Restoring Water Quality in the Lake Memphremagog Basin: Evaluating Project Effectiveness along Nine Tributaries in 2018

Prepared for the

Orleans County Natural Resources Conservation District and
Vermont Department of Environmental Conservation

by

Fritz Gerhardt, Ph.D.

24 January 2019

Orleans County Natural Resources Conservation District

The Orleans County Natural Resources Conservation District was established in 1946 as a non-regulatory, grant-funded organization led by local landowners. The Conservation District's mission is to protect and enhance the quality of all of the waters in Orleans County by providing leadership, education, and services for implementing sound land stewardship practices. As part of these efforts, the Orleans County Natural Resources Conservation District administers the Memphremagog Regional Conservation Partnership Program (RCPP), which helps farmers fund and implement agricultural Best Management Practices.

Memphremagog Watershed Association

Founded in 2007, the Memphremagog Watershed Association (MWA) is a nonprofit organization dedicated to the preservation of the environment and natural beauty of the Lake Memphremagog Basin. The Memphremagog Watershed Association achieves this mission by 1) promoting the ecological awareness of people who live in, work in, and visit the Lake Memphremagog Basin; 2) promoting efforts to preserve the environment and natural beauty of the basin; 3) working with area lake associations; local, state, and federal governments; and businesses to develop guidelines and policies that protect and improve the quality of life in and around the basin; and 4) participating in efforts to monitor water quality in the lake and its tributaries, clean-up and re-naturalize shorelines, and protect local plants and wildlife.

Beck Pond LLC

Beck Pond LLC, a limited liability company founded in 2008, partners with public and private organizations to conduct scientific research that not only increases our understanding of the natural environment but also informs and guides on-the-ground conservation and management. Among other projects, Beck Pond LLC has conducted scientific studies and helped develop conservation projects that assessed the impacts of historical land uses and invasive plants on forest plant communities in northern New England; identified, assessed, and proposed solutions to water quality problems in the Lake Memphremagog, White River, Mad River, and Missisquoi Bay Basins; protected and restored floodplain forests and wetlands along the Connecticut River and in the Lake Memphremagog Basin; and identified and protected critical wildlife habitat across northern New England and eastern Canada.

Cover. *Much of the water quality sampling in 2018 focused on assessing possible impacts of agricultural practices, such as livestock and farm roads and infrastructure, on water quality in the Lake Memphremagog Basin. Examples include livestock standing in a small stream alongside a failed culvert in Holland, Vermont on 11 June 2018.*

Table of Contents

Table of Contents i
Acknowledgments ii
Executive Summary iii

1.0 Introduction 1
2.0 Study Goals 3
3.0 Description of Watershed 3
4.0 Methods 6
4.1 Statistical Analyses 8
5.0 Results and Discussion 9
5.1 Quality Assurance 9
5.2 Stream Flow 9
5.3 Past Projects 11
5.3.1 Brighton Brook 11
5.3.2 Junkyard Tributary 16
5.3.3 Tributary of Stearns Brook 20
5.4 New Projects 25
6.0 Conclusions 26
7.0 Bibliography 28

Appendix A. Quality Assurance Data 29
Appendix B. Sample Farm Handout 32

Acknowledgments

This project would not have been possible without the support and assistance of many individuals and organizations. Sarah Damsell (Orleans County Natural Resources Conservation District) obtained funding for and administered this project, collected water samples, and coordinated efforts with local farmers to develop and implement Best Management Practices and other conservation projects. Ben Copans (Vermont Department of Environmental Conservation) helped develop and implement all aspects of this project, including obtaining funding and support from the Vermont Agriculture and Environmental Laboratory, designing and implementing the project, collecting water samples, and compiling and analyzing the water quality data. David Pasco (Vermont Department of Environmental Conservation) administered the grant funding for this project, and Jim Kellogg (Vermont Department of Environmental Conservation) enabled establishment of the Analytical Services Partnership to analyze the water samples at the Vermont Agriculture and Environmental Laboratory. Kendall Lambert (Memphremagog Watershed Association), Mel Lohrer (Memphremagog Watershed Association), and Tim Buzzell (Orleans County Natural Resources Conservation District) helped collect water samples. Numerous landowners graciously allowed us to sample water quality and undertook numerous restoration and protection projects on their properties. The Vermont Agency of Natural Resources supported this project financially through a LaRosa Partnership Program Volunteer Water Quality Monitoring LaRosa Organizational Support Grant (2018-WQMON-07) and LaRosa Partnership Program Volunteer Water Quality Monitoring LaRosa Analytical Services Grant. The assistance and support of all of these individuals and organizations are greatly appreciated.

Executive Summary

1. Over the past decade, there has been increasing concern about water quality conditions in Lake Memphremagog, especially the high phosphorus levels and frequent and widespread algal and cyanobacterial blooms. Because most of the lake's watershed lies in Vermont, considerable effort has been expended to identify, assess, and remediate nutrient and sediment sources along the Vermont tributaries of Lake Memphremagog. In 2018, we continued these efforts by further pinpointing and assessing possible sources of water quality problems and evaluating the success of projects and practices implemented to correct those problems. In this report, we present the data and analyses that evaluate the success of water quality improvement projects and practices that were implemented along three tributaries of Lake Memphremagog and the Tomifobia River and briefly discuss the sampling data collected along six other tributaries where phosphorus-reduction projects are currently being planned and implemented.

2. To evaluate the effectiveness of these water quality improvement projects and practices, we collected water samples for total phosphorus and total nitrogen at 35 sites on eight dates during April-October 2018. We then analyzed the resulting water quality data to evaluate whether or not these projects and practices actually led to improvements in water quality.

3. In general, water quality conditions were relatively stable or slightly improved along the three tributaries where phosphorus-reduction projects had been implemented previously. At the three sites along Brighton Brook and its northern tributary, where farmstead improvement projects and field practices were implemented during 2015-2017, decreases in total phosphorus concentrations were only statistically significant at the upstream-most site, which was located nearest to the agricultural production area and several large corn fields. In contrast, phosphorus and sediment levels remained high at several sites along the Junkyard Tributary, where field practices have been improved in several steep, highly-erodible corn fields but farmstead improvements were not initiated until October 2018. Finally, water quality conditions improved at some but not all sites along the Tributary of Stearns Brook, where numerous farmstead improvement projects and field practices were implemented during 2015-2018.

4. In addition, we collected pre-project data along six other tributaries of Lake Memphremagog and the Tomifobia River, where landowners are planning or already implementing phosphorus-reduction projects and practices on their farms. These data were then presented directly to the farmers in order to encourage them to undertake Best Management Practices and other conservation practices on their farms.

5. Collectively, these data and analyses greatly increased our understanding of water quality conditions and possible sources of water quality problems in the Lake Memphremagog and Tomifobia River Basins. In 2019, we will continue to refine our knowledge of nutrient and sediment sources along the Vermont tributaries of Lake Memphremagog and the Tomifobia River and to implement and assess on-the-ground protection and restoration projects that most effectively reduce nutrient and sediment inputs.

1.0 Introduction

Lake Memphremagog straddles the United States/Canada border between the Northeast Kingdom of Vermont and the Eastern Townships (Cantons de l'Est) of Quebec. Lake Memphremagog and its tributaries are highly-valued resources that serve important ecological, economic, and aesthetic functions. Water bodies in the basin are used extensively for boating, swimming, fishing, hunting, nature-viewing, and other recreational activities. Lake Memphremagog and the Clyde River (one of four major tributaries of Lake Memphremagog in Vermont) are important links in the Northern Forest Canoe Trail, which extends 1,191 km (740 mi) from Old Forge, New York through Vermont, Quebec, and New Hampshire to Fort Kent, Maine. Lake Memphremagog and other surface waters in the basin serve as public water supplies, provide hydroelectric power and disposal of treated wastewater, and support agricultural and industrial production. The floodplains and the many wetlands around the lake and its tributaries serve important flood control and water filtration functions and provide important fish and wildlife habitat. In addition, the surface waters and associated habitats support a number of rare plants and animals and significant natural communities, which contribute greatly to regional biodiversity.

Lake Memphremagog and its tributaries currently face a number of threats, including elevated sediment and nutrient levels, excessive algal growth, eutrophication, elevated mercury levels in walleye (*Sander vitreus*), and exotic species invasions (State of Vermont 2016, 2017b, 2018, Quebec/Vermont Steering Committee 2008). Over the past decade, there has been increasing interest in protecting and improving water quality in Lake Memphremagog and its tributaries. This interest has been spurred by concerns that water quality in Lake Memphremagog is declining and is threatened by high nutrient and sediment levels and accelerated eutrophication (Figure 1). This concern has been further exacerbated by frequent and widespread occurrences of algal and cyanobacterial (blue-green algal) blooms (Figure 2). Lake Memphremagog has been listed by the State of Vermont as impaired due to elevated phosphorus levels, nutrient enrichment, and excessive algal growth (Part D, State of Vermont 2018). In September 2017, the Environmental Protection Agency (EPA) approved a phosphorus Total Maximum Daily Load (TMDL) for Lake Memphremagog that requires a 29% reduction in phosphorus loading to the lake (State of Vermont 2017a). In addition to reductions from developed lands, forested lands, and stream channel erosion, the TMDL requires large reductions from agricultural lands, including a 46% reduction from farm fields and a 64% reduction from agricultural production areas. To promote these efforts, the Memphremagog Regional Conservation Partnership Program (RCPP) provides farmers with funding to identify, develop, and implement agricultural Best Management Practices and other phosphorus-reduction projects and practices.

Figure 1. *Turbid water and algae near the mouth of the Johns River in Derby, Vermont in 2006. Excessive nutrients and sediment increase plant and algal growth and decrease water quality.*

Figure 2. *Cyanobacterial bloom along the north shore of Derby Bay in Derby, Vermont on 23 September 2008 (photograph courtesy of Karen Lippens). Cyanobacterial blooms are exacerbated by high nutrient and sediment levels and indicate that water quality is declining in Lake Memphremagog.*

Efforts to identify and assess the various threats and to protect and improve water quality in the Lake Memphremagog Basin are coordinated by the Quebec/Vermont Steering Committee on Lake Memphremagog, an international partnership of governmental and non-governmental stakeholders from Quebec and Vermont. Since 2004, the Steering Committee has coordinated water quality monitoring efforts in both Quebec and Vermont. The overall goal of these efforts has been to identify, prioritize, implement, and evaluate projects and practices that protect and improve water quality throughout the Lake Memphremagog Basin. To that end, monitoring efforts have focused on documenting water quality conditions throughout the basin, assessing compliance with applicable water quality standards, calculating phosphorus loading in order to develop a comprehensive pollution control plan for the Vermont waters, identifying possible sources of water quality problems, identifying and prioritizing watersheds where protection and restoration projects will most effectively reduce nutrient and sediment loads, and developing and implementing on-the-ground projects and practices to protect and improve water quality. Since 71% of the Lake Memphremagog Basin lies in Vermont, many of these efforts have been focused along the Vermont tributaries of Lake Memphremagog.

2.0 Study Goals

In 2018, the Orleans County Natural Resources Conservation District (OCNRCD), Memphremagog Watershed Association (MWA), Vermont Department of Environmental Conservation (DEC), and Beck Pond LLC again partnered to undertake a multi-part program to protect and improve water quality in the Lake Memphremagog Basin as well as along Stearns Brook, a tributary of the Tomifobia River. As part of these efforts, we undertook targeted water quality sampling focused along three tributaries where phosphorus-reduction projects and practices had been implemented previously. The goal of this sampling was to evaluate the effectiveness of these projects and practices in protecting and improving water quality. In addition, we collected pre-project data along six other tributaries, where landowners are planning and/or implementing phosphorus-reduction projects through the Memphremagog Regional Conservation Partnership Program (RCPP). As in previous years, we continued to share these data and analyses with key agency and organizational partners, who were able to further evaluate the need for and develop and implement projects and practices to reduce nutrient and sediment exports into Lake Memphremagog and the Tomifobia River.

3.0 Description of Watershed

The Lake Memphremagog Basin is located in the Northeast Kingdom of Vermont and the Eastern Townships (Cantons de l'Est) of Quebec and is a tributary watershed of the Saint-François River, which ultimately flows into the St. Lawrence River. This study focused on the Vermont portion of the Lake Memphremagog Basin, which includes approximately 1,266 km^2

(489 mi^2) in Orleans, Essex, Caledonia, and Lamoille Counties in northeastern Vermont (Figure 3). The Southern Basin of Lake Memphremagog is fed by three major tributaries that lie entirely within Vermont (Barton, Black, and Clyde Rivers) and one medium-sized tributary that straddles the Quebec/Vermont border (Johns River). In addition, numerous small tributaries flow from the eastern and western shores directly into Lake Memphremagog. Lake Memphremagog is listed as impaired and has a completed and approved TMDL due to nutrient enrichment, elevated phosphorus levels, and excessive algal growth (State of Vermont 2017a; Part D, State of Vermont 2018). Lake Memphremagog has also been altered by water level fluctuations that may be altering aquatic habitats and de-watering wetlands and shoreline areas (Part F, State of Vermont 2018). Finally, Lake Memphremagog and South Bay are listed as stressed due to elevated levels of mercury in walleye (State of Vermont 2016). As noted earlier, a phosphorus TMDL was completed and approved for Lake Memphremagog in 2017 (State of Vermont 2017a).

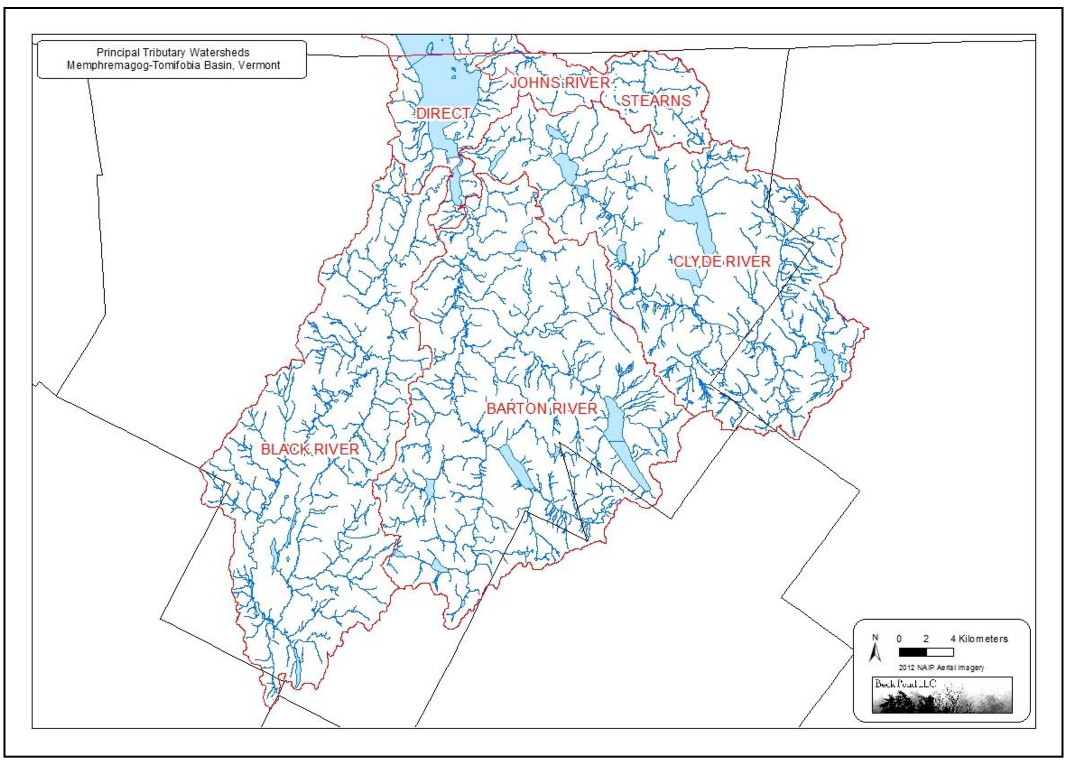


Figure 3. *Vermont portion of the Lake Memphremagog Basin, including the watersheds of the four major tributaries (Barton, Black, Clyde, and Johns Rivers), and the watershed of Stearns Brook, a tributary of the Tomifobia River.*

The Black River (Waterbody ID VT17-09/10) drains an area of 349 km^2 (135 mi^2) extending from its headwaters in the towns of Craftsbury and Greensboro downstream to the western shore of South Bay in Newport City. The watershed includes one major tributary (Lords

Creek) and several small lakes and ponds. Walker Pond in Coventry and Mud Pond in Craftsbury are listed as impaired and in need of a TMDL due to extremely elevated phosphorus levels due to agricultural influences (Part A, State of Vermont 2018). Lake Elligo has been altered by aquatic invasive species due to locally abundant Eurasian watermilfoil (*Myriophyllum spicatum*)(Part E, State of Vermont 2018). Finally, Seaver Brook has been altered by flow regulation due to the possible lack of minimum flows below a water withdrawal intake and fish passage is prevented by an associated structure (Part F, State of Vermont 2018).

The Barton River (Waterbody ID VT17-07/08) drains an area of 445 km^2 (172 mi^2) extending from its headwaters in the towns of Barton, Glover, and Westmore downstream to the south end of South Bay in the town of Coventry. This watershed includes one major tributary (Willoughby River) and several large lakes, including Lake Willoughby [657 ha (1,623 acres)] and Crystal Lake [274 ha (677 acres)]. The Barton River in Orleans is listed as stressed due to the presence of toxins (State of Vermont 2016). Roaring Brook, a tributary of the Barton River, is listed as impaired and in need of a TMDL due to elevated nutrients and impacted macroinvertebrates possibly due to agricultural runoff (Part A, State of Vermont 2018). Lake Willoughby has been altered by invasive aquatic species due to locally abundant Eurasian watermilfoil (Part E, State of Vermont 2018). Finally, Shadow Lake has been altered by seasonal water level fluctuations that may be harming aquatic habitats and aesthetics (Part F, State of Vermont 2018).

The Clyde River (Waterbody ID VT17-04) drains an area of 373 km^2 (144 mi^2) extending from its headwaters in the towns of Brighton and Morgan downstream to its mouth in Newport City. The watershed includes two major tributaries (Pherrins River and the outlet of Seymour and Echo Lakes) and numerous large lakes, including Seymour Lake [667 ha (1,648 acres)], Lake Salem [232 ha (573 acres)], and Island Pond [221 ha (546 acres)]. Lake Salem is part of an approved TMDL addressing elevated mercury levels in walleye (Part D, State of Vermont 2018). Lake Derby has been altered by aquatic invasive species due to locally abundant Eurasian watermilfoil (Part E, State of Vermont 2018). An unnamed tributary in Brighton has been altered by flow regulation due to the possible lack of minimum flows below a water supply intake (Part F, State of Vermont 2018). Finally, Clyde Pond has been listed as stressed due to elevated mercury levels in walleye (State of Vermont 2016).

The Johns River (Waterbody ID VT17-01) drains an area of approximately 29 km^2 (11 mi^2) in the towns of Derby, Vermont and Stanstead, Quebec. The Johns River is fed by Crystal Brook and several smaller tributaries and flows into Lake Memphremagog at Derby Bay, just south of the Quebec/Vermont border. The Johns River has been listed as stressed due to elevated nitrogen and turbidity levels (State of Vermont 2016). However, Crystal Brook was recently removed from the list of impaired surface waters in need of a TMDL thanks to projects that reduced sediment and nutrient inputs from agricultural runoff.

In addition, the Southern Basin of Lake Memphremagog is fed by numerous small tributary streams that flow directly into the eastern and western shores of the lake. Although small, any nutrients or sediments carried by these streams are delivered directly into and impact the health of the lake. None of these tributaries are listed as impaired or stressed (State of Vermont 2016, 2018), although high nutrient and sediment levels have been measured in several of these tributaries (Gerhardt 2009, 2010).

In 2014, we expanded this project to assess water quality conditions, to pinpoint and assess possible nutrient and sediment sources, and to work with landowners to implement phosphorus-reduction projects and practices in several small tributaries of Stearns Brook, which is a tributary of the Tomifobia River and ultimately of Lac Massawippi in Quebec. Stearns Brook (Waterbody ID VT17-02) drains an area of approximately 33 km^2 (13 mi^2) in the towns of Derby and Holland, Vermont and Stanstead-Est, Quebec. One of its tributaries is listed as impaired and in need of a TMDL due to elevated nutrients from agricultural runoff (Part A, State of Vermont 2018). Stearns Brook itself is listed as stressed due to sediment eroding from streambanks, poor logging practices, and poor road maintenance (State of Vermont 2016).

4.0 Methods

In 2018, we sampled and analyzed water quality at 35 sites along nine Vermont tributaries of Lake Memphremagog and Stearns Brook (Figure 4). These 35 sites included five sites along two tributaries of the Black River, 16 sites along three tributaries of the Barton River, two sites along one tributary of the Clyde River, and 12 sites along three tributaries of Stearns Brook. Of these 35 sites, 14 sites were sampled to assess the success of phosphorus-reduction projects and practices that had been or were being implemented along three tributaries of the Black River (Brighton Brook, 3 sites), Barton River (Junkyard Tributary, 5 sites), and Stearns Brook (Tributary of Stearns Brook, 6 sites). The remaining 21 sites were located on six tributaries where landowners were planning or already implementing phosphorus-reduction projects or practices. These 21 sites will provide the data needed to identify and prioritize the projects and practices to be implemented and to evaluate the success of these projects and practices after they are implemented.

To accomplish the goals of this study, we collected water samples on eight dates during April-October 2018. These eight dates included six regularly-scheduled sampling dates and two rain events. On each sample date, we collected water samples from each site to be analyzed for total phosphorus and total nitrogen. Samples were collected in pre-labeled, sterilized bottles according to protocols established in conjunction with the Vermont DEC and the Vermont Agriculture and Environmental Laboratory (State of Vermont 2006, 2009). At all sites, we collected grab samples with or without a dip sampler. Before collecting samples, we rinsed the total nitrogen bottles and dip sampler with sample water three times. All samples were collected on a single day, stored in coolers, and delivered to the Vermont Agriculture and Environmental Laboratory the next day or the following morning. This schedule ensured that the laboratory was able to process the samples in a timely manner.

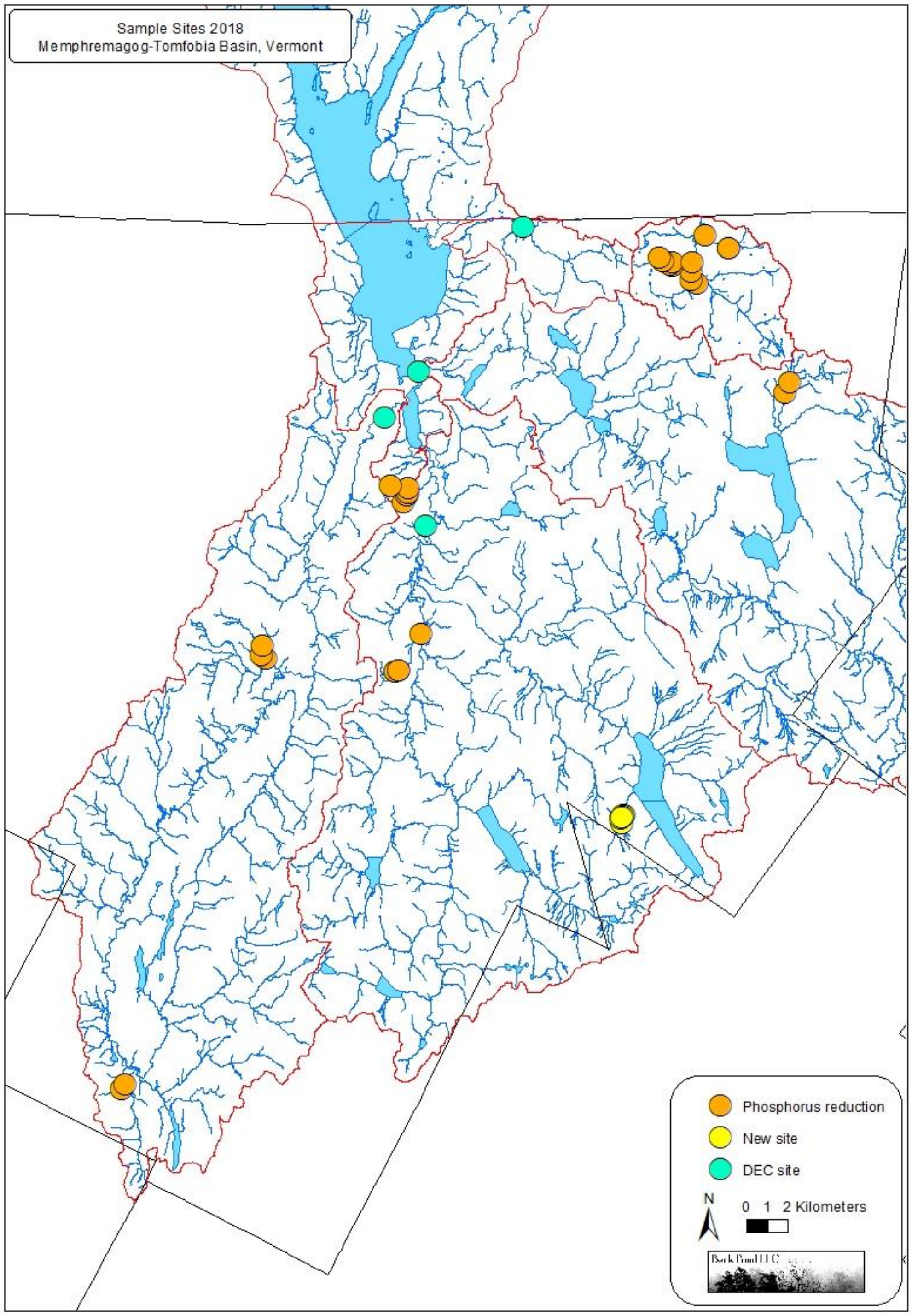


Figure 4. *Locations of 35 sample sites (plus four Vermont DEC sites) where water quality was sampled along the Vermont tributaries of Lake Memphremagog and the Tomifobia River during April-October 2018.*

Prior to sampling, we prepared a Quality Assurance Project Plan (QAPP) in conjunction with the Vermont DEC. To implement the Quality Assurance Project Plan, we collected four sets of field blanks and four sets of field duplicates on each sample date. Blank sample containers were rinsed and filled with de-ionized water and, if done properly, should result in values below the detection limits for each parameter (5 µg/l for total phosphorus and 0.1 mg/l for total nitrogen). Field duplicates required collecting a second set of samples at the same time and place as the original set of samples. When done properly, the mean Relative Percent Difference (RPD) among all pairs of duplicate samples should be less than 30% for total phosphorus and less than 20% for total nitrogen. For total phosphorus, we also collected matrix spikes at four sites on each sample date, so that the Vermont Agriculture and Environmental Laboratory could perform in-house quality assurance analyses.

To relate the water quality data to stream flows, we relied on a single source of stream flow data. The U.S. Geologic Survey (USGS) maintains gage stations that measure water depths and stream flows on the Barton, Black, and Clyde Rivers. For this study, we used the daily stream flows measured at the Black River as a proxy for stream flows at all sites, although all of our sites were located 4-30 km (2.5-18 mi) away on streams that were smaller and generally had higher gradients than the Black River.

Both field and laboratory data were entered into Microsoft Excel spreadsheets (Microsoft Home and Office 2010, Microsoft, Redmond, Washington). All data sheets and analyses were archived by the author, and the electronic data were uploaded to the Vermont DEC for inclusion in their online databases.

4.1 Statistical Analyses

To evaluate the effectiveness of the water quality improvement projects, we used linear regressions to analyze changes in water quality conditions over time. A linear regression models the relationship between two numerical variables (in this study, the sample dates and total phosphorus or total nitrogen concentrations) to determine whether or not there is a statistically-significant relationship. For all statistical tests, a P-value less than the established level of significance (0.05) indicated that the linear relationships were statistically significant. A P-value greater than 0.05 indicated that the linear relationships were not statistically significant and/or that the available data were insufficient to detect a significant difference. The latter was particularly relevant for this study, because phosphorus levels can be extremely variable, and this variability and the strong relationship between phosphorus levels and stream flows combined with small sample sizes often make it difficult to detect significant relationships, even when there are relatively large changes in mean or median values. For these parametric tests, total phosphorus and total nitrogen concentrations were $\log_{10}$-transformed to approximate a normal distribution.

5.0 Results and Discussion

5.1 Quality Assurance

This project was conducted in accordance with a Quality Assurance Project Plan developed in conjunction with the Vermont DEC. The field duplicates generally met the quality assurance standards for both total phosphorus and total nitrogen, but, unlike previous years, the field blanks often exceeded the detection limits, especially for total phosphorus (quality assurance data are presented in Appendix A). More specifically, the mean Relative Percent Differences between duplicate samples were well below the prescribed differences for both total phosphorus [10% (prescribed difference <30%)] and total nitrogen [4% (prescribed difference <20%)]. In addition, only one of the 28 pairs of total nitrogen samples and only one of the 28 pairs of total phosphorus samples exceeded the prescribed differences, and, interestingly, those two pairs of duplicate samples were collected at the same site (Middle Stearns Tributary) and on the same date (11 June 2018). In contrast, the field blanks, which indicate possible contamination during sampling, were more problematic. Three of the 30 field blanks for total nitrogen and eleven of the 30 field blanks for total phosphorus exceeded the detection limits. Eight of these total phosphorus field blanks and all three of these total nitrogen field blanks were collected on two dates (9 July and 6 August). In particular, the four total phosphorus field blanks collected on 6 August 2018 all exceeded 400 μg/l (range = 428-497 μg/l), values that greatly exceeded all of the actual sample values collected on that date (maximum = 348 μg/l). Thus, it seems likely that the problems with the field blanks were caused by contaminated de-ionized (DI) water, rather than improper sample collection and processing techniques. It should also be noted that other watershed groups in Vermont had similar problems with their field blanks in 2018. Otherwise, the quality assurance samples, including both field blanks and field duplicates, indicated that the water samples were being collected in a repeatable manner and were not being contaminated during collection or processing.

5.2 Stream Flow

Stream flow measures the volume of water passing a specific location per unit of time (usually measured as cubic feet or cubic meters per second) and is calculated by multiplying the cross-sectional area of the stream by water velocity. Stream flow affects both water quality and the quality and characteristics of aquatic and riparian habitats. For example, fast-moving streams are more turbulent and better aerated than slow-moving streams. High flows also dilute dissolved and suspended pollutants but, at the same time, typically carry more surface runoff and stormwater and the associated sediment and nutrients. Stream flow is extremely dynamic and changes frequently in response to changes in temperature, precipitation, and season.

To approximate stream flows at the sites sampled in this study, we used the daily stream flows measured for the Black River at Coventry, Vermont (USGS station 04296000). The 2018 sampling season was characterized by modestly high but prolonged peak spring flows throughout April and the first half of May (Figure 5). Subsequently, flows decreased steadily during May and were extremely low throughout the summer months (June - early September) before rising modestly in late September and October following repeated rains.

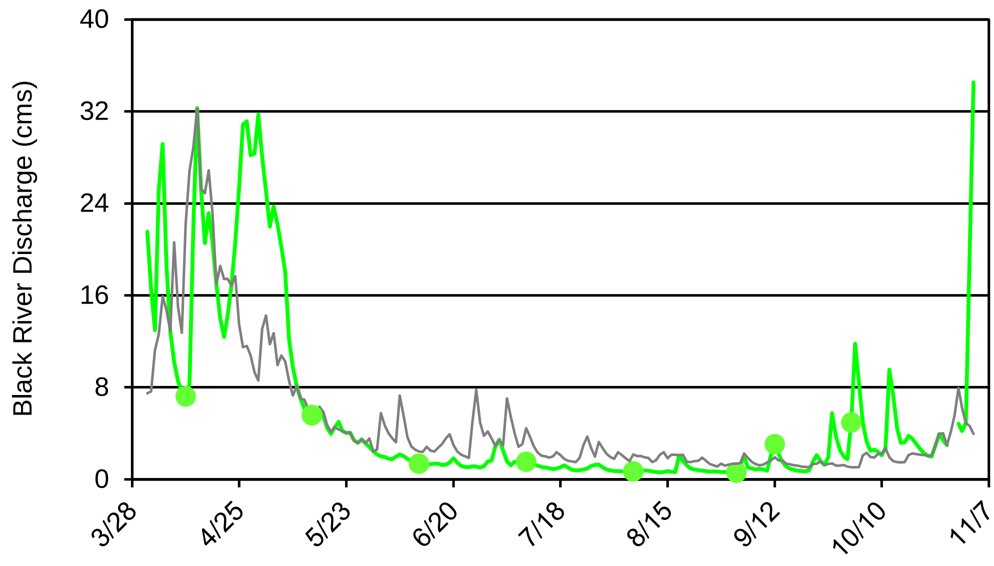


Figure 5. *Stream flows along the Black River at Coventry, Vermont during January-December 2018. Stream flows were measured by the U.S. Geological Survey (USGS station 04296000). The eight dates on which water samples were collected are indicated by green circles. The gray line indicates the median flows measured on each date during 2010-2018.*

Our sample dates largely reflected the variation in stream flows during 2018 (Figure 5). The sample dates included no high flows, five moderate flows (10 April, 14 May, 4 September, 11 September, and 2 October), and three low flows (11 June, 9 July, and 6 August). However, the last two sample dates (11 September and 2 October) were well-timed to sample two rain events, when there was considerable surface runoff during and following moderate to heavy rainfall. Collecting water samples across this range of stream flows and rain events enhanced our ability to identify and assess water quality problems, especially those affected by stream flow. Low flows were most informative for identifying and assessing nutrient and sediment inputs originating from point and groundwater sources. In contrast, moderate flows, especially during rain events, were more informative for identifying and assessing nutrient and sediment inputs originating from surface runoff and other nonpoint sources, which typically generate the majority of the nutrient and sediment loads exported from these watersheds.

5.3 Past Projects

In the sections that follow, we discuss the water quality data and analyses for three tributaries of Lake Memphremagog and the Tomifobia River where water quality improvement projects and practices were implemented previously. More specifically, we describe possible sources of water quality problems, the water quality protection and improvement projects implemented to date, the water quality data, and recommendations for future efforts to protect and improve water quality along these tributaries.

5.3.1 Brighton Brook

Brighton Brook, a tributary of the Black River, drains approximately 1,403 ha (3,466 acres) in the towns of Irasburg and Newport Town. Water quality in Brighton Brook was first sampled in 2010 and exhibited high levels of phosphorus, nitrogen, and turbidity. In subsequent years, we sampled water quality at additional sites along this stream and its tributaries to better pinpoint and assess possible nutrient and sediment sources. During 2011-2014, total phosphorus and total nitrogen concentrations were consistently high along the northern branch of Brighton Brook and extremely high in a small tributary of this northern branch. This small tributary drains an area encompassing a large agricultural production area, including barns, manure pits, silage storage bunkers, and a mortality compost pile, as well as large areas of corn and hay fields. Identifying the source(s) of the high nutrient levels in this tributary was complicated by 1) the presence of a series of small ponds and wetlands that likely store nutrients during high flows and release them during low flows in late summer, 2) the draining and filling of a large wetland formerly located in the upper watershed, and 3) the installation of drain pipes and grassed waterways in many of the corn fields and wetlands in the upper watershed. Nevertheless, following heavy rains in 2014, we were able to identify leachate from a large mortality compost pile as a likely source of nutrients flowing into the northern branch of Brighton Brook (Figure 6). Despite repeated requests to relocate and/or collect the leachate from this mortality compost pile, no actions were undertaken, and so the State of Vermont pursued an environmental enforcement action that resulted in an agreement in 2015 to correct this problem. Based on conversations with agency staff and field observations, it is our understanding that the mortality compost pile was removed slowly during 2016 and 2017.

Figure 6. *Mortality compost pile (to front and left of barns) and agricultural production area on a large farm operation along the northern branch of Brighton Brook in Irasburg, Vermont on 8 October 2013. Note the darkened ground where leachate from the mortality compost pile flowed along and puddled at the bottom of the farm road.*

During 2010-2014, we sampled water quality at seven sites along the main stem and northern branch of Brighton Brook (Table 1, Figure 7). During 2015-2018, we resampled the three downstream-most sites in order to assess whether water quality conditions had improved as a result of the corrective actions undertaken in this watershed.

Table 1. Seven sites where water quality was sampled along the main stem and northern branch of Brighton Brook during 2010-2018. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
502663	Brighton Brook	71	2010-2018
505538	Brighton Brook North	63	2011-2018
507928	Upper Brighton Brook North	35	2012-2018
508495	Lower Farm	14	2013-2014
508485	NW Pipe	15	2013-2014
508485	Northwest	1	2013
508484	Upper Northwest	3	2013

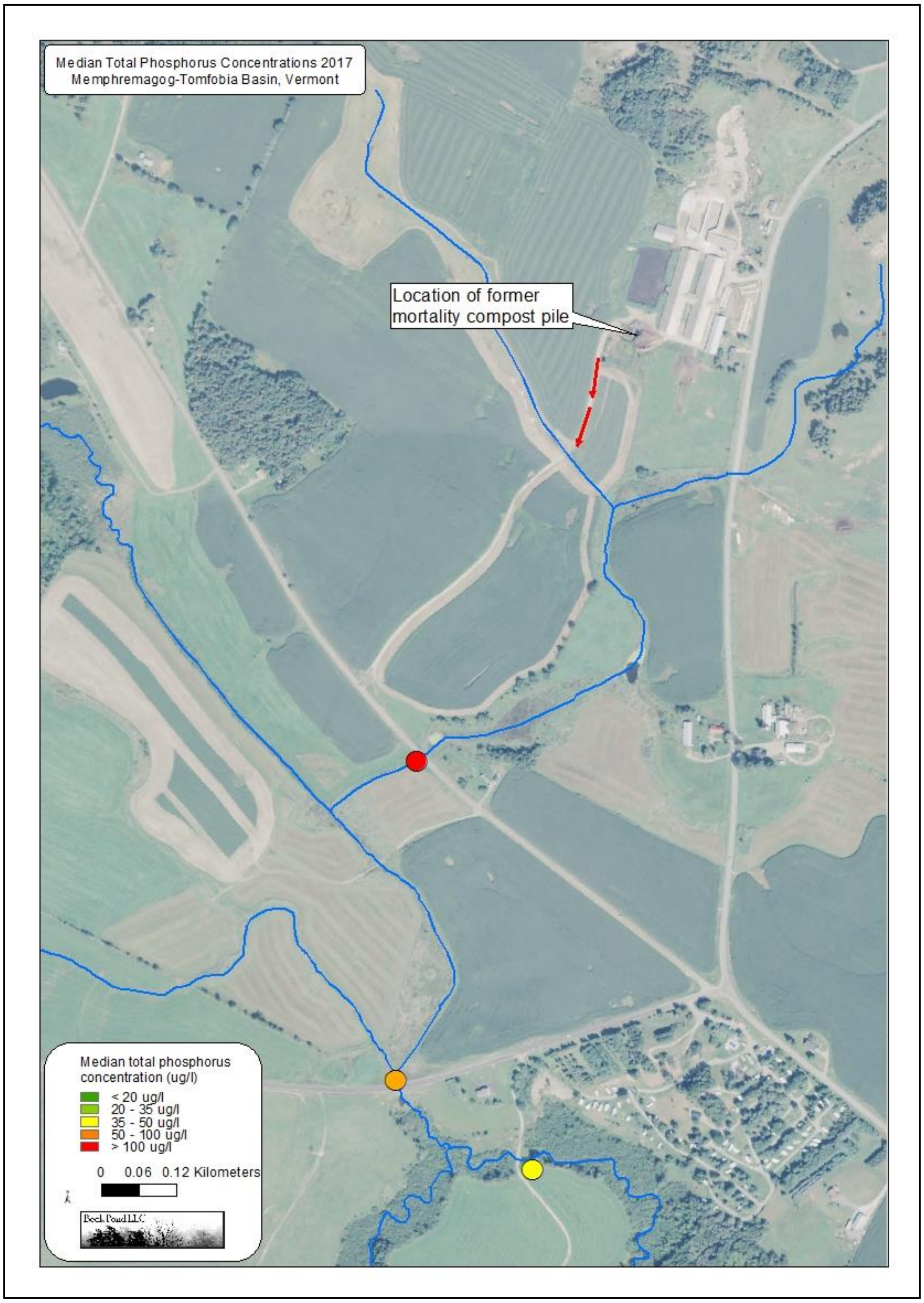


Figure 7. *Locations of three sites sampled along Brighton Brook during 2015-2018. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site. Note former location of mortality compost pile and pathway of leachate draining from the mortality compost pile during rain events (red arrows).*

As in previous years, total phosphorus concentrations were moderately high at the downstream-most site (Brighton Brook, median = 38.2 µg/l, range = 20.2-343 µg/l), markedly higher at the downstream site on the northern branch (Brighton Brook North, median = 57.3 µg/l, range = 29.5-700 µg/l), and extremely high at the upstream-most site (Upper Brighton Brook North, median = 439 µg/l, range = 184-777 µg/l). During the past nine years (2010-2018), total phosphorus concentrations have shown a statistically significant change at only the upstream-most site, Upper Brighton Brook North (Figure 8; F=5.545, df=1,33, P=0.025). At this site, mean and median total phosphorus concentrations have decreased 65-71% during 2012-2018, and no values exceeded 880 µg/l during 2016-2018 while they often exceeded that value in prior years (Figure 9). In contrast, total phosphorus concentrations at the other two sites have not shown statistically significant changes over time (Brighton Brook, F=0.153, df=1,69, P=0.697; Brighton Brook North, F=1.049, df=1,61, P=0.310).

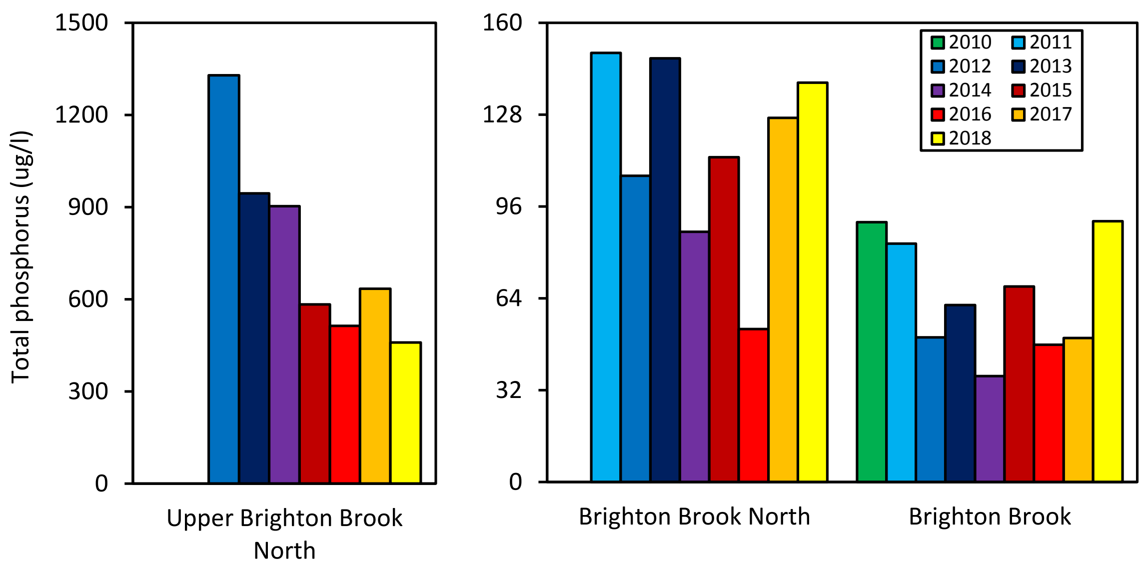


Figure 8. *Mean total phosphorus concentrations at three sites along Brighton Brook and its northern branch from Upper Brighton Brook North downstream to Brighton Brook during 2010-2018. Note the different scales on the y-axes of the two graphs.*

Similarly, total nitrogen concentrations were consistently highest at the upstream-most site (Upper Brighton Brook North, median = 4.16 mg/l, range = 1.58-6.63 mg/l). At that site, both median and mean total nitrogen concentrations decreased roughly 70% between 2011 and 2012 but have increased slightly since then (Figure 10).

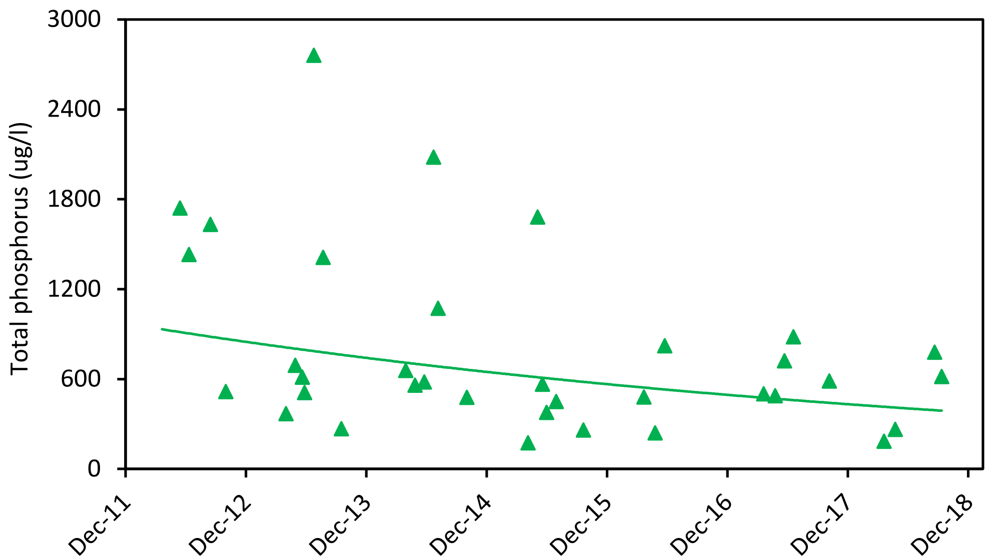


Figure 9. *Total phosphorus concentrations in relation to sample date at the Upper Brighton Brook North site during 2012-2018.*

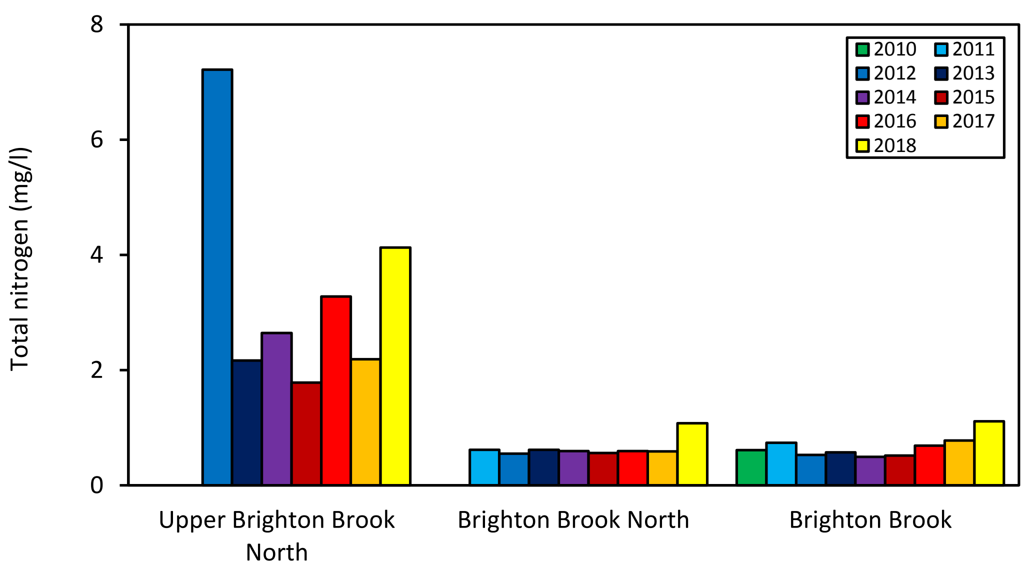


Figure 10. *Mean total nitrogen concentrations at three sites along Brighton Brook and its northern branch from Upper Brighton Brook North downstream to Brighton Brook during 2010-2018.*

Although there is reason to be optimistic that water quality conditions are improving in this tributary of the Black River, especially at the upstream-most site, these improvements are not apparent further downstream and have not consistently or significantly reduced phosphorus or nitrogen loading into the Black River. This lack of consistent and steady improvement may partly reflect the ongoing heavy use of the agricultural production area and the many large corn fields in this watershed. In addition, incidental observations along the western branch of the northern tributary during 2018 indicated that other sources of nutrients and sediment may be affecting water quality at the two downstream sites. Thus, we recommend collecting additional data and conducting additional field assessments to further evaluate other possible sources of nutrients and sediment in the Brighton Brook watershed.

5.3.2 Junkyard Tributary

The Junkyard Tributary, a small tributary of the Barton River, drains approximately 348 ha (860 acres) in the towns of Irasburg and Barton. This small tributary drains large areas of agricultural lands, almost 2 km (1.2 mi) of Interstate 91, small areas of forest, and a residential area in the village of Orleans. Water quality in this tributary was first sampled in 2012 and identified elevated phosphorus levels as an issue of concern. In 2013, we added a second site further upstream, and, in 2014, we added two additional sites on two forks of this tributary in order to better pinpoint and assess possible nutrient and sediment sources. Finally, in 2017 and 2018, we added 2-3 sites further upstream to evaluate the impacts of the Best Management Practices implemented in 2016. In 2014, staff from Vermont Agency of Agriculture, Food & Markets (VAAFM) and Vermont DEC visited a medium farm operation in this watershed to discuss water quality concerns. Subsequently, the owners developed a nutrient management plan, undertook no-till and cover-cropping on several steep corn fields, created a filter strip to capture runoff and sediment at the downhill edge of the steepest corn field, converted another corn field to hay, and widened the riparian buffer in one area (Figure 11). In October 2018, the owner initiated a project to add storage capacity and infrastructure to capture overflows from the manure pit and leachate from the silage storage bunker.

During 2012-2018, we sampled water quality at seven sites along the main stem and tributaries of the Junkyard Tributary (Table 2, Figure 12). In 2018, we resampled five sites that had been sampled in previous years in order to evaluate whether water quality conditions had improved as a result of the improved field practices.

Table 2. Seven sites where water quality was sampled along the main stem and tributaries of the Junkyard Tributary during 2012-2018. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
507929	Rock Junkyard	64	2012-2018
508527	Upper Junkyard	8	2013
510229	Route 58 Farm	48	2014-2018
510230	Route 58 Tributary	47	2014-2018
515578	Route 58 Ditch Lower	10	2017-2018
515579	Route 58 Ditch Upper	5	2017
515582	Upper Route 58 Farm	14	2017-2018

Figure 11. *Agricultural improvement projects, such as this filter strip along a small, ditched stream, have the potential to greatly improve water quality in the Lake Memphremagog Basin. Photographed in Irasburg, Vermont on 2 October 2017.*

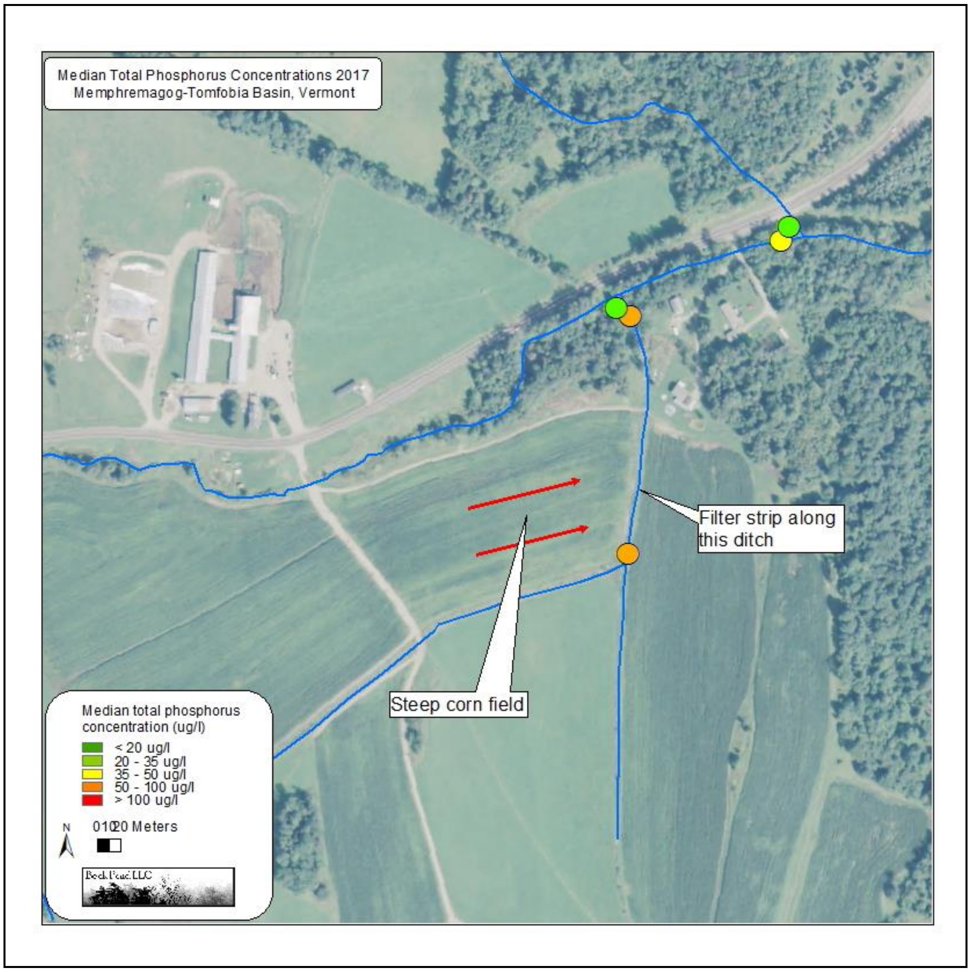


Figure 12. *Locations of seven sites sampled along the Junkyard Tributary during 2012-2018. The two downstream-most sites are located off the map to the right. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site. Note direction of flow off of steep corn field and location of filter strip installed at the start of the 2015 growing season.*

As in previous years, total phosphorus concentrations were slightly elevated at the downstream-most site (Rock Junkyard, median = 29.0 µg/l, range = 21.4-1,051 µg/l) and moderately high along the two branches of this tributary (Route 58 Farm, median = 54.4 µg/l, range = 30.9-1,350 µg/l; Route 58 Tributary, median = 50.3 µg/l, range = 27.2-836 µg/l). None of the three sites showed significant changes in total phosphorus concentrations over time during 2014-2018 (Figure 13; Rock Junkyard, F=1.201, df=1,54, P=0.278; Route 58 Farm, F=0.036, df=1,38, P=0.851; Route 58 Tributary, F=0.016, df=1,37, P=0.900). Thus, despite the improvements in field practices, no consistent improvements in phosphorus concentrations have been measured at these three sites during 2014-2018.

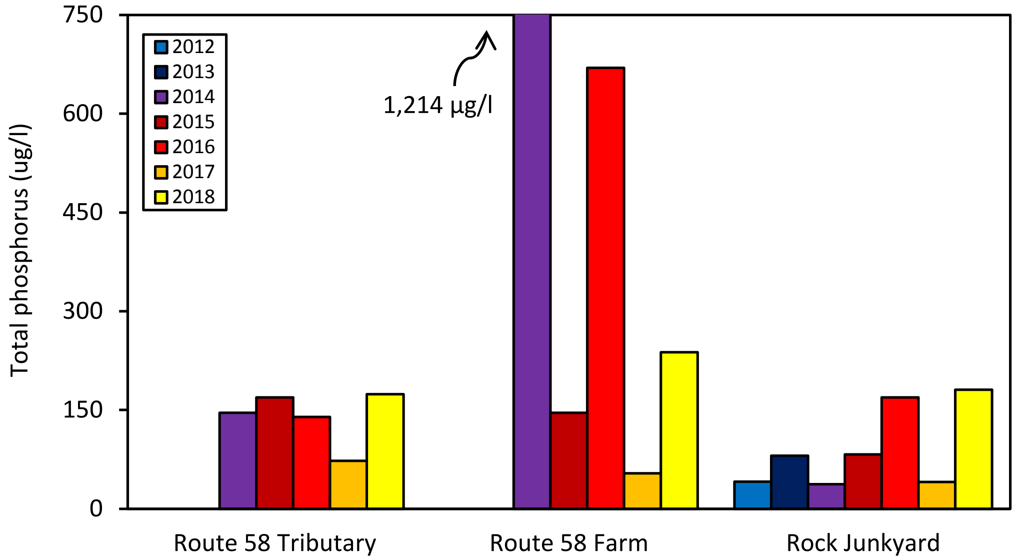


Figure 13. *Mean total phosphorus concentrations at three sites along the Junkyard Tributary from Route 58 Farm and Route 58 Tributary downstream to Rock Junkyard during 2012-2018.*

As in previous years, total nitrogen concentrations were slightly elevated at two of the three sites (Rock Junkyard, median = 1.01 mg/l, range = 0.35-6.37 mg/l; Route 58 Farm, median = 1.00 mg/l, range = 0.69-7.95 mg/l). In contrast, total nitrogen concentrations were modestly but consistently higher at the third site (Route 58 Tributary, median = 1.99 mg/l, range = 0.39-4.81 mg/l), which drained much of the agricultural production area. However, there were no consistent changes in total nitrogen concentrations at any of the three sites over time (Figure 14).

Given the prior improvements in field practices and the ongoing projects in the agricultural production area, there is reason to be optimistic that water quality conditions will improve in this tributary of the Barton River. Unfortunately, any improvements thus far have not been consistent and/or long-lasting. This lack of consistent and steady improvement may partly reflect the only recently-initiated improvements to the agricultural production area and the many corn and hay fields in this watershed. In addition, other sources of nutrients and sediment may be affecting water quality at the downstream-most site. Thus, we recommend collecting additional data and conducting additional field assessments to further evaluate other possible sources of nutrients and sediment in the watershed of this tributary, especially given the ongoing improvements to the agricultural production area.

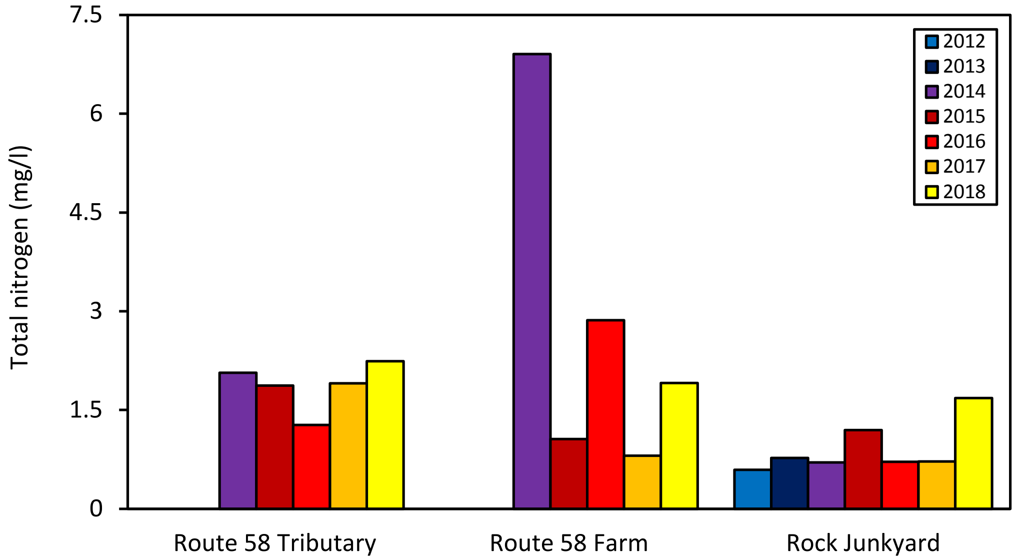


Figure 14. *Mean total nitrogen concentrations at three sites along the Junkyard Tributary from Route 58 Farm and Route 58 Tributary downstream to Rock Junkyard during 2012-2018.*

5.3.3 Tributary of Stearns Brook

This western tributary of Stearns Brook drains approximately 275 ha (679 acres) in the towns of Holland and Derby. Based on an assessment of aquatic life, the Biomonitoring and Aquatic Studies Section of the Vermont DEC designated this tributary as impaired and in need of a TMDL due to nutrients and sediment from agricultural runoff (Part A, State of Vermont 2018). Beginning in 2014, we analyzed water quality conditions along the main stem (four sites) and two smaller tributaries (two sites) in order to pinpoint and assess possible nutrient and sediment sources. In addition, whenever flows were sufficient, we sampled the outflows from two culverts and two ditches that drained the agricultural production area of a large farm operation. Based on the sampling in 2014-2015, we determined that phosphorus levels increased dramatically downstream of the two upstream sites (Upper Stearns Tributary and Stearns Tributary Falls) and upstream of the next site downstream (Middle Stearns Tributary). In addition, total phosphorus concentrations were consistently high in one of the two small tributaries (Valley Road South) and extremely high during rainfall events in the other small tributary (Twin Bridges Road). Like total phosphorus, total nitrogen concentrations increased steadily from the upstream sites down to the Middle Stearns Tributary site, but they were also extremely high in one of the two small tributaries (Twin Bridges Road). We also measured extremely high phosphorus and nitrogen levels flowing from the two culverts and two ditches that drained much of the agricultural production area. Collectively, these data suggested that much of the nutrients and sediment in this stream was originating from the agricultural production area and adjacent agricultural fields. In partnership with VAAFM and the Orleans

County Natural Resources Conservation District, the owners of this farm developed and implemented a number of water quality improvement projects and practices during 2015-2018 to divert runoff from driveways into hay fields, to divert clean water away from the barnyards and laneways, to collect contaminated runoff from the barnyards and laneways into the manure pits, and to add filter strips and cover-cropping to many of the corn fields (Figure 15).

During 2014-2018, we sampled water quality at eleven sites along the main stem and tributaries of the Tributary of Stearns Brook (Table 3, Figure 16). In 2018, we resampled six sites along the main stem and two small tributaries in order to evaluate the success of the farmstead projects and improvements to field practice undertaken by the large farm operation.

Table 3. Eleven sites where water quality was sampled along the main stem and tributaries of the Tributary of Stearns Brook during 2014-2018. Sites are ordered from downstream to upstream.

Location ID	Site Name	# Dates Sampled	Years Sampled
501642	Lower Stearns Tributary	40	2014-2018
510234	Twin Bridges Road	34	2014-2018
510251	Valley Road South	37	2014-2018
510222	Middle Stearns Tributary	40	2014-2018
515583	Valley Road Ditch	10	2015-2016
515585	Valley Road Pipe	3	2016
515584	Valley Road Garage	4	2015-2016
515577	Lower Barnyard Culvert	19	2014-2017
515581	Upper Barnyard Culvert	19	2014-2017
510233	Stearns Tributary Falls	40	2014-2018
510235	Upper Stearns Tributary	40	2014-2018

Figure 15. *The large farm along the Tributary of Stearns Brook undertook numerous clean water diversion and runoff control projects during 2015-2018 to improve water quality conditions in the Tributary of Stearns Brook. The top photograph shows a barnyard area on 3 July 2015, and the bottom photograph shows the same area during construction of a barrier to separate clean and contaminated water on 28 September 2015 (bottom photograph courtesy of Ben Copans).*

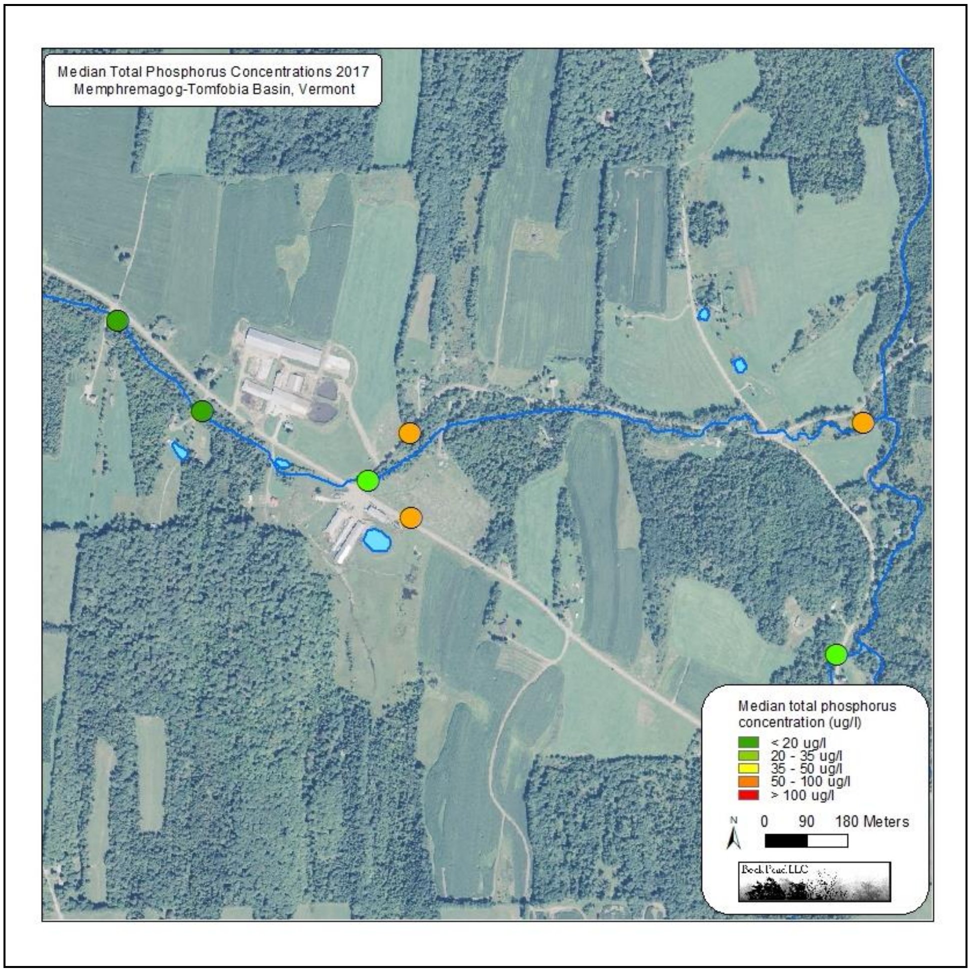


Figure 16. *Locations of eleven sites sampled along the Tributary of Stearns Brook during 2014-2018. The sample sites are color-coded according to the median total phosphorus concentrations measured at each site.*

The six sites differed in patterns of total phosphorus concentrations over time during 2014-2018 (Figure 17). At the two upstream sites (Upper Stearns Tributary and Stearns Tributary Falls), total phosphorus concentrations remained low and fairly stable across all five years. Although not statistically significant (F=3.546, df=1,38, P=0.067), total phosphorus concentrations tended to decrease at the Middle Stearns Tributary site during 2014-2018 (Figure 18). At the downstream-most site (Lower Stearns Tributary), mean total phosphorus concentrations did not change over time (F=0.051, df=1,38, P=0.822). In part, the general increase in phosphorus concentrations between the Middle Stearns Tributary and Lower Stearns Tributary sites may reflect the fact that total phosphorus concentrations remained unchanged or even increased in the two small tributaries (Twin Bridges Road and Valley Road South) that flow into the Tributary of Stearns Brook between the Middle and Lower Stearns Tributary sites.

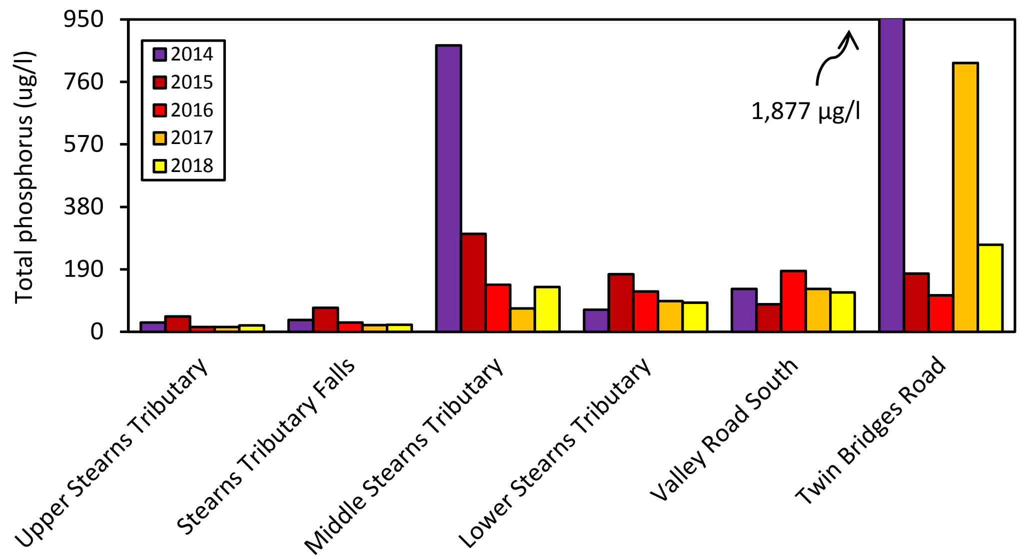


Figure 17. *Mean total phosphorus concentrations at six sites along the Tributary of Stearns Brook from Upper Stearns Tributary downstream to Lower Stearns Tributary during 2014-2018.*

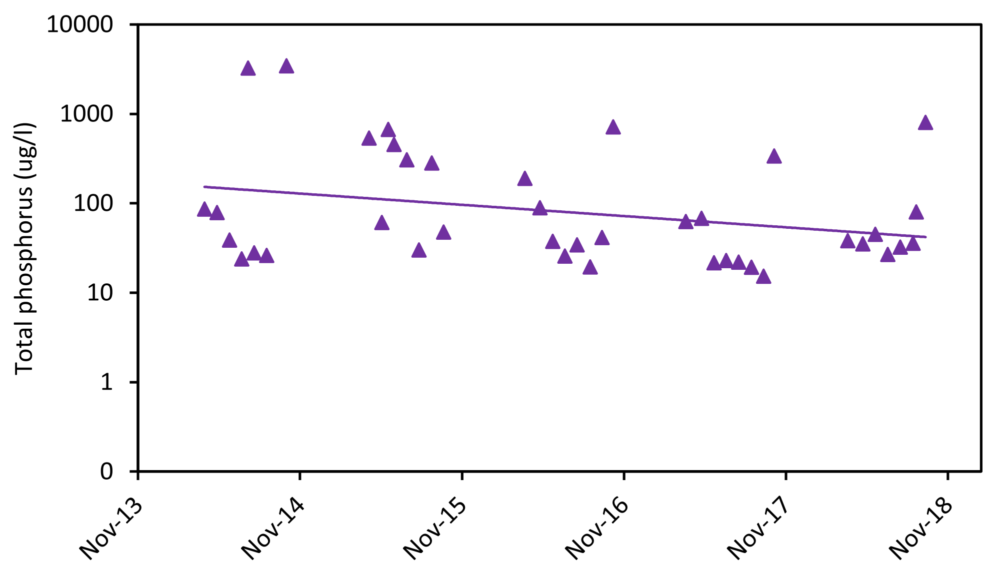


Figure 18. *Total phosphorus concentrations in relation to sample date at the Middle Stearns Tributary site during 2014-2018. Note logarithmic scale on y-axis.*

In contrast to total phosphorus, total nitrogen concentrations remained high and relatively stable at all sites, except Valley Road South where total nitrogen concentrations have remained consistently low (Figure 19).

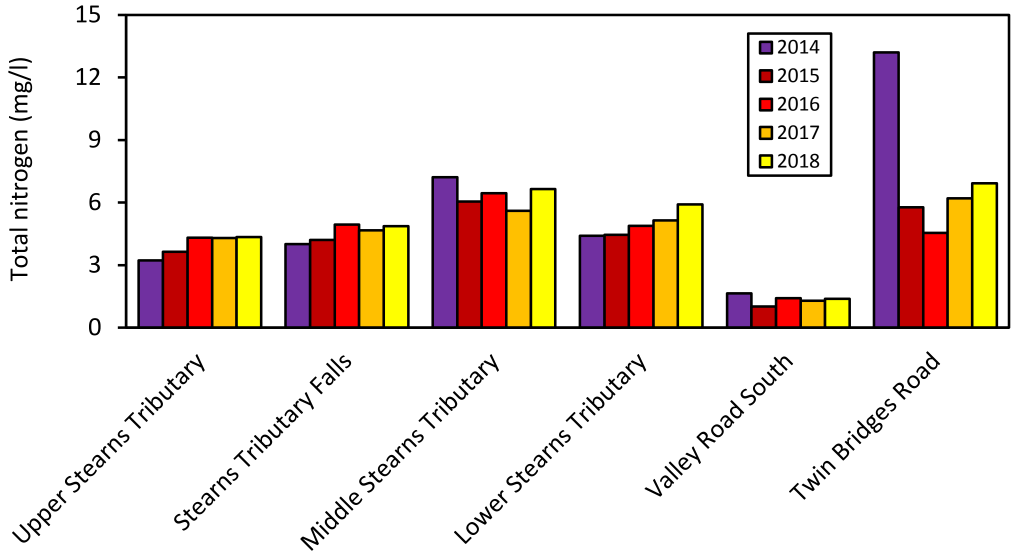


Figure 19. *Mean total nitrogen concentrations at six sites along the Tributary of Stearns Brook from Upper Stearns Tributary downstream to Lower Stearns Tributary during 2014-2018.*

Based on these results, the projects and practices undertaken by the large farm operation appear to have improved water quality somewhat in the Tributary of Stearns Brook. Improvements in water quality were most evident at the Middle Stearns Tributary site, which is located just downstream of the majority of the agricultural production area. In contrast, water quality remains poor in the two small tributaries that flow into the Tributary of Stearns Brook further downstream. Thus, we recommend sampling all of these sites again in 2019 to further evaluate the success of the ongoing water quality improvement projects and practices, especially those implemented during 2017 and 2018.

5.4 New Projects

In addition to assessing the effectiveness of projects and practices that were already implemented along those three tributaries, we also sampled water quality at 21 sites along six other tributaries where landowners were proposing to or already undertaking phosphorus-reduction projects and practices through the Memphremagog Regional Conservation Partnership Program (RCPP). The data collected at these 21 sites will help to identify and prioritize the numerous phosphorus-reduction projects and practices being planned and/or implemented along these six tributaries (Table 4). Once these projects and practices are implemented, we will continue to measure water quality conditions, so that we can use the pre- and post-project data to evaluate the success of these projects and practices in improving water quality conditions. As part of these efforts, we will summarize and present these data to each of the six landowners to assist them in planning and implementing projects and practices to protect and improve water quality in these tributary watersheds. As part of this outreach, we will prepare handouts that summarize the water quality data, describe the key results, recommend key projects and/or practices (or the need for further evaluation), and make recommendations for future water quality sampling (see sample handout in Appendix B).

Table 4. Phosphorus-reduction projects and practices being planned or implemented through the Memphremagog Regional Conservation Partnership Program (RCPP) along six tributaries of Lake Memphremagog and the Tomifobia River during 2018.

Project or Practice	# Farms
Stormwater mapping and management	3
Manure storage improvements	4
Silage storage improvements, including leachate collection	2
Cover-cropping	3
Grass filter strips and critical area seedings	2
Ditch and stream buffers and livestock-exclusion fencing	4
Stream crossing improvements	2
Farm and town road improvements	2

6.0 Conclusions

The water quality sampling in 2018 succeeded in collecting the data needed to assess the success of the water quality improvement projects and practices implemented along three tributaries of Lake Memphremagog and the Tomifobia River. However, our analyses also indicated that additional sampling is needed to conclusively confirm the success of these projects and practices and that additional projects and practices are still needed to protect and improve water quality along all three tributaries. Collecting additional data are particularly important in allowing us to evaluate the success of ongoing and future projects and practices, especially given the inherently high variability in total phosphorus concentrations and the strong relationship between total phosphorus concentrations and stream flow.

Brighton Brook - During 2010-2015, our sampling indicated that nutrient and sediment levels were extremely high in this tributary of the Black River. Furthermore, the sampling in 2014 confirmed that leachate flowing from a mortality compost pile at a large farm operation was a major source of the high phosphorus, nitrogen, and turbidity levels. In 2018, we continued to sample water quality at three sites to assess whether the corrective actions had been successful in improving water quality in this tributary. These updated data indicated that total phosphorus concentrations have decreased significantly at the upstream-most site. In contrast, no significant changes in phosphorus concentrations were detected at the two downstream sites, and incidental observations while sampling during one of the rain events indicated that high sediment and possibly high nutrient levels were flowing out of the western branch of the northern tributary.

Thus, additional sampling and/or field surveys are needed to identify and assess other possible source(s) of nutrients and sediment in this watershed.

Junkyard Tributary - Our sampling during 2012-2018 allowed us to further pinpoint and assess possible sources of the high nutrient and sediment levels in the two upstream branches of this tributary of the Barton River. Despite numerous improvements in field practices, the 2016-2018 data did not show any clear and consistent improvements in water quality along this tributary. However, in October 2018, the owner of a medium farm operation in this watershed began a major project to improve stormwater runoff and manure and silage storage in an agricultural production area. Thus, we recommend resampling all five sites in 2019 in order to assess the water quality benefits of these latest agricultural improvements.

Tributary of Stearns Brook - Our sampling during 2014-2018 indicated that nutrient and sediment levels were very high in this tributary of Stearns Brook, especially along the main stem and two small tributaries draining a large farm operation. During 2015-2018, the owners of the large farm operation undertook numerous farmstead improvement and clean water diversion projects. Following these improvements, water quality conditions have improved significantly at the site located immediately downstream of the majority of the agricultural production area but did not improve further downstream below the confluences of two smaller tributaries. Thus, we recommend resampling all six sites in 2019 in order to further evaluate the success of these projects as well as the additional projects and practices undertaken during 2017-2018.

In 2019, we recommend continuing to use the water quality data and other analyses to identify, prioritize, and develop projects and practices that will most effectively improve water quality and to evaluate the success of previously-implemented projects and practices along the Vermont tributaries of Lake Memphremagog and the Tomifobia River. In addition, we will continue to work with farmers and other landowners to develop and implement phosphorus-reduction projects and practices through the Memphremagog Regional Conservation Partnership Program (RCPP). As part of these efforts, we will continue to coordinate our efforts with those of other key partners to pinpoint and assess possible sources of water quality problems and to develop and implement projects and practices to correct those problems. In addition, an additional year of water quality data will increase the robustness of our statistical analyses and will allow us to better evaluate the success of previously-implemented projects and practices along these and other tributaries of Lake Memphremagog and the Tomifobia River.

7.0 Bibliography

Gerhardt, F. 2009. *Restoring Water Quality in the Lake Memphremagog Basin: Nutrient and Sediment Sources along the Johns River and Seven Smaller Tributaries*. Memphremagog Watershed Association, Newport, Vermont.

Gerhardt, F. 2010. *Restoring Water Quality in the Lake Memphremagog Basin: Phosphorus and Nitrogen Levels along the Johns River and Seven Smaller Tributaries*. Beck Pond LLC, Newark, Vermont.

Quebec/Vermont Steering Committee. 2008. *The Water Quality of Lake Memphremagog: Results of the Joint Quebec-Vermont Water Quality Monitoring Initiative and Recommendations for Strategy Development*. Quebec/Vermont Steering Committee on Lake Memphremagog, Newport, Vermont and Magog, Quebec.

State of Vermont. 2006. *Water Quality Division Field Methods Manual*. Vermont Department of Environmental Conservation, Waterbury, Vermont.

State of Vermont. 2009. *A Guide to Analytical Laboratory Services*. Vermont Department of Environmental Conservation, Waterbury, Vermont.

State of Vermont. 2016. *Stressed Waters List*. Vermont Department of Environmental Conservation, Montpelier, Vermont.

State of Vermont. 2017a. *Lake Memphremagog Phosphorus Total Maximum Daily Load*. Vermont Department of Environmental Conservation, Montpelier, Vermont.

State of Vermont. 2017b. *Basin 17 Lake Memphremagog, Tomifobia and Coaticook Tactical Basin Plan*. Vermont Agency of Natural Resources, Montpelier, Vermont.

State of Vermont. 2018. *303(d) List of Impaired Waters*. Vermont Department of Environmental Conservation, Montpelier, Vermont.

Appendix A. Quality assurance data, including field blanks and field duplicates, collected at 35 sample sites along the Vermont tributaries of Lake Memphremagog and the Tomifobia River during April-October 2018. Bold values indicate field blanks that exceeded detection limits (5 µg/l for total phosphorus and 0.1 mg/l for total nitrogen) or field duplicates that differed by >30% for total phosphorus and >20% for total nitrogen.

Field Blanks

Site	Date	Total Nitrogen (mg/l)	Total Phosphorus (µg/l)
Brighton Brook	4/10/2018	<0.1	<5
LBartonT Lower	4/10/2018	<0.1	<5
Tice Mill Trib Upper	4/10/2018	<0.1	**5.8**
Upper Stearns Tributary	4/10/2018	<0.1	<5
Brighton Brook North	5/14/2018	<0.1	<5
Stearns Tributary Falls	5/14/2018	<0.1	<5
Tice Mill Trib Lower	5/14/2018	<0.1	<5
LBartonT Field Upper	6/11/2018	<0.1	<5
Middle Stearns Tributary	6/11/2018	<0.1	<5
Route 58 Farm	6/11/2018	<0.1	<5
Tice Mill	6/11/2018	<0.1	<5
Brighton Brook	7/9/2018	<0.1	**5.69**
Lakeview Big Valley	7/9/2018	<0.1	**15.2**
Lower Stearns Tributary	7/9/2018	<0.1	**12.6**
Upper Stearns Tributary	7/9/2018	**0.13**	**7.65**
Brighton Brook North	8/6/2018	<0.1	**436**
East Stearns Tributary	8/6/2018	**0.2**	**497**
Lakeview Wheeler Mountain	8/6/2018	**0.24**	**490**
Stearns Tributary Falls	8/6/2018	<0.1	**428**
Lakeview Big Valley	9/4/2018	<0.1	<5
Sucker North Driveway	9/4/2018	<0.1	<5
Tice Mill	9/4/2018	<0.1	<5
Brighton Brook	9/11/2018	<0.1	**7.99**
LBartonT Lower	9/11/2018	<0.1	<5
Tice Mill Trib Upper	9/11/2018	<0.1	<5
Upper Stearns Tributary	9/11/2018	<0.1	<5
Brighton Brook North	10/2/2018	<0.1	<5
Lower Stearns Tributary	10/2/2018	<0.1	<5
Rock Junkyard	10/2/2018	<0.1	<5
Sucker North Pasture	10/2/2018	<0.1	**8.63**

Field Duplicates

Total Nitrogen

Site	Date	1st Total Nitrogen (mg/l)	2nd Total Nitrogen (mg/l)	Relative % Difference
Brighton Brook	4/10/2018	1.05	1.03	2
LBartonT Lower	4/10/2018	2.37	2.39	1
Tice Mill Trib Upper	4/10/2018	3.18	3.21	1
Upper Stearns Tributary	4/10/2018	4.69	4.77	2
Brighton Brook North	5/14/2018	0.43	0.41	5
Stearns Tributary Falls	5/14/2018	5.42	5.43	0
Tice Mill Trib Lower	5/14/2018	3.95	4.11	4
LBartonT Field Upper	6/11/2018	0.75	0.67	11
Middle Stearns Tributary	**6/11/2018**	**7.87**	**6.47**	**20**
Route 58 Farm	6/11/2018	1.28	1.39	8
Tice Mill	6/11/2018	2.03	1.99	2
Brighton Brook	7/9/2018	0.91	0.91	0
Lakeview Big Valley	7/9/2018	0.29	0.26	11
Lower Stearns Tributary	7/9/2018	8.75	8.8	1
Upper Stearns Tributary	7/9/2018	5.56	5.6	1
Brighton Brook North	8/6/2018	0.68	0.66	3
Lakeview Wheeler Mountain	8/6/2018	0.72	0.67	7
Stearns Tributary Falls	8/6/2018	5.64	5.74	2
Lakeview Big Valley	9/4/2018	0.27	0.27	0
Sucker North Driveway	9/4/2018	0.25	0.25	0
Brighton Brook	9/11/2018	1.6	1.6	0
LBartonT Lower	9/11/2018	6.55	6.55	0
Tice Mill Trib Upper	9/11/2018	0.88	0.88	0
Upper Stearns Tributary	9/11/2018	2.64	2.8	6
Brighton Brook North	10/2/2018	3.4	3.56	5
Lower Stearns Tributary	10/2/2018	3.06	3.42	11
Rock Junkyard	10/2/2018	6.37	6.37	0
Sucker North Pasture	10/2/2018	0.35	0.36	3
Mean				**4**

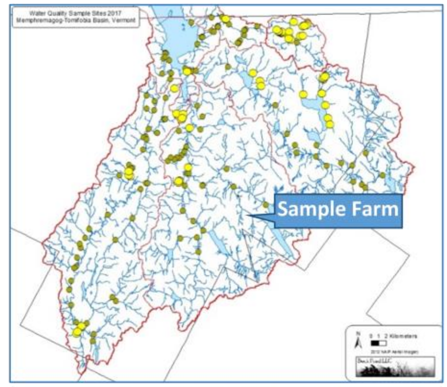
Total Phosphorus

Site	Date	1st Total Phosphorus (µg/l)	2nd Total Phosphorus (µg/l)	Relative % Difference
Brighton Brook	4/10/2018	23.5	23.7	1
LBartonT Lower	4/10/2018	85.6	83.4	3
Tice Mill Trib Upper	4/10/2018	34.3	36.2	5
Upper Stearns Tributary	4/10/2018	8.36	7.98	5
Brighton Brook North	5/14/2018	36.2	32.4	11
Stearns Tributary Falls	5/14/2018	9.32	8.84	5
Tice Mill Trib Lower	5/14/2018	28.7	31.3	9
LBartonT Field Upper	6/11/2018	50.1	46.1	8
Middle Stearns Tributary	**6/11/2018**	**45**	**13.2**	**109**
Route 58 Farm	6/11/2018	37.8	44.7	17
Tice Mill	6/11/2018	14.8	14.4	3
Brighton Brook	7/9/2018	39.8	40.4	1
Lakeview Big Valley	7/9/2018	15.3	15.8	3
Lower Stearns Tributary	7/9/2018	44.7	44	2
Upper Stearns Tributary	7/9/2018	17.3	21.4	21
Brighton Brook North	8/6/2018	62.9	55	13
East Stearns Tributary	8/6/2018	39.5	37.3	6
Lakeview Wheeler Mountain	8/6/2018	34.6	35	1
Stearns Tributary Falls	8/6/2018	11.4	12.3	8
Lakeview Big Valley	9/4/2018	16.8	16.7	1
Sucker North Driveway	9/4/2018	9.12	9.22	1
Brighton Brook	9/11/2018	159	163	2
LBartonT Lower	9/11/2018	324	348	7
Tice Mill Trib Upper	9/11/2018	30.1	30.2	0
Upper Stearns Tributary	9/11/2018	44.4	36.6	19
Brighton Brook North	10/2/2018	700	660	6
Lower Stearns Tributary	10/2/2018	306	305	0
Rock Junkyard	10/2/2018	1051.5	1062	1
Sucker North Pasture	10/2/2018	20.3	24.4	18
Mean				**10**

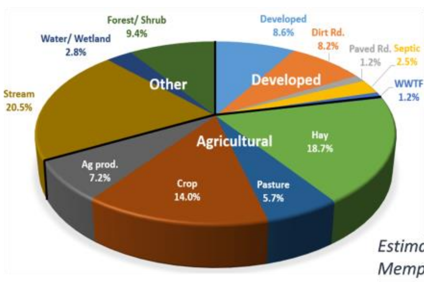
Appendix B. Sample farm handout that is being used to present water quality data and recommendations to landowners.

2018 Sample Water Quality Summary Report

Introduction: Phosphorus is a water quality concern in the Lake Memphremagog and Tomifobia watersheds, because elevated levels of phosphorus have caused increased plant and algae growth in Lake Memphremagog and Lake Massawippi. Phosphorus levels have also been increasing in eleven other lakes in these watersheds. Phosphorus and sediment runoff into Roaring Branch in Barton and a tributary to Stearns Brook in Holland have caused the impairment of biological conditions in those streams as well.



Watershed sampling map: Over 190 sites have been sampled since 2005, including 35 sites in 2018.



Estimates of phosphorus loading to Lake Memphremagog from land uses across the watershed.

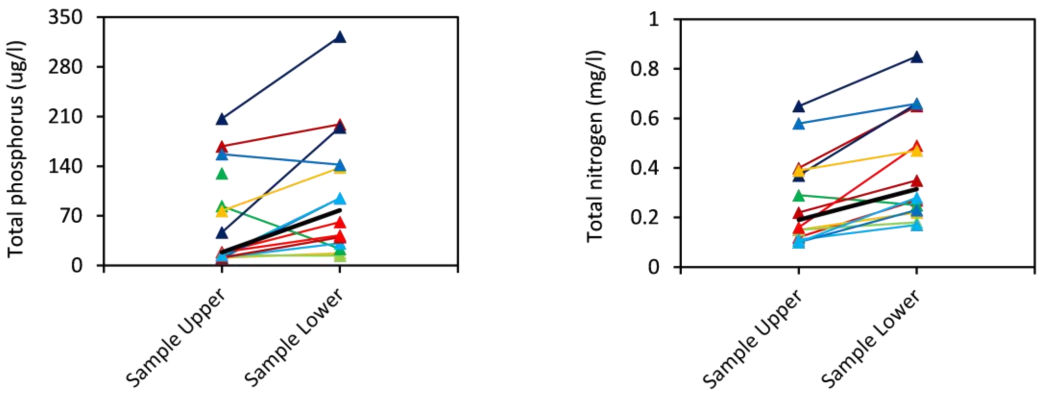
A phosphorus cleanup plan for Lake Memphremagog (or TMDL) was approved in 2017 and includes a 46% load reduction from agricultural lands in addition to load reductions from streambanks, forest lands, waste water, and developed lands to meet phosphorus targets in the lake. To address these issues, state and local nonprofit groups have cooperated on a water quality sampling program since 2005 to identify sources of nutrient runoff and to develop and implement phosphorus-reduction projects through the Memphremagog Regional Conservation Partnership Program (RCPP).

The intended use of this document is to relay findings to individual farmers to inform and recommend management practices to improve water quality. If needed, state and federal funding is available to provide technical and financial support to farmers to implement projects and practices. Following installation, water quality sampling will continue in order to assess improvements in water quality conditions. This pre- and post-project sampling has measured significant nutrient runoff reductions in several cases, has been highlighted in our farmer success story publications, and has helped to inform TMDL modeling to better estimate load reductions to the lake based on local watershed data.

Process and Methods: In 2018, we sampled water quality in streams flowing through nine farms. Water quality was first sampled along Sample Brook near its mouth in 2010, and two additional sites (Sample Upper and Sample Lower) were added along the small northern tributary of this stream that flows through Sample Farm in 2017. Water quality was sampled on eight dates in both 2017 and 2018. Twelve of these sample dates occurred on regularly-scheduled dates four weeks apart during April-October, and four sample dates targeted snowmelt and rain events to evaluate water quality during runoff conditions when phosphorus levels tend to be highest. We collected samples for total phosphorus

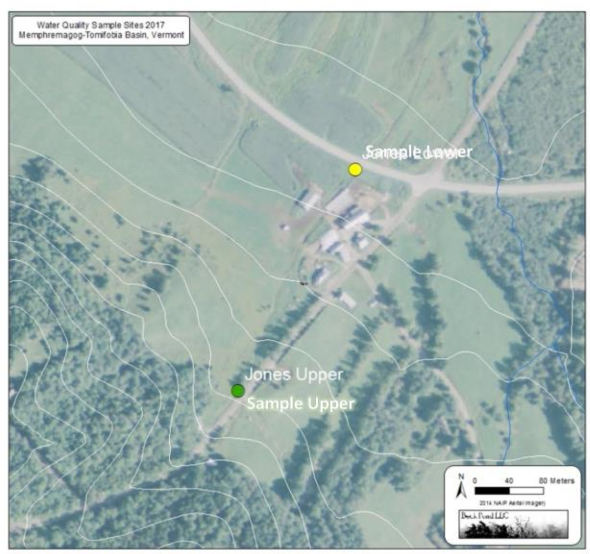
Sampling Results:

- **Total phosphorus concentrations, which increased from the upper to the lower site on all but two sample dates, were almost twice as high on average at the lower than the upper site. Phosphorus concentrations at the lower site were consistently high during snowmelt and following heavy rains. Average concentrations at the lower site during low to moderate flow conditions were almost four times as high as the State of Vermont phosphorus criteria of 12 ug/l.**
- **Total nitrogen concentrations, which often indicate the presence of manure or silage leachate, were generally low on all sample dates but consistently increased from the upper to the lower site.**
- **The pasture, including some areas that receive heavy use, and agricultural production area were identified as possible sources of nutrients along this stream.**



Total phosphorus and nitrogen "profiles" from the upper to lower sites along the tributary of Sample Brook during April-October 2017-2018. Lines and symbols represent total phosphorus or total nitrogen concentrations at the two sites on each sample date.

Recommendations and Next Steps:



Coordinate with the Orleans County Natural Resources Conservation District and/or other federal, state, and local partners and the Regional Conservation Partnership Program to identify, develop, and implement projects and practices that will benefit both water quality and farm operations. These projects and practices might include:

1. Livestock exclusion fencing
2. Riparian buffers or filter strips
3. Stream crossings
4. Improved manure storage

Once projects or practices are installed, we recommend collecting two additional years of water quality data in order to evaluate the water quality benefits of these projects and practices. These additional data can also be used to complete a success story publication.

THANK YOU FARMERS FOR YOUR PARTICPATION IN THIS PROGRAM TO PROVIDE IMPORTANT WATER QUALITY DATA. This document will only be shared with the Sample Farm and non-regulatory water sampling staff (OCNRCD staff, VTDEC watershed coordinator, and Beck Pond LLC).

Memphremagog Watershed Association

P. O. Box 1071
Derby, VT 05829

memphremagogwatershedassociation.com

Orleans County Natural Resources Conservation District

59 Waterfront Plaza
Newport, VT 05855

https://www.vacd.org/conservation-districts/orleans-county/

Beck Pond LLC

394 Beck Pond Road
Newark, VT 05871

beckpond@gmail.com