension of the bottom sediment. Awareness campaigns were done, but they need consistent financial and human resources. A stronger regulatory approach would be needed.

There are more than 2000 permanent motorboats on the Quebec portion of the Lake (MCI, 2012). The impacts of wake boats on shoreline erosion and the impacts of all types of boats on the resuspension of bottom sediments in shallow areas have been studied in Lake Memphremagog or other lakes in Quebec (Section 3.2.1.2). Lack of regulation for boating in some sensitive areas of Lake Memphremagog is an issue that can cause shoreline erosion and the resuspension of the bottom sediment. The process required by the federal government to allow a municipality to regulate boating is known to be administratively hard and few municipalities have succeeded in regulating boating for an environmental issue. In the past years, awareness campaigns were done to prevent the problem, but they need consistent financial and human resources (Bleu Massawippi *et al.*, 2016). In May 2019, a new version of the Local Authorities' Guide was released by the Federal government to make the regulatory process simpler, faster and less administratively cumbersome for MRCs and municipalities wishing to adopt new boating regulations (Transport Canada, 2019). In 2019, one municipality of the watershed began the new process (Simard, P., pers. Comm., 2019).

More than 1,000 permanent boats located on the Quebec portion of the Lake have a toilet, but little is known about the possible discharge of black waters from boats in the lake (MCI, 2012). It has been mentioned that the *Regulation Respecting Water Protection Against Discharges of Pleasure Craft* (Règlement sur la protection des eaux contre les rejets des embarcations de plaisance; Q-2, r. 36) which prohibits to discharge any wastewater from a pleasure craft is not easy to apply (Networking report). Because the public pump out stations are only located in Magog and Newport, the need to add a pump out service in the Quebec south part of the lake has to be addressed (see Section 5.1.5).

> More than 1,000 boats have a toilet and the public pump-out stations are only located in Magog and Newport. The need to add a pump out service in the Quebec south part of the lake must be addressed.

4.1.2.6.Collaborations

The inventory of management efforts in the Quebec portion of the watershed showed numerous management practices done by several stakeholders (Section 3.2.1). While these efforts support numerous outreach and on-the-ground projects, a central challenge is to ensure that these efforts are developed and done collaboratively. The Canadian stakeholders questioned in the Networking survey believe that, just after on-the-ground projects and applying regulation, planning coordinated actions would have the greatest impact on reducing nutrient loading in Lake Memphremagog watershed (Networking report). Some municipalities and MCI are implementing action plans for sub-watersheds in the Quebec portion of the watershed, and COGESAF is implementing a water management plan (PDE) for the St-Francis River Watershed (Section 3.2.1.3). It has been suggested that the Memphremagog Watershed should have a coordinator or a team working to implement an action plan at a Memphremagog watershed scale (Networking report). When we reviewed other collaboration approaches in other parts of North America, an agreed upon set of priorities for all parties involved is often used to implement a nutrient reduction plan and reach water quality targets (Foulon & Rousseau, 2019).

> Numerous management practices are done by several stakeholders, and a central challenge is to ensure that these efforts are developed in a complementary way. The implementation of a joint action plan at a watershed scale would allow the coordination of these efforts.

4.1.2.7. Funding

> Watershed assessments and on-the-ground projects are generally financed by municipalities and local associations. The new *Quebec Water Strategy* announced in 2018 includes funding at a provincial scale of $552 million CAN for 5 years and several measures to supports local stakeholders in watershed assessments and on-the-ground projects.

Generally, the watershed assessments and on-the-ground projects done in the Quebec portion of the watershed, such as tributary monitoring, territory environmental assessment, awareness campaign or revitalization of shorelines, are financed by municipalities and local associations. Local associations are generally funded directly by local citizens and can find funds for specific projects from some municipal green funds. In the Networking report, several municipalities have mentioned a lack of human resources to coordinate the implementation of existed action plans and on-the-ground projects, and to apply regulations through the watershed (Networking report). Local associations, depending largely on membership, have mentioned to lack of consistent resources to plan and implement projects (Networking report). This new *Quebec Water Strategy* announced in 2018 includes funding at a provincial scale of $552 million CAN ($409 million US) for 5 years and several measures: requiring the municipalities to realize an analysis of the vulnerability of their drinking water source, supporting the municipalities in conserving and restoring aquatic environments, meeting government objectives for protected areas, encouraging municipalities to adopt sustainable storm water management practices, increasing the knowledge on lakes, and strengthening integrated water resource management, including intergovernmental and international cooperation (Section 3.2.1.1, see Sections 5.1.1 to 5.1.5; and 6.1 to 6.3). The federal government may also provide programs to implement support initiatives to reduce nutrient loading in Lake Memphremagog and its tributaries (Section 3.2.1.1).

4.2 United States Policy and Science Analysis

The Lake Memphremagog Watershed is located in the Northeast Kingdom of Vermont. 71% of the drainage area of the watershed is in Vermont, including three major tributaries, the Clyde, Barton, and Black Rivers, and one smaller tributary, the Johns River. The predominate land cover in Vermont is natural lands at 77.5% of the land cover, followed by agricultural lands at 17.5%, and developed lands with 5.4% of the land cover.

In 2017, the Vermont Department of Environmental Conservation (VDEC) established a Total Maximum Daily Load (TMDL) for phosphorus for the Lake Memphremagog Watershed due to elevated concentrations of phosphorus recorded in the Vermont portion of Lake Memphremagog (Section 3.2.2.2). The TMDL includes a phosphorus reduction target of 29% for the Vermont portion of the watershed. Reduction targets are further broken down by land use type. The TMDL is a legally binding document that requires Vermont to invest in clean water projects in the Memphremagog Watershed and the policy and science analysis in this report is geared towards identifying successes and gaps to further assist with reaching clean water goals.

4.2.1. United States Science Analysis

In stakeholder surveys, additional water quality monitoring for phosphorus, other nutrients, and pollutants was identified as the primary need to support the science analysis. US respondents indicated that these additional data can be used for multiple purposes, including: 1) to celebrate and market of successes by measuring the impact and benefits of projects; 2) to evaluate the effectiveness of BMPs; 3) to identify water quality hotspots, allowing for project prioritization; and 4) to measure progress towards reaching the clean water goals in the Memphremagog TMDL (See Sections 5.2.1.4, 5.2.3.3 & 5.2.2.4).

One challenge to current tributary water quality monitoring is the annual funding cycle. For water quality data to be meaningful, long-term and continuous monitoring is required to identify trends. Year to year funding puts the consistency of collecting these data at risk and requires additional work for partners to annually apply for funding to do water quality monitoring. Further, additional state resources for technical assistance in interpreting water quality results and developing linkages between BMPs and water quality results would increase the efficacy of the program and impact of the success stories.

Stream Geomorphic Assessments are a decision support tool from the Vermont Agency of Natural Resources (VANR) (See Section 3.2.2.4) to help manage and restore rivers and balance the natural state of the river with development. These assessments have not yet been completed for all the major rivers in the watershed and would be helpful for municipalities and landowners in making decisions about protecting stream channels (See Section 5.2.3.1).

Interestingly, overall, survey respondents ranked additional research as the lowest need to remain sustainable and engaged in their work to reduce nutrient loading. However, at the same time, research was rated a 6.7 out of 10 on an impact scale for assisting with project implementation. This suggests that stakeholders feel that research is important to project implementation but are not advocating for additional research in the US, but rather a focus on implementation of current plans and regulatory support to implement the on-the-ground projects required by regulatory framework.

4.2.2. United States Policy Analysis

As listed in chapter 3, there are both federal and state laws that affect nutrient loading in the United States. The Lake Memphremagog TMDL for phosphorus was required by the federal Clean Water Act once phosphorus concentrations reach the level at which Lake Memphremagog became listed as an impaired water. Further, due to both federal TMDL reporting requirements and the state Basin Plan (TBP) (3.2.2.2 & 3.2.2.4), the Lake Memphremagog watershed has an action plan for achieving the TMDL reduction targets, which was finalized in 2017. Due to state requirements, the TBP for the basin will be updated every five years, allowing Vermont to track progress toward phosphorus reduction targets, adapt plans as needed, and monitor for additional water quality parameters. Through both federal and state policy requirements, Vermont has a strong plan of action to reach our clean water goals.

Federal and state policies also support on-the-ground project implementation and regulate activities to reduce nutrient loading. This includes federal and state regulations that require the establishment of industry BMPs, establish technical assistance program, funding streams for grants or cost shares for implementation. Other state regulations like VT Act 250 and the Shoreland Protection Act regulate the impact of human activities through rules and permitting processes to reduce nutrient loading. Further, municipal laws in Vermont can regulate development activities in environmentally sensitive areas. Most of the programs, BMPs, and initiatives currently underway in the Vermont portion of the Lake Memphremagog watershed as listed in chapter 3 are directly supported or mandated by federal, state, or municipal policy.

Comments from the United States stakeholders to the stakeholder survey indicated that overall experts in our region found the US, state, and municipal regulation and policy to be comprehensive.

However, additional emphasis on widespread implementation, enforcement, and local support of existing policies was necessary to fully realize the reduction in nutrient loading and water quality benefits.

Responses from United States stakeholders indicated that the top three barriers to project implementation in the Memphremagog Watershed were financial resources, human resources, and political will (mostly local). Stakeholders indicated that especially at the state level, Vermont has strong laws and regulations for stormwater; however, what is lacking is follow through on those regulations to ensure dissemination of knowledge about regulations, enforcement, long-term and predictable funding sources, staff to assistance with compliance, and local compliance. 50% of respondents indicated that the most effective tool to reduce nutrient loading were on-the-ground projects. This suggests that Vermont needs to close gaps in regulatory implementation with funding, staff, and resources to implement the on-the-ground projects, BMPs, and regulatory requirements already enumerated in Vermont state laws like Act 64 and Shoreland Protection Act.

Looking holistically at the policy affecting nutrient loading, survey respondents identified three overarching gaps that hinder project implementation and execution of existing policy requirements by: 1) gaps in project funding; 2) lack of enforcement of existing state regulations; 3) lack of federal, state, and municipal by-in.

Given that many of Vermont's laws that regulate clean water and nutrient loading are not sector specific but regulate categories of activities or multiple sectors at once, this policy analysis first explores the three general gaps as they relate to all sectors and then analyzes policy as it pertains to agriculture, natural lands, and developed lands. Recreational land use is included in natural lands and point sources are not analyzed here as there were no gaps identified specifically for that land use type.

4.2.2.1. Funding gaps

Since Act 64 was passed in 2015, the Vermont legislature has been funding clean water projects with short term funding options. In June of 2019, Act 76 signed by the Governor of Vermont. This bill assigns a long term and dedicated sources of funding for clean water projects by shifting 6 % of the revenue from the Vermont Rooms and Meal Tax from education funding to clean water funding. This shift begins in October of 2019 (VLEG, 2019b).

In addition to establishing a much needed and dedicated source of funding for clean water, Act 76 also develops a new distribution model for disseminating clean water funding, by mandating the creation of "clean water service providers" or CWSP for the major watersheds and subwatersheds of Vermont. At the writing of this report, how CWSPs will function has not yet been determined by VANR, except that the CSWP will receive funding from the state each year to reach pollution reduction targets determined for each area. Lastly, the bill outlines new grant programs and timelines for phosphorus reduction plans.

The VANR has been tasked with implementing Act 76, determining details of funding distribution and dissemination, grant making, and pollution reduction targets. With a dedicated a long-term funding source available, Vermont has an incredible opportunity to develop a clean water funding system that adequately funds all stages of clean water projects, increases collaborative approaches, provides a wholistic and multi-sector approach to clean water, and equably distributes funding across the state. Stakeholders indicated in the survey that funding for all stages of clean water projects from identification to operations and maintenance has been lacking.

To close gaps in project funding, United States stakeholders of the Memphremagog Watershed indicated that clean water funding in Vermont should include provisions for the following types of projects phases, which can be addressed in implementation out and rulemaking associated with Act 76.

- Human Resources/Capacity Building and Collaborative groups: Stakeholders suggested that wholistic solutions to the nutrient management problem are needed which requires additional collaboration. Currently collaborative groups such as the Memphremagog Agriculture Working Group, the Memphremagog Stormwater Collaborative, the NEK River and Roads Group, and the Quebec Vermont Steering Committee bring organizations and agencies together through semi-regular meetings, but funding for staff participation and organization is difficult to achieve. These meeting provide a forum for organization to increase and maximize collaboration, prioritize projects, apply for joint funding, and increase knowledge sharing.
- Project Development: Funding for project initiation to include, but not limited to: outreach to landowners and municipalities, site visits, initial scoping, and preliminary design work. This work is vital to the development of 100% designs of capital projects and is important

as grant applications and other necessary development work are time and resource consuming. Project development ensures landowner by-in and guarantees that projects are well planned before full design and implementation funds are sought.

- Design and Implementation: Continued funding for design and to fully implement projects.
- Operations/Maintenance/Monitoring/Follow Up (depending on project type): To ensure that installed practices are maintained and working properly for the full life of the designed practice, funding is needed to support these categories. If installed projects fail or are not properly maintained, then not only is the reduction in nutrient loading not realized, but the investment of funding in the previous phases of project scoping through implementation are lost. Continued monitoring for a specific time-period can also provide experts with valuable information on the life of the practice, effectiveness as the practice ages, and cost of operations and maintenance. Results from continued monitoring can be used to further improve and refine practices.

4.2.2.2. Enforcement

As enumerated in chapter 3, Vermont has strong environmental regulations in Act 64, the Shoreland Protection Act, and Act 250. However, stakeholders indicated in the survey that enforcement of state laws specifically regarding the permitting process and restriction on new development from the Shoreland Protection Act are not being strongly enforced, and without enforcement, the laws and regulations are not effective. VDEC only has three regional lake and shoreland permitting analysts and seven regional enforcement officers for the state. Additional staff would support not only enforcement but proactive outreach to regulated communities to increase compliance with new regulations. Responses from state employees to the stakeholder survey indicated that the greatest barriers for project implementation at the state level are limited financial resources and limited human resources. This suggests that additional funding appropriated by the legislature for state agencies or internal agency redistribution of funding to obtain additional staff is needed to improve enforcement and permitting operations. Limitations staff are likely to be an ongoing challenge so more effective targeting of enforcement efforts in areas with the highest phosphorus loading potential could increase the impact of these efforts for reducing phosphorous loading to Lake Memphremagog.

4.2.2.3. Political Will- local, state, and federal

Lack of political will was cited as a barrier to project implementation. From US stakeholders this referred to lack of political will to commit funding from all levels of government, but also lack of political will to implement projects on the local level. Political will is necessary to pass legislative initiatives and at the local level, it is necessary for project implementation, the commitment of in-kind funding for grants and projects, and for the adoption of local bylaws that protect environmental resources, such as river corridor protection by-laws. There is no clear single path to increasing political will and political advocacy which require a combination of outreach and education for the public and local officials which are both time and resource consuming. However, stakeholders indicated that more outreach to the public, local officials, and state government officials is necessary to promote project successes and the importance of investing in clean water projects in the Lake Memphremagog Watershed.

4.2.2.4. Agricultural Lands (Corresponds to suggestions in 5.2.1)

Implementation of practices on agricultural lands represents one of the greatest needs and challenges in the Vermont portion of the Lake Memphremagog watershed. TMDL estimates indicate that phosphorus loading from agricultural lands needs to be reduced by 46% to meet our clean water goals. As outlined in section 3.2.2.5a, there are a number of programs set up through the United State Department of Agriculture/Natural Resource Conservation Service (USDA/NRCS) and Vermont Agency of Agriculture, Food and Markets (VAAFM) that have set guidelines for agricultural BMPs, provide funding for implementation and technical service providers, as well as government employee staff who provide direct assistance. Many of these programs are statutorily mandated and funded through the US Farm Bill, VT Act 64, and state and federal budgets that support agency staffing. However, although these programs are in place, stakeholders in the survey indicated that there are substantial gaps in coverage and that program resources are not sufficient to meet program needs.

For on-farm BMPs to be effective in reducing nutrient loading long term, wide-spread adoption of practices is required as well as continued operation and maintenance of installed practices. Wide spread adoption of practices is a large hurdle due to: 1) the number of individual operations and number of practices needed per operation; 2) Limited financial resources of agricultural producers to provide matching funds for BMPs and the financial strain involved in taking land out of production for conservation or BMPs; 3) Limited time agricultural producers have to interface with complicated program requirements, applications, and reporting; 4) Limited capacity for technical service providers to provide direct assistance or financial assistance for planning, applications, and BMP implementation.

To reach implementation goals, stakeholders in the survey and in conversations with the Memphremagog Agricultural Workgroup identified categories of challenges and gaps in current regulatory framework, which are barriers to implementation. Many of these gaps can be addressed through regulation which ensure long term funding, increasing knowledge of regulations, and expanding what is eligible for clean water funding.

1) Uncertainty in long-term funding for implementation and planning projects. For example, the Memphremagog Regional Conservation Partnership Program (RCPP) (section 5.2.1.5a) has been a successful collaborative effort to provide technical support and implementation funding, however, it is a discrete five-year project with a limited scope. There is uncertainty around whether or not the gains made from this program will be sustained, expanded, or continued after the initial program funding ends. Further, the US Farm Bill is reauthorized about every 5 years; with each reauthorization comes uncertainty regarding which programs will be funded and how much funding will be granted (See Section 5.2.1.3).

2) Gaps in programmatic support for follow-up, operations, and maintenance. Technical service providers and producers receive little to no funding for this step. Follow-up and operations and maintenance are key to ensuring that installed practices continue to reduce nutrient loading in the long term (See Section 5.2.1.3).

3) Gaps in collaboration among service providers. Locally, the Memphremagog Agricultural Working Group meets to discuss efforts in the watershed, but this is funded through the Memphremagog RCPP, making its sustainability uncertain. However, given the various levels of service providers and programs from federal, state, local, and non-profit sources, members at the Memphremagog Agricultural Working Group expressed frustration with trying to coordinate and collaborate on projects to provide agricultural producers with the best information and program assistance (See Section 5.2.1.1).

4) Gaps in the dissemination of information to agricultural producers and private sector agricultural product representatives. Agricultural producers often receive advice on farm management from equipment and feed sales representatives. Stakeholders indicated that many sales representatives are not aware of Required Agricultural Practices (RAPs) and regulatory requirements, making the advice given from the technical service provider and the sales representative conflicting and practice adoption more difficult for the agricultural producer (See Section 5.2.1.4).

5) Gap in the understanding of the impact, limiting factors, and effectiveness of BMPs on Lake Memphremagog Watershed producers. Given that the watershed has a unique make up of producers, stakeholders suggested that a greater understanding of barriers to BMP implementation specific to the watershed would help service providers understand how to overcome these barriers. Further, more work can be done to understand the widespread impact of certain Environmental Quality Incentives Program (EQIP) and NRCS practices specific to the watershed (See Section 5.2.1.2).

4.2.2.5. Developed Lands (Corresponds to suggestions in 5.2.2)

According to TMDL estimates, phosphorus loading from developed lands needs to be reduced by 18% to reach Vermont's clean water goals. The two largest contributors of phosphorus in that category are dirt roads and developed parcels (homes, businesses, etc.). In Vermont, the majority of dirt roads are owned by municipalities. Under Act 64, VDEC was required to develop the Municipal Roads General Permit (MRGP) and set standards to reduce erosion from all hydrologically connected road segments. As described in chapter 3, section 3.2.2, municipalities are required to complete an inventory of all hydrologically connected road segments (paved and dirt), and then fix all erosion by 2037. Under Act 64, VTrans is also required to reduce erosion from state owned roadways and infrastructure.

Although the road standards and programs are in place, stakeholders have indicated that the road erosion inventories, and subsequent upgrades present a challenge for the smaller Vermont municipalities. Small Vermont towns are generally without full time administrative staff and usually have a part-time town clerk. Further, town government consists of part-time Select Boards or other governing bodies. Town staff and officials may or may not have expertise in roadways and town road budgets for maintenance are limited. Although there is state funding available for the road erosion inventories and currently funding available for road improvement projects, to access funding, towns must submit grant applications and then hire out for the initial inventory. There is also no guarantee how much funding will be available for road improvements, especially as demand increases for access to funding as regulatory deadlines approach (See Section 5.2.2.). Further, implementation of road projects and upgrades may require expensive equipment that the town does not want to purchase, as the level of use of the equipment does not justify the cost of purchase, such as a hydro-seeder (See Section 5.2.2.2). In the Lake Memphremagog Watershed, in addition to assistance from state agencies, there are also non-profits, Northern Vermont Development Association (NVDA), and the collaborative group, the Northeast Kingdom (NEK) River and Roads Group, who are working with towns to help municipalities through this process as mandated by state regulation; however, this capacity is limited (See Sections 5.2.2.1 & 5.2.2.4).

All development within 250 ft of the shoreline is regulated under the Shoreland Protection Act, which both restricts new development and requires permitting to protect Vermont's shorelines. Further, the Vermont Act 250 permitting process requires the review of the environmental impacts of major subdivisions and development. For existing development, Act 64 required that VDEC adopt a 3-acre permit rule which requires stormwater remediation projects for all developed parcels that have 3 acres or more of impervious surface; this rule is still be developed at the writing of this report.

Stakeholders indicated that the greatest hurdle to implementation of the Shoreland Protection Act is dissemination of information and enforcement. VDEC has three permit officers for the entire state who are tasked with assisting landowners through the permitting process, enforcing permit requirements, and identifying violators. Although no statistics exist to capture this, stakeholders expressed frustration that development is occurring within 250 feet of the shoreline and is in violation of the law by landowners who are either willfully ignoring state regulations or are unaware. Due to limited staff at VDEC for this program, it then falls to neighbors and citizens to contact VDEC to report potential violations. Further, given the complexity of the Shoreland Protection Act, additional landowner assistance with understanding the regulations would prevent violations. The state does offer a Shoreland Erosion Control Certification for professionals, such as contractors and landscapers, to understand state regulations and assist with compliance with the Shoreland Protection Act (See Sections 5.2.2.2, 5.2.2.3, & 5.2.2.4).

For existing development, the Lake Wise program is a voluntary program through VDEC to assess and retrofit shorelands. This program is not in statue, and no stakeholders suggested that it should be statutorily mandated or defined. However, expansion of the program by expanding VDECs efforts or working with local lake associations/groups to increase landowner buy-in and adoption of BMPs was highlighted by multiple stakeholders in the survey (See Sections 5.2.2.2 & 5.2.2.3).

4.2.2.6. Natural Lands (Corresponds to suggestions in 5.2.4 and 5.2.5)

TMDL estimates indicated that a reduction in loading from natural lands includes 2.3% from "other" category, which includes wetlands, water, and forest, and 23% reduction from stream channels. Under Act 64, AMPs for forestry practices were updated and are currently being implemented on logging operations with assistance from Vermont Forests, Parks and Recreation (VFPR), Vermont Land Trust (VLT), Northwoods Stewardship Center, and county foresters (See Section 3.2.2.5c).

In order to protect streambanks and river corridors, municipalities can pass zoning laws or river corridor by-laws. Some communities have been exploring these regulatory options which would restrict development around the rivers in the watershed to reduce erosion. However, there are municipalities in the watershed that currently have no zoning laws, making getting citizen and municipal buy-in for adopting zoning laws for environmental protection difficult. There is also a generally a lack of political will for river corridor by-laws. NVDA does provide direct assistance to municipalities for adopting zoning or by-laws; however, this is a time-consuming task and NVDA has limited capacity, as they provide services to a wide geographic range beyond the Memphremagog Watershed (See Section 5.2.3.3).

There are currently no regulatory requirements in Vermont to restore riparian buffers, or streambanks. If the streambanks are located on agricultural lands, the landowner could access agricultural BMP funding, for example through EQIP, to protect those streambanks. Landowners can also work with VLT or other qualified entities like Ducks Unlimited to protect streambanks or other natural lands with conservation easements (See Section 5.2.3.1 & 5.2.3.1).

Maintaining access to funding and support from state and federal agencies for streambank and habitat restoration is necessary to continue and expand programs like those described in section 3.2.2.5c currently underway by Vermont Fish and Wildlife (VF&W). In fiscal year 2019, federal funding from the Great Lakes Fisheries Commission (GLCF) was dedicated to the Lake Memphremagog Watershed for riparian habitat restoration as well; however, it is unknown if this funding will continue (See Section 5.2.5.2)

Access points to streams and lakes are managed by VF&W or VFPR. Changes to these access points on shorelines would be regulated under the shoreland protection act. However, there is no regulatory requirement for assessment of these access points to ensure that no erosion is present (See Section 5.2.5.1.).

4.3. Quebec and Vermont Science and Policy Analysis

Since 2004, both the Quebec Vermont Steering Committee and the smaller Technical Subcommittee meetings have provided a successful and valuable space for international collaboration. For example, meetings were used as the conduit to develop the models to estimate phosphorus loading numbers that were used for the Lake Memphremagog TMDL. Participation in the Steering Committee has fostered relationships and introduced individuals to their binational professional counterparts. Out of these relationships, collaborative and transborder fieldwork and projects have emerged, such as the Creel Survey Project initiated in 2018.

Given the established leadership role and collaborative space that the Quebec Vermont Steering Committee has already provided, many from the Memphremagog Study Advisory Group (MSAG) and stakeholders have advocated for strengthening and using the Quebec Vermont Steering Committee as a platform for meeting the binational water quality goals (recommendation 6.3). The policy and science analysis in this chapter in regard to the Quebec Vermont Steering Committee is presented in the context of the past successes and strength of the committee, as well as opportunities to enhance binational work and collaboration under the guidance and direction of the current steering committee leadership team and provincial and state governments.

4.3.1. Quebec and Vermont: Science Analysis

> Differences between the monitoring done by Vermont and Quebec make it difficult to compare water quality. A sampling strategy allowing the comparison of the results would facilitate an overall reading of the water quality.

There are some similarities and differences between the water quality monitoring done by Vermont and Quebec in the Lake Memphremagog Watershed. Both focus on the trophic status assessment based on the measurement of total phosphorus (PT) concentration, chlorophyll a (chl-a) concentration and transparency measured with the Secchi disk. Water samples are not collected at the same times and there are differences between paired samples caused by unknown factors that make it difficult to compare water quality results coming from Quebec and Vermont. Quebec and Vermont continue the evaluation of these factors. There are also differences between some parameters sampled: in Quebec, the oxygen and temperature profiles have been measured in the lake body since 2012 and fecal coliform samples are collected in the tributaries, when nitrogen is analyzed for the Vermont tributaries and the lake. Finally, limited nitrogen data exist for the Quebec portion of the Lake and its tributaries (See Sections 2.3.2, 3.2.1.2). A global analysis of the datasets is necessary in order to propose a sampling strategy allowing the comparison of the results (See Section 6.1).

> Impacts of climate change are already noticeable, but little information exists on the potential impacts. Studies must be done to take climate change into account when developing management plans and recommendations to reduce nutrient loading.

Furthermore, climate change is already altering precipitation patterns and increasing average temperatures in Vermont and Quebec and this is expected to continue. Increases in the intensity of storm events can lead to flooding, riverbank instability, runoff, and increased pollution and nutrient loading. Warmer average annual temperatures can also affect the intensity and duration of algal blooms and prolong thermal stratification, potentially leading to an increase of phosphorus released from sediments. However, little information exists on the potential impact of climate change on future nutrient loading and algal blooms in Lake Memphremagog and more information is needed to take climate change into account when developing management plans and recommendations to reduce nutrient loading in the Memphremagog watershed (See Section 2.1.5; 6.1).

The segmented lake model developed for the Lake Memphremagog phosphorus TMDL did not suggest substantial internal phosphorus loading from any lake segments. On the other hand, when internal loading is not likely to happen in Vermont due to the shallow and better mixed waters, internal loading is more likely to be an issue in the Quebec portion of the watershed. There is a need to better characterize the potential for internal phosphorus loading particularly with considerations for changes in the length of stratification which may occur with climate change.

Staying current with emerging technologies, methods, and best management practices to reduce nutrient loading would lead to increased project efficiency and cost savings.

Also, it is important that governments and organizations stay current with emerging technologies, methods, and best management practices to reduce nutrient loading. This research can lead to cost savings for project implementation, increased project efficiency, and increased nutrient reduction. Increased knowledge sharing between Lake Champlain Basin groups, such as the University of Vermont Lake Champlain Basin Program and OBV (Watershed Organization/Organisme de bassin versant) Missisquoi Bay, and the Steering Committee could help local organizations stay abreast of this new information (See Section 6.1).

A common portal would lead to increased sharing of scientific data and project efficiency.

Finally, it is difficult to access all the scientific data and research done by the stakeholders from the two countries because the information is distributed in different locations. The Steering Committee can facilitate the sharing of scientific data, including water quality monitoring, cyanobacteria bloom occurrence, land use and climate change, among others, by establishing a common portal (See Sections 6.1 and 6.3).

4.3.2. Quebec and Vermont: Policy Analysis

Stakeholders identified a need for additional support to coordinate Steering Committee meetings, presentations, and initiatives, house and fund a website presence for the Steering Committee and provide a public face for the Steering Committee in the local community and at the provincial/state and federal levels.

Following the last report prepared by the Monitoring and Assessment Work Group of the Quebec/Vermont Steering Committee in 2008, the recommendations have not all been implemented. For example, the report was recommending implementing an action plan done from the recommendations of 1993, and hiring, in Quebec, one person full-time to coordinate with the existing Vermont Memphremagog Basin Planner, to ensure the recommendations are carried out and to give an administrative support to the Quebec/Vermont Steering Committee (Quebec/Vermont Committee, 2008).

> The Quebec Vermont Steering Committee has provided a successful and valuable space for international collaboration. A need for additional support to coordinate Steering Committee meetings, presentations, initiatives, and provide a public face for the Steering Committee in the local community and at the provincial/state and federal levels was identified as a priority recommendation.

Given that there is an opportunity to strengthen scientific and political connections between Quebec and Vermont, as well as an existing committee to support that process, providing additional financial and human resources for the Quebec Vermont Steering Committee has been offered by stakeholders as a priority recommendation. The Quebec Vermont Steering Committee is currently limited in its capacity, in part because the group is unfunded. The attendance and presentation preparation of most participants is supported by internal budgets. The State of Vermont and the Government of Quebec do financially support the meetings for the Steering Committee with room rentals and hospitality for each meeting, as well as supporting staff to organize biannual meetings.

Consultation with Steering Committee organizers and government officials is needed to determine the level of financial support required, to decide how those funds would be used, and to ensure that the autonomy and independence of the Steering Committee are maintained (See Section 6.3).

Chapter 5

Stakeholder suggestions for best management practices and initiatives

Chapter 5 is a list of specific suggestions for best management practices (BMPs) and initiatives to reduce nutrient loading in Lake Memphremagog separated by country and by land use type. The suggestions presented in this chapter were gathered through the Networking Survey Questionnaire and through individual conversations with stakeholders. The Networking Survey Questionnaire was sent to 161 stakeholders, 105 Canadians and 56 Americans in November and December of 2018. 26 Canadians and 33 Americans responded to the survey. A complete analysis of the survey results is included in a separate Networking Report.

It should be noted that many of the suggestions for initiatives and BMPs presented in this chapter have not yet been verified for cost effectiveness, viability, or general need. However, since the Networking Survey captures the experience of experts working in the Memphremagog Watershed, their suggestions are informed opinions that could be the basis of further investigation, action, and innovation. Although still unverified, the suggestions for BMPs and initiatives are capture here in the report to provide inspiration for future research and on-the-ground actions. Further, the analysis of these suggestions allowed for the identification of commonalities in areas of need between Canada and the United States to help develop the broader binational recommendations for governments in chapter 6.

After the Networking Survey results were compiled, individual follow up interviews and email conversations with individual stakeholders to clarify, refine, and improve these suggestions were conducted. MWA and Orleans County NRCD also conducted focus group meetings with the Memphremagog Agricultural Working Group and the Memphremagog Stormwater Collaborative.

Suggestions by sector are grouped into four categories, although not all four were applicable to each land use type. This includes: 1) supporting capacity building of active groups; 2) addressing hurdles to Best Management Practices (BMPs); 3) increased financial support; 4) expanding knowledge. Land use types are presented alphabetically, not in order of importance.

5.1. Canadian Initiatives

5.1.1. Agricultural Sector

5.1.1.1. Expand knowledge

- Assess manure spreading practices including on perennial crops.
- Assess erosion within the fields, prioritizing fields with higher phosphorus export coefficients, such as annual crops and perennial crops on steep slopes.
- Provide a follow up after the agricultural riparian buffer characterization to evaluate the implementation of BMPs along agricultural watercourses.

5.1.1.2. Address hurdles to on-the-ground projects and BMP Implementation

- Ensure the Agricultural Operations Regulation (REA, Règlement sur les exploitations agricoles) implementation regarding shorelines, livestock access to the watercourses and manure spreading, such as fall spraying and separation distances from streams.
- Provide support and incentives to agricultural farms that have problems regarding manure spreading to improve their practices (incorporation to the ground, limitation of the spreading in fall).
- Provide information on erosion reduction techniques and help in implementing soil conservation practices for the agricultural producers with erosion problems.
- Provide incentives to avoid the conversion of perennial crops into annual crops, particularly in high risk areas, such as steep slopes.

5.1.1.3. Financial support

- Provide a source of financial compensation to landowners for the loss of agricultural production acreage for planting large riparian buffers. Fund riparian buffer restoration programs.
- Provide sufficient funding to offer incentives to the agricultural producers to avoid the conversion of perennial crops into annual crops and implement BMPs.

5.1.2. Developed Lands

5.1.2.1. Expand knowledge

- Conduct a stormwater management plan at the Quebec portion of the watershed scale. For the development of this plan, it would be important that stakeholders from all the sectors, including forest and municipal sectors, are represented.
- Support the completion of municipal and private road erosion assessments.

- Support the completion of private septic system compliance assessments.

5.1.2.2. Address hurdles to on-the-ground projects and BMP Implementation

- Provide assistance to municipalities for bylaw updates and to implement non-regulatory efforts.
- Use the Regional County Municipality (MRC, Municipalité régionale de comté) Memphremagog Land Use Planning and Development Plan (SAD, Schéma d'aménagement et de développement) as a tool to expand some municipal regulations to other municipalities about construction on steep-slopes, management of stormwater and erosion control.
- Increase municipal and provincial staffing and provide continuous assistance to ensure that the construction of new roads and the maintenance of unpaved roads, ditches and culverts limit erosion along the road network.
- Increase outreach and landowner support for soil erosion control and stormwater management on private lands.
- Expand the municipal funding programs to help owners to improve their non-compliant septic system.

5.1.2.3. Financial support

- Provide funding to municipalities to assess individual septic systems.
- Provide sufficient funding to assess problems along the municipal and provincial road networks, for example, along unpaved roads, ditches and culverts.
- Provide sufficient funding to implement erosion mitigation measures along the municipal and provincial road networks.
- Provide funding to municipalities to inspect residential construction sites, including private road construction and maintenance.
- Provide information to municipalities to promote funding sources for road improvements and water quality projects.

5.1.3. Natural lands

5.1.3.1. Expand knowledge

- Develop a conservation plan of the natural lands at a watershed scale. A *Regional Wetlands and Bodies of Water Plan* is already planned for 2022 by the Ministry of Environment and Fight against Climate Change (MELCC, Ministère de l'Environnement et de la Lutte contre les Changements climatiques) and the MRC for the Quebec portion of the watershed.

5.1.3.2. BMPs needed

- Use the MRC's SAD has a tool to protect by specific zoning assignments the natural lands of ecological interest, such as wetlands, forests and shorelines. The review of the MRC's SAD began in 2019.
- Establish a target percentage of protected areas at a watershed scale to support the implementation of an action plan.
- Support municipalities in integrating the conservation of natural lands in their town by-laws, zoning by-laws, and town plan.
- Support local organizations in increasing awareness regarding conservation of natural lands of ecological interest and BMPs for landowners, entrepreneurs, foresters, and forest advisors.

5.1.3.3. Financial support

- Provide funding support to purchase conservation easements or lands to protect natural lands to perpetuity in the Lake Memphremagog watershed.
- Provide solid incentives to landowners who create private nature reserves.
- Provide national guidelines and financial support to municipalities that faces loss in tax revenue due to the actual private nature reserve system.
- Provide funding support to natural landowners and local organizations to implement voluntary conservation agreements, for example, to carry out ecological evaluations of properties.
- Provide solid incentives to foresters to implement and improve bridges and culverts, to apply the Forest Stewardship Council (FSC) certification and to implement Forest Management Plans (PAF, Plan d'aménagement forestier) integrating BMPs.

5.1.4. Point sources

5.1.4.1. Address hurdles to on-the-ground projects and BMP implementation

- Continue to assess industry effluents to ensure the comply with nutriment requirements.
- Continue to support wastewater treatment plant managers in the achievement of clean water requirements.

5.1.5. Recreational tourism sector

5.1.5.1. Address hurdles to on-the-ground projects and BMP Implementation

- Address the possibility of adding a pump out service in the southern portion o the lake in Quebec.

- Regulate boating, such as sports generating oversized waves, in sensitive zones of Lake Memphremagog.
- Raise awareness of the population about the importance of protecting the water quality of the lake supporting public beaches and lake access for all citizens and promoting ecotourism.

5.1.5.2. Expand knowledge

- Assess the impacts of the six golf courses and the two ski resorts on nutrient loading in Lake Memphremagog and its tributaries.
- Support the completion of erosion diagnosis along all-terrain vehicle roads.

5.1.6. Water quality monitoring

5.1.6.1. Expand knowledge

- Analyse the water quality datasets to identify the limits of these and to propose a sampling strategy.
- Improve the monitoring program of the Quebec portion of the watershed to identify water quality hotspots, to evaluate the effectiveness of BMPs and to measure the evolution of the water quality in the watershed. An increase of the monitoring efforts for phosphorus and water flow could be necessary in the main tributaries of the watershed. The monitoring plan would have to be harmonized with the Vermont monitoring plan.
- Improve the cyanobacteria blooms monitoring program to be able to monitor the evolution of this issue in Lake Memphremagog.

5.1.6.2. Address hurdles to on-the-ground projects and BMP Implementation

- Set nutrient concentration goals for the Quebec portion of the lake to support the implementation of an action plan.

5.1.6.3. Increase financial support

- Provide sufficient and a long-term funding to implement a monitoring plan for the Quebec portion of the watershed to be able to identify water quality hotspots, evaluate the effectiveness of BMPs and measure the evolution of the water quality in the watershed.

5.1.7. General suggestions

- Provide resources to implement an action plan, coordinate the implementation of the existed action plans and to implement BMPs in the different sectors.
- Assess the impact of climate change on Lake Memphremagog.

5.2. United States Initiatives

5.2.1. Agricultural Sector

The greatest number of suggestions for BMPs and initiatives suggested in the networking survey were for the agricultural sector. This is not surprising given the hurdles and barriers described in chapter 4 and the assistance and expansion of programing for agricultural producers and agricultural service providers presents one of the greatest opportunities for reductions in phosphorus loading in the watershed. Suggestions in this section were also discussed with the Memphremagog Agricultural Working Group and individual stakeholders as follow up to the initial survey.

5.2.1.1. Support capacity building of active conservation organizations in the watershed

- Ensure long-term financial support for coordination of the Memphremagog Agricultural Workgroup.
- Provide ongoing technical assistance (TA) funds to support Conservation Districts for nutrient management planning (NMP) and BMP implementation services to agricultural producers.
- Continue support for the USDA/NRCS Memphremagog Regional Conservation Partnership Program (RCPP) with active and meaningful partnerships through innovated and targeted strategies.
- Facilitate better communication among agencies and organizations to coordinate projects and funding, as well as streamline implementation

5.2.1.2. Address hurdles to BMP related programing

- Operation and Maintenance (O&M) – The state and partners should create a long-term state funded O&M BMP follow up protocol. Follow up and O&M is also a learning opportunity to understand how practices work in the long term. This suggestion could also include additional enforcement and inspection of installed practices as well, however, additional resources for VAAFM would be required.
- Direct financial assistance funds for farmers for on-farm BMPs from the Memphremagog RCPP have been incredibly successful in providing for the implementation of BMPs. As of the writing of this report, the financial assistance fund from the Memphremagog RCPP grant have been spent. New funding sources need to be made available to provide direct financial assistance funds to Conservation Districts to continue to increase farm BMP implementation for discrete low-tech projects and matching state BMP dollars.
- Manure storage – to better develop a program for manure storage upgrades and BMPs, field work is needed to identify limiting factors to on-farm improvements. This work

requires engineering expertise and funding to work with farmers to assess on-farm practices.

- Agricultural Stormwater- additional field work and on-site assessments are needed to determine how to prioritize projects on-farm to manage the source of stormwater runoff, reduce runoff, and intentionally work on filter areas and other BMPs at outlets areas.
- Provide administrative support to farmers for grant management and certifications which could include assistance with NMP, improving herd health, organic certification, and other paperwork requirements.
- Increase NRCS Vermont Nutrient Management Plan Code 590 practice implementation by addressing limitations of NRCS engineering or look to alternative ways to provide financial support to farmers.
- Work with Natural Resource Conservation Service (NRCS) and local feed nutritionists to understand the need for Technical Service Providers (TSPs) for NRCS Feed Management Conservation Activity Plan (CAP) practice. If this is identified as a need, work to train and certify TSPs covering the watershed to lead toward Feed and Nutrient Management implementation. A recent UVM study highlights accumulation of phosphorus and looks at feed imports.

5.2.1.3. Increased financial support directly to agricultural producers to ease financial burden of BMP implementation.

- Increased agricultural conservation equipment incentive grants for BMP related equipment (for example, manure injection or precision agriculture) for farmers, non-profits, and technical support. To include capital grants and grants for technical service providers.
- Support farmers and partners to conduct on farm demonstration projects related to soil health and improved tillage methods. For this to be successful, agricultural producers will need services providers to follow-up and resources to support demonstration projects and associated promotion.
- Support implementation of ecosystem and tourism services payments to farmers at the state level.
- Ensure long-term federal support for the Conservation Reserve Enhancement Program (CREP) or provide another source of financial compensation to landowners for loss of agricultural production acreage for planting riparian buffers. Fund riparian buffer restoration programs.
- Reposition funding from the federal government that currently supports large farms to smaller farms. This funding would be used for the implementation of BMPs and engagement in programs or with organizations that attract farm tourism, revitalize local areas, and promote BMPs.

5.2.1.4. Expand knowledge

- Support agricultural conservation promotion and educational activities including expanding current efforts, such as art exhibit, road signs, success story write ups, the videos, and conservation field days.
- Fund ongoing agricultural pre and post BMP monitoring through targeting water sampling programs paired with the creation and distribution success stories.
- Formally include local water quality data in land treatment plans.
- Increase knowledge base of fertilizer dealers on the nutrient management plans and required agricultural practices (RAP).
- Create large farm operations (LRO) and medium farm operations (MFO) farm labor RAP and natural resource training program.
- Increase the working relationship with Agricultural Science Department at the North Country Career Center and continue to create opportunities for involving Future Farmers of America students.
- Support agricultural producers in understanding and implementing strategies for climate resiliency.
- Where applicable, provide for shared learning opportunities with Quebec through invitations to workshops, collaboration, and the Quebec Vermont Steering Committee.

5.2.2. Developed Lands

Suggestions for BMPs and initiatives for developed lands came from the networking survey. Suggestions in this section were also discussed with the Memphremagog Stormwater Collaborative (SWC) and individual stakeholders as follow up to the initial survey. These suggestions focus heavily on assisting municipalities with the requirements of the Municipal Roads General Permit (MRGP), expanding the voluntary Lake Wise program, and the installation of small and large scale GSI retrofits on developed parcels.

5.2.2.1. Support capacity building of active organizations and state agencies in the watershed.

- Provide ongoing support and coordination for the NEK River and Roads Group and the Memphremagog Stormwater Collaborative as local groups providing professional support, technical assistance, and meeting platforms for collaborative project development.
- Improve state departmental staffing and/or provide additional mechanism to increase outreach and landowner support for project permitting under the Shoreland Protection Act and Act 250.
- Continue to increase connections among local and regional groups with state wide advocates to provide a conduit for input on state legislation that affects development and stormwater, utilizing Federation of Vermont Lakes and Ponds (FOVLAP), Watersheds United Vermont (WUV), the Clean Water Network, and the Clean Water Caucus.

5.2.2.2. Address hurdles to on-the-ground projects and BMP Implementation

- Establish equipment sharing programs and determine the need and feasibility for the purchase and subsequent lease of equipment, such as hydro-seeders, for local municipalities or organizations to use for water quality projects.
- Install and use demonstration sites to promote BMPs for stormwater remediation projects, especially in high need areas.
- Increase state permitting and environmental regulation and enforcement. Increase long-term follow up to ensure landowner compliance and long-term operations and maintenance. Include education and providing technical support for landowners and/or municipalities to ensure long-term effectiveness of installed practices.
- Increase local engagement with the Lake Wise Program to obtain Lake Wise Gold Awards for all lakes in the watershed. Develop a Lake Wise Master Planning system to outline how each lake can obtain gold status.
- Engage with lake associations to train volunteers and members to help identify properties and areas that may benefit from stormwater practices, such as roadways, developed parcels, and private properties. Use lake association volunteers as first contacts for outreach and projects, as early adopters and local and trusted community messengers.
- Provide grant writing assistance to municipalities to increase access to state funding for project implementation.
- Prioritize projects identified in stormwater master planning for design and implementation.

5.2.2.3. Increased financial support

- Increase access and designated funding for project scoping, landowner outreach, and design phases at the state level.
- Increase access for funding projects on private land, including shoreland erosion projects, private road projects, and home-scale green stormwater infrastructure.
- Explore feasibility of creating a "Lake Wise Assistance Program" similar to the "Weatherization Assistance Program" to provide financial assistance for professionals to complete Lake Wise Assessments.

5.2.2.4. Expand knowledge

- Provide information to municipalities, as needed, to promote funding sources for road improvements and water quality projects, as well as provide assistance for town planning and bylaws updates.
- Prioritize outreach to individual landowners on BMPs for homes and businesses.
- Increase the local knowledge base through workshops for road crews, homeowners, professionals, and other stakeholders implementing projects on developed land.
- Use water quality monitoring data and/or case studies on implemented projects to promote success stories and impact of BMPs and projects.

5.2.3. Natural lands

Suggestions for BMPs on natural lands were informed by the networking survey and were also discussed with the Memphremagog Stormwater Collaborative (SWC) and individual stakeholders as follow up to the initial survey. The most significant contributor of phosphorus from natural lands is from unstable stream channels. Suggestions for natural lands focus on the continuation and expansion of streambank assessment programs, riparian and wetland habitat restoration, and continued assistance to municipalities for river corridor protection by-laws and zoning laws.

5.2.3.1. Address hurdles to on-the-ground projects and BMP Implementation

- Work to complete Phase 1 and Phase 2 Stream Geomorphic Assessments of all major streams.
- Support stream buffer, wetland, and riparian habitat restoration to reduce streambank erosion on both private and public lands.
- Continue to protect and preserve riparian lands through conservation easements.
- Use local organizations to implement "Blueberries for Blue Waters" or "Trees for Streams" programs to encourage vegetation along shores and streambanks.

5.2.3.2. Increased financial support

- Increase access and designate funding for project identification, landowner outreach, and planning from state and federal funding streams.
- Continue to provide federal funding for riparian buffers and streambank restoration projects.

5.2.3.3. Expand knowledge

- Provide outreach and support to municipalities in adopting flood plain protection and buffer zones in municipal zoning regulations.
- Use water quality monitoring data and/or case studies on implemented projects to promote success stories and impact of BMPS and projects.
- Increase public engagement through workshops, recreational and educational events like bird walks, forest walks, canoe paddles- to provide information on the importance of stewardship and improvement of natural lands for water quality and other benefits.

5.2.4. Point sources

Point sources in the Vermont portion of the watershed consist solely of the four Wastewater Treatment Facilities (WWTF). There was no specific policy or science analysis included in chapter 4 for this land use, as there is already a program underway in Vermont to optimize phosphorus concentrations in WWTF effluent (3.2.1.5d). The suggestion below is based on the implementation of the optimization process and was informed by following up with individual stakeholders after the initial networking survey.

5.2.4.1. *Address hurdles to on-the-ground projects and BMP implementation*

- As the phosphorus optimization process begins in watershed wastewater treatment facilities, maintain close contact with municipalities and plant managers to understand avenues for support, coordination, and process assistance.

5.2.5. Recreational tourism

Recreational tourism section focuses on the use of natural lands for recreation. This includes trails by waterways, river and lake access points, and boating. In Vermont, there are no downhill ski resorts in the watershed. Although this land use type is not a major contributor of phosphorus, suggestions for BMPs and initiatives in this section focus on assessing current recreational access points and trails for erosion and applying BMPs and repairs to fix erosion and stormwater runoff. Suggestions were informed by the networking survey and individual follow ups after the initial survey.

5.2.5.1. *Address hurdles to on-the-ground projects and BMP implementation*

- Complete watershed wide assessments of public access points to waterways to determine if shoreline erosion control projects, improvements to parking areas, and/or Lake Wise practices are needed. Assessments include Fish and Wildlife access points, boat launches, and public beaches. Assessments can utilize state and local organizational staff. Move projects to implementation once assessments are completed.
- Continue and increase recreational trail maintenance and construction to reduce erosion from recreational trails and increase public access to waterways to increase public appreciation and awareness to support local-by in for BMPs and project implementation.
- Support class 4 road maintenance to stop erosion from hydrologically connected segments and ensure class 4 roads are open for recreation.

5.2.5.2. *Increased financial support*

- Ensure continued funding for BMP scoping, design, and implementation, including funding for watershed crews and local organizations.

5.2.5.3. *Expand knowledge*

- Create semi-permanent informational signage or kiosks explaining projects and benefits of installed practices at public access points and public trails.
- Ensure that information regarding projects and benefits is disseminated into the community via press releases, websites, social media, and other avenues. Provide unveiling events or involve community volunteers where applicable to increase awareness for projects, practices, and benefits.

Chapter 6

Recommendations for a Binational Approach

Introduction

The recommendations below are provided to the International Joint Commission and aim to demonstrate the importance of organizing, catalyzing, and coordinating actions around Lake Memphremagog and the Memphremagog Watershed. It is imperative that swift and decisive action is taken to reduce nutrient loading throughout the watershed to reduce nutrient concentrations and the frequency and severity of harmful algal blooms (HABs) in Lake Memphremagog. Concurrently, steps must be taken to strengthen the monitoring, coordination and governance of these actions.

The recommendations and urgency of action are supported by the following underlying factors and context:

- The environmental and economic impact of the frequency and duration of HABs in Lake Memphremagog is a concern for both the Canadian and United States stakeholders. Between 2006 and 2018, 156 cyanobacteria blooms have been reported by the population on both sides of the border. Preventive drinking water avoidance advisories have been issued in two municipalities and public beaches have been closed following cyanobacteria bloom occurrence. There is immediate need to develop binational solutions to control nutrient loading to reduce current blooms.
- Climate change is already altering precipitation patterns and increasing average temperatures in Vermont and Quebec and is expected to continue. It is predicted that climate change will increase future nutrient loading and algal bloom frequency in the lakes of the region by increasing water temperatures and the frequency of high intensity rainfall events. As such, current efforts to reduce nutrient loading to maintain or improve water quality may prove insufficient to meet the challenges of a changing climate. There is immediate need to develop binational solutions to understand and prepare for the impacts of climate change.
- The phosphorus concentration of Lake Memphremagog has been either stable or slightly decreased since the early 2000s, when the chlorophyll concentration indicates stability. According to the trophic status classification chart used by the Ministry of Environment and Fight against Climate Change (MELCC, Ministère de l'Environnement et de la Lutte contre les Changements climatiques), the lake is at an oligo-mesotrophic level according to the total phosphorus concentration, whereas according to the indicator of algal biomass, the chlorophyll-a concentration, it is situated at the mesotrophic level in the southern half of the lake and at the oligo-mesotrophic level in the northern half of the lake. Fitch Bay and South Bay, which are isolated and distinct sections of the lake, show a more advanced state of eutrophication.

- Quebec makes measurements of the trophic level as a general indication of the lake condition and trend. The Quebec approach to eutrophication control is based on implementing several measures (legal, financial, administrative and management practices) in order to stabilize or decrease the nutrients level in aquatic ecosystems over the Quebec territory and to specific area, taking in consideration water quality criteria and the ecosystem condition for point source effluent loads. The monitoring programs serve to evaluate the effect of these measures.
- Water quality monitoring of Lake Memphremagog has shown that over time phosphorus levels averaged 18 μg/L in the Vermont portion of the lake, exceeding the state phosphorus standard for the lake of 14 μg/L (VDEC, 2017c). The elevated levels of phosphorus triggered a regulatory response in the United States, and the Vermont Department of Environmental Conservation (VDEC) was required to study and set a Total Maximum Daily Load (TMDL) for phosphorus and outline reduction goals by land use type. The results of the study indicated that a total phosphorus load reduction of 29%, from the Vermont portion of the watershed, was needed to meet Vermont's clean water goals (VDEC, 2017c). Unlike Vermont, Quebec does not have a water quality target for the lake with a force of law.
- Three quarters of the lake is in Quebec and one quarter in Vermont, with the water flowing north. Therefore, approximately 71% of the watershed is located in Vermont and 29% of the watershed is located in Quebec.
- Lake Memphremagog is a drinking water source for approximately 175,000 Canadian residents including the citizens of Magog and Sherbrooke. No public drinking water uptakes are located in the US portion of the Lake.
- Lake Memphremagog is a major tourist draw and fishing destination in Eastern Townships. The increased frequency and duration of HABs predicted under climate change may adversely affect this important tourism economy.
- The Quebec portion of Lake Memphremagog watershed is still mainly natural: the natural lands represent about 82% of the land use, followed by 10% agricultural lands and 8% of developed land, including paved and dirt road, representing respectively 33% and 42% of the Quebec phosphorus loading estimate. The Regional County Municipality (MRC, Municipalité régionale de comté) Memphremagog experienced constant growth, with a 20% population increase between 2001 and 2016.
- The Vermont portion of the lake Memphremagog is also mainly natural lands, making up 78% of the watershed followed by 17% agricultural lands and 5% developed lands. Estimated phosphorus loading from agricultural lands in the Vermont portion of the watershed is 46%, and 21% from developed lands. In contrast to the Quebec portions of the watershed, the population of Orleans County – which closely matches the watershed – has dropped by 1.2% from 2010 to 2018.

- The importance of Lake Memphremagog needs to be highlighted to ensure that it receives the level of attention and funding from federal, provincial and state governments necessary to meet the challenges posed by HABs and climate change.
- Since 2003, the Quebec Vermont Steering Committee has been a positive platform for supporting coordination, sharing information, and strengthening projects and relationships that needs to be strengthened to meet these challenges.

Recommendation 1: Establish watershed nutrient loading reduction goals through a binational watershed model

Reducing nutrient loading will require careful planning and understanding of current state of water quality, areas of concern, and reduction targets. A binational model has been developed to support the development of the TMDL, but this model has not been calibrated in Quebec, and so there may be inaccuracies in how the model estimates phosphorus loading for the Quebec portion of the watershed. The lack of a calibrated watershed-wide model limits the binational understanding of reduction goals, the management techniques needed to meet those goals, and the effectiveness of those management techniques. Given the need for management and the threat of climate change, the first recommendation is to develop a binational watershed model building on the Vermont TMDL model (section 3.2.2.2).

The following are recommendations for the development of a binational set of tools to support efforts to reduce phosphorus loading in the Lake Memphremagog watershed:

a) Complete a collaborative process lead by the Quebec Vermont Steering Committee or technical committee to evaluate how the watershed model can be updated to more accurately estimate phosphorus loading from the Quebec portions of the watershed and to facilitate making these updates.

b) Establish binational lake phosphorus concentration goals for lake segments and use the watershed model to: 1) support the establishment of watershed nutrient reduction goals by land use type; 2) evaluate the effectiveness of BMPs; 3) evaluate the limits to land use conversion; and 4) guide land management decisions binationally.

c) Develop a tool to estimate Best Management Practices (BMPs) installation costs and phosphorus reduction benefits for both Quebec and Vermont so that a cost/benefit analysis can be completed to guide implementation efforts and help communicate benefits to landowners on lands where projects with high benefit to cost ratios are located.

d) Develop long-term research and development partnership between Lake Memphremagog Watershed stakeholders and local universities to address complex issues including the impacts of climate change on nutrient loading in the watershed, improving in lake modeling, the potential for internal phosphorus loading, evaluating the effectiveness of BMP projects and other emerging topics. This partnership would support the development of more dynamic models to answer many of these questions.

e) The Quebec Vermont Steering Committee or its technical committee to provide leadership to coordinate the development of the watershed model and act as a platform for discussion and collaboration to maintain and improve the watershed model over time, to support research and development partnerships, and share information with the Lake Champlain Basin Program technical advisory committee and the Binational Phosphorus Reduction Task Force.

f) Through the modeling process, Quebec and Vermont will analyze the existing water quality and HABs dataset and propose a sampling strategy to ensure consistent water quality sampling and monitoring methods and consider new satellite technology that may support more consistent Cyanobacteria monitoring in both countries.

g) Use satellite data to evaluate cyanobacteria blooms on the lake and to compare data obtained through traditional monitoring and voluntary mechanisms in Vermont and Quebec. Address differences in sampling frequency and protocols and track progress towards nutrient reduction goals.

h) Once the model is developed and BMPs are installed, water quality monitoring will be used to track progress towards nutrient reduction goals and adjust long-term plan accordingly.

i) Technical support and potential funding will be needed for the development of the model.

Recommendation 2: Adopt and expand practical solutions to reduce nutrient loading by land use type through the installation of BMPs and investment in clean water projects

Even though there is not currently a calibrated binational mass balance model for the Memphremagog Watershed, the existing science and monitoring data presented in Chapter 2 does indicate that nutrient loading reductions are needed to reduce the frequency and duration of HABs and improve water quality. Vermont TMDL modeling indicates a 29% reduction in phosphorus loading is needed from the Vermont side of the watershed (VDEC, 2019d). Although there are current efforts and projects underway as presented in Chapter 3 to increase BMP installation and on-the-ground projects to reduce nutrient loading, widespread adoption and investment in clean water projects must be strengthened to improve water quality, and the opportunities and gaps explained in Chapter 4 will have to be addressed.

Widespread adoption of BMPs and investment in clean water projects is needed to reduce nutrient loading, and although these recommendations included here for practical solutions will be refined with the development of the watershed model, work on these BMPs and solutions should begin concurrently.

2.1 Agriculture – Adopt widespread on-farm BMPs supported by resources for implementation, direct service providers and provide incentives to reduce nutrient loading on agricultural lands

Agricultural production in the Memphremagog Watershed is important to the culture and economy of the region. However, according to TMDL estimates, agriculture is largest contributor of phosphorus in the Vermont portion of the watershed and requires a 46% reduction in current loading to meet clean water goals. Reaching this reduction goal is particularly challenging given that agricultural producers have limited financial resources and time to invest in BMPs and nutrient management planning.

Phosphorus loading from agriculture is greater in Vermont than Quebec; however, while specific loading reductions for Vermont exist, they do not for Quebec. Load reduction goals, including Quebec agriculture, would be developed from the Watershed Model. Meanwhile, it is clear phosphorus loading reduction goals cannot be met for the Memphremagog Watershed unless loading from agricultural lands is reduced.

It should be noted that similar challenges exist in Quebec regarding barriers to on-farm BMPs installation. Agricultural producers and service providers in Vermont do not currently have enough resources or support to implement BMPs on the scale required to reduce nutrient loading. In Quebec, programs exist to financially support the implementation of BMPs, but they are not commonly used, therefore, assistance to agricultural producers could be needed. Given climate change will impact loading from agricultural lands with more intense rain events, steps need to be taken immediately to install on-farm BMPs.

The following are recommendations specific to agriculture:

a) Use the Watershed Model to determine high priority areas and loading reduction goals for agricultural lands in the watershed, and to evaluate the efficiency and effectiveness of BMPs over time and under climate change scenarios in both Quebec and Vermont.

b) Develop binational approach and goals for BMP implementation for the agricultural sector under the leadership of the Quebec Vermont Steering Committee.

c) Provide a follow-up of the implementation of riparian buffers along agricultural watercourses, and assess erosion and manure management on agricultural lands to prioritize BMPs and areas.

d) Continue and expand existing outreach initiatives using scientific information to present the need for BMPs in Lake Memphremagog watershed.

e) Develop a long-term framework for providing direct assistance to agricultural producers for installation, operations and maintenance, and follow-up for BMP installation. Target a one-on-one support and consulting services to effectively carry out existing initiatives. Present progress in water quality to the agricultural producers and communicate that results of actions can take time to be observed on water quality.

f) Provide incentives to: 1) avoid the conversion of perennial crops in annual crops; 2) to protect or restore natural lands; 3) to provide ecological services.

g) Support technical service providers to help assist agricultural producers.

h) Assess long-term effectiveness of BMPs after installation and assist in the understanding of the lifetime, operations, and improvement of existing practices.

i) Provide resources for agricultural land assessments and implementation of BMPs.

2.2 Developed Lands – Adopt BMPs and stormwater regulations for new development projects and increased implementation of retrofit projects for existing development

Stormwater runoff from existing developed parcels and roadways in the Memphremagog Watershed presents a significant challenge as solutions to capturing runoff from existing impervious services requires municipalities, the state or province, and/or private landowners to invest in stormwater retrofits. It is estimated that developed lands are the largest source of phosphorus in the Quebec portion of the watershed, representing 42% of the Quebec phosphorus loading. Nutrient loading reduction cannot be met for the Memphremagog Watershed unless loading from developed lands is reduced. Stormwater runoff has not been modeled at a watershed scale, which would be the first step to implement a strategy to reduce nutrient loading from developed lands.

In Quebec, municipal regulations and non-regulatory efforts to reduce nutrient loading from developed lands and private septic systems are implemented at various levels. The implementation of stormwater retrofit projects and the compliance of existing private septic systems would be supported by the enforcement of existing laws and by support for municipalities and private landowners. An opportunity would be to expand by-laws throughout other municipalities ensuring that assistance for bylaws updates and resources for by-laws implementation are provided. The Land Use Planning and Development Plan (Schéma d'aménagement et de développement, SAD) of the MRC would also give the opportunity to adopt a stronger regulatory framework to control development in steep slopes, improve the stormwater management and control erosion.

Vermont is in the process of implementing stormwater retrofit requirements for parcels greater than 3 acres of impervious surfaces, and the new Municipal Roads General Permit will assist in phosphorus loading reduction. A Stormwater Master Plan was completed for the watershed and several projects are in the design phase. Additional funding though Vermont Act 76 should accelerate these efforts. Additional project development work is necessary to gain landowner support for implementing these projects and to identify additional projects that may be necessary to meet load reduction targets.

The following are specific recommendations for developed lands:

a) Use the Watershed Model to: 1) determine loading reduction goals for the developed lands in the watershed; 2) approach stormwater management with a holistic vision; 3) to evaluate the efficiency and effectiveness of BMPs over time and under climate change scenarios in both Quebec and Vermont.

b) Ensure that new development is in compliance with environmental regulations and occurs in a way that minimizes environmental impacts.

c) Ensure that stormwater regulation at the state, provincial and MRC level is updated to reflect current technologies.

d) Provide support for municipal and regional planning to ensure that stormwater management and technologies are incorporated into town planning and infrastructure updates

e) Provide support for municipalities to develop erosion control by-laws for municipal and private road construction and maintenance and for fertilizer limitation on private lands. Provide incentives and outreach for private landowners and landscapers to adopt stormwater retrofits and limit the use of fertilizers. For example, pervious surface, as parking lots, must be promoted, and the use of fertilizers could be reduced through a fee or tax.

f) Provide resources for municipal stormwater assessments and implementation of BMPs.

g) Study loading from private septic systems and use results to improve regulation, monitoring, enforcement, and direct assistance to landowners as necessary.

2.3 Natural Lands – Identify priority conservation areas that support essential ecological services provided by natural lands in the watershed and implement programs and providing incentives to conserve and restore these lands

Land management includes active conservation and/or restoration of natural lands of ecological interest (riparian areas, wetlands, and forests).

As described in Chapter 3, there are efforts and programs in both Quebec and Vermont to conserve and restore natural lands; however, the effectiveness of these programs is limited due to inadequate resources, lack of political will, and lack of land-owner commitment and cooperation. The Province of Quebec and Canada currently have a goal of conserving a total of 17% of terrestrial and inland water areas by 2020, but a goal has not been set for the Quebec portion of the Memphremagog watershed. Vermont also lacks a conservation percentage goal, although through TMDL modeling VDEC estimated anticipated phosphorus loading from stormwater runoff associated with an increase in developed lands over time.

To reduce and prevent the increase of nutrient loading protecting and maintaining natural lands, a binational Land Management Study is necessary. The study would identify conservation areas that are a priority for maintaining ecological services that prevent/reduce phosphorus loading. In addition, the study will identify degraded lands that need restoration. In Quebec, the Regional Wetlands and Bodies of Water Plan (Plan régional des milieux humides et hydriques, PRMHH) scheduled for 2022 presents an opportunity to plan the protection of the wetlands and Lake Memphremagog in the Quebec portion of the watershed. The binational Land Management Study would be used to incorporate natural land into town planning and would inform decisions on conservation programs, payments for ecosystem services, restoration projects, as well as project prioritization. In Quebec, municipal regulations to direct residential expansion and control development in natural areas have different strengths. The actual review of the MRC SAD is an opportunity to increase the control of the development in sensitive areas and to ensure the protection of natural areas, including wetlands, forests, and riparian buffers.

The Land Management Study will be supported by the Watershed Model, as well as conservation goals and the TMDL modeling tools.

The following are specific recommendations for the binational Land Management Study:

a) Develop a Land Management Study to identify high-priority areas for conservation and restoration, while considering climate change scenarios for Quebec and Vermont.

b) Ensure financial investment for conservation and restoration projects from state, provincial, and federal governments to meet land management goals.

c) Expand and increase financial incentives for programs to conserve and restore natural lands of ecological interest, value, and/or significance.

d) Support local organizations to identify opportunities for land conservation and/or restoration and implement conservation of natural lands.

e) Compensate the municipalities for the loss of tax revenues associated with conservation and restoration.

f) Assist regional planning efforts to maintain and restore natural lands understanding that some land-use conversion is inevitable. Support efforts to direct residential expansion, control development in natural areas, and offset development through restoration.

2.4 To support all practical solutions on all land use types, it is further recommended that the following are incorporated into each recommendation:

Climate Change

Climate change has the potential to impact the effectiveness, efficiency, and longevity of BMPs and on-the-ground projects. Further, it is predicted that the effect of climate change will negate a part of current efforts to reduce nutrient loading. This means that in order to reduce nutrient loading to meet reduction target goals, current efforts need to be increased to offset the effects of climate change.

a) Incorporate climate change impacts into all decision-making in order to ensure nutrient loading targets are met and investments in BMPs and implementation projects are long-term and that finite resources are used effectively.

Enforcement

Existing environmental laws at the state, provincial, and federal level need to be equitably and consistently enforced to ensure compliance with existing laws.

b) It is recommended that to understand current conditions, an analysis of existing enforcement of regulation is conducted to determine if there are gaps in enforcement areas, and to develop a plan to address gaps and identify opportunities for improvement.

c) In order to enforce regulation, it is recommendation that state and provincial agencies and those invested with enforcement authority are provided with increased resources and more effectively target enforcement systems to reach this goal.

Regulation

Regulation can support practical solutions through funding initiatives. Although resources have been invested in projects in the Memphremagog Watershed, there is still substantial work to be done.

d) Funding initiatives from state, provincial, and federal sources should focus on achieving the binational goals developed from these recommendations.

Education and Awareness programs

Education and awareness can lead to the implementation of more practices to reduce nutrient loading in the watershed and to local, state/provincial, and federal by-in. Further, showcasing local successes and projects can lead to additional participation in projects.

e) Incorporate education and awareness to all projects to ensure that more BMPs are implemented, to ensure local, state/provincial and federal by-in, and additional participation in projects.

Recommendation 3: Strengthen the cooperation through Quebec Vermont Steering Committee to implement a long-term strategy

The Quebec Vermont Steering Committee is an established leadership group for the Memphremagog Watershed that provides a binational forum for the presentation of materials and in-depth analyses and collaboration on environmental issues within the watershed.

It is recommended that the Quebec Vermont Steering Committee is supported to provide coordination and leadership for the recommendations and initiatives outlined in this chapter and the continuation of creating an on-going collaborative environment to develop binational approaches and solutions for the Memphremagog Watershed.

Although the Steering Committee has been successful in supporting collaboration and initiatives since 2003, the initiatives and recommendations outlined in this chapter represent an expansion of projects and leadership roles. Binational collaboration is necessary to reach clean water goals in the Memphremagog Watershed, therefore, the Steering Committee requires support to achieve collaborative ends. As outlined in Chapter 4, the Steering Committee does not have a direct funding source, apart from funds from VDEC and MELCC operational budgets, meaning financial support is necessary to expand the leadership role of the committee. Support for the Quebec

Vermont Steering Committee and the specific expansion of the leadership role must be coordinated and agreed upon by the current leadership of the committee and state and provincial governments.

The following are recommended:

a) The Quebec Vermont Steering Committee provides coordination, oversight, and leadership for the binational approaches and initiatives to reduce nutrient loading outlined in this report and any resulting initiatives.

b) Use the Environmental Cooperation Agreement on Managing the Waters of Lake Memphremagog and its Watershed to recommend a long-term plan that would be action-oriented, to include data sharing protocols as well as to ensure that all necessary stakeholders are represented on the committee.

c) Provide leadership for development and implementation of a long-term strategy through the Quebec Vermont Steering Committee by:

    - increasing meeting frequency of the technical subcommittee;
    - sharing responsibilities among the stakeholders;
    - tracking and adjusting progress towards the achievement of its objectives;
    - increasing binational knowledge sharing;
    - and providing leadership for climate change impacts and awareness.

d) Develop a communication plan for the Steering Committee to increase binational knowledge sharing, improve reporting and transparency, and define specific outcomes of interest for each stakeholder. A website must be created which includes a public face and a private portal. This website would be bilingual and provide a binational and coordinated message on the efforts underway in the Memphremagog Watershed. The website can be used to present a unified message to the public and raise awareness for nutrient loading concerns and promote successes in the watershed. The private portal on the website can provide members of the Steering Committee with access to internal documents such as meeting minutes, presentations, handouts, and data.

e) Provide financial resources to be used at the Quebec Vermont Steering Committee's discretion to meet these objectives and to fund and assign dedicated staff from Quebec and Vermont.

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Global Scan

The cyanobacteria, and associated harmful algal blooms (HABs) problem is pervasive throughout the world. It is restricting the development of society and the economy. In 2010 the United States Environmental Protection Agency (USEPA) estimated the cost of HAB related impacts to be nearly 5 billion dollars per year. The International Joint Commission (IJC) conducted a global scan of how jurisdictions are addressing the problem; this served to inform our recommendations to governments.

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https://iwaponline.com/wqrj/article/55/1/1/69781/A-global-scan-of-how-the-issue-of-nutrient-loading

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A global scan of how the issue of nutrient loading and harmful algal blooms is being addressed by governments, non-governmental organizations, and volunteers

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ABSTRACT

Harmful algal blooms (HABs) in aquatic ecosystems are of concern worldwide. This review deals with how jurisdictions around the world are addressing this water quality issue to inform recommendations regarding nutrient loading and HABs in Missisquoi Bay-Lake Champlain and Lake Memphremagog; transboundary lakes located in the USA and Canada that suffer from symptoms of eutrophication. A global scan of the literature resulted in the consideration of 12 case studies of large water bodies within large watersheds, excluding in-lake geoengineering approaches. Although all of the systems experience excessive nutrient loading, they vary in two key ways: sources of nutrients and manifestations of eutrophication ranging from HABs, to limited recreational uses, to the additional complexity of internal loadings and fish kills, up to drinking water shutdowns. The case studies were analyzed with respect to four categories of approaches, namely: (i) regulatory; (ii) incentive-based; (iii) risk mitigation; and (iv) outreach, engagement, and educational. We found that the management frameworks are based on integrated watershed management planning and national standards. National water quality standards, however, are not stringent enough to prevent HABs. Overall, identified case studies did not successfully remediate HABs, they simply managed them.

Key words | approach, incentive, regulatory, rehabilitation, remediation, risk mitigation