Lake Champlain Long-Term Water Quality and Biological Monitoring Program

Summary of Program Activities During 2016

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Purpose of Report

The workplan for the Lake Champlain Long-Term Water Quality and Biological Monitoring Program approved by the Lake Champlain Basin Program specifies the following annual reporting requirements:

An annual report will consist of a summary of the history and purpose of the (program), description of the sampling network, summary of field sampling and analytical methods, parameter listings, and data tables. The purposes of this annual report will be achieved by maintaining an up-to-date Program Description document, graphical presentations of the data, and an interactive database, including statistical summaries, on the project website…… In addition, the quarterly report produced in April each year will provide a summary of program accomplishments for the calendar year just ended, including the number of samples obtained and analyzed at each site by parameter.

The Program Description document, interactive access to the project data, and graphical and statistical summaries of the data are available on the program webpage. The purpose of this report is to provide a summary of sampling activities and other accomplishments during 2016.

Sampling Activities During 2016

Table 1 lists the number of sampling visits to each lake and tributary station in relation to the target frequencies specified in the project work plan. Table 2 lists the number of samples collected and analyzed for each monitoring parameter. The New York lake and tributary field sampling was conducted by the Lake Champlain Research Institute at SUNY Plattsburgh under an MOU between NYSDEC and SUNY.

The frequency of lake sampling exceeded workplan targets at all stations during 2016. The frequency of tributary sampling was below the workplan targets for all stations due to a dry summer and fall. The number of tributary samples obtained each year depends to some extent on the number and timing of high flow events, since sampling is geared toward capturing the highest flow conditions when loading of phosphorus and other materials is greatest. There is little value in obtaining more samples under low or moderate flow conditions simply to meet workplan targets since low flow data do not contribute significantly to improving the precision of annual loading estimates. Figure 1 shows that sampling at each tributary captured most peak flow events during 2016.

Table 1. Number of sampling visits during 2016 at each lake and tributary station in comparison with workplan targets.

Number of Lake Sampling Visits					**Number of Tributary Sampling Visits**				
Lake Station	**NY**	**VT**	**Total**	**Workplan Target**[1]	**Tributary Station**	**Crew**	**All Parameters** TP, DP, TSS, Cl, TN	**Total Phosphorus**	**Workplan Target**[2]
2	8	8	16	12	AUSA01	NY	10	12	14/17
4	8	9	17	12	BOUQ01	NY	11	13	14/17
7	10	9	19	12	GCHA01	NY	11	13	14/17
9	10	9	19	12	LAMO01	VT	10	14	14/17
16	10	9	19	12	LAPL01	VT	10	15	14/17
19	10	9	19	12	LAUS01	NY	11	13	14/17
21	10	9	19	12	LCHA01[3]	NY	11	13	14/17
25	10	10	20	12	LEWI01	VT	10	15	14/17
33	10	8	18	12	LOTT01	VT	10	15	14/17
34	10	8	18	12	METT01	VT	9	11	14/17
36	10	9	19	12	MISS01	VT	10	15	14/17
40	10	9	19	12	OTTE01	VT	10	15	14/17
46	10	6	16	12	PIKE01	VT	9	10	14/17
50	9	8	17	12	POUL01	VT	9	11	14/17
51	9	8	17	12	PUTN01[4]	VT	0	0	14/17
					ROCK02	VT	9	13	14/17
					SALM01	NY	11	13	14/17
					SARA01	NY	11	13	14/17
					WINO01	VT	11	16	14/17
					JEWE02	VT	10	15	14/17
					STEV01	VT	10	15	14/17
					MILL01	VT	10	15	14/17

[1] Workplan target for lake sampling (12) applies to most chemical parameters and to phytoplankton, zooplankton, and zebra mussel veligers. Sampling for zebra mussel juveniles in Lake Champlain and for veligers in tributaries and inland lakes is done once annually.

[2] The project workplan calls for 14 samples per year for most chemical parameters, including 10 samples at high flow and four samples at low flow. Additional sampling for total phosphorus only should occur on 3 other dates under high flow conditions, for a target of 17 samples per year for total phosphorus.

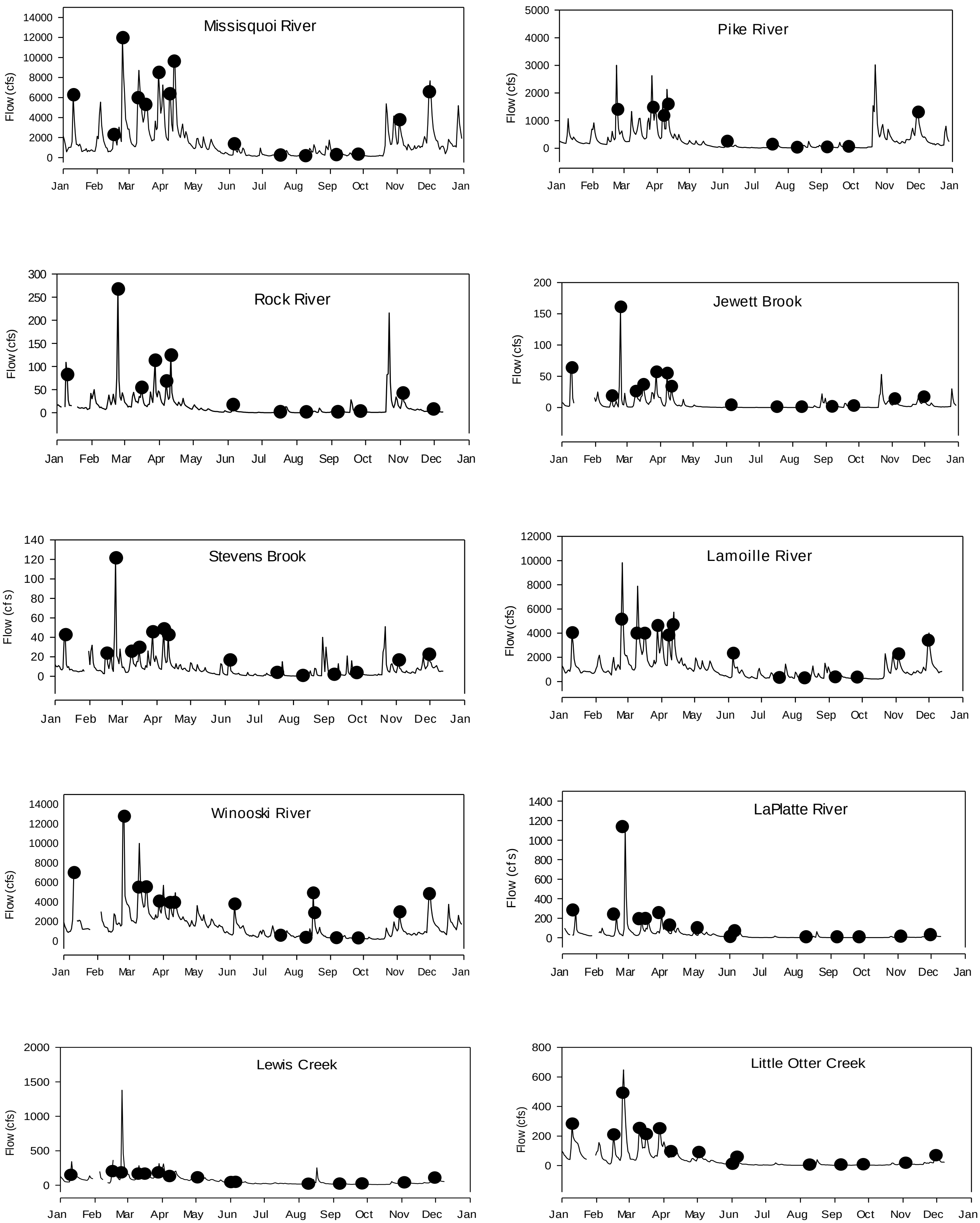
[3] Little Chazy flow gage was discontinued in 2014, but was re-established on 9-25-2015.

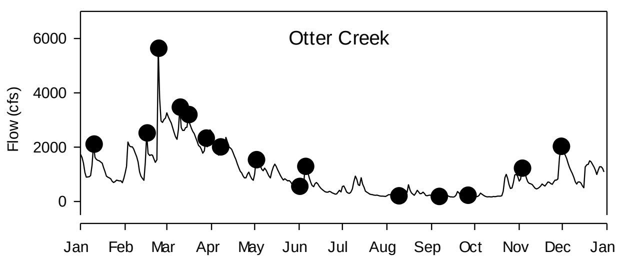
[4] Putnam Creek sampling was discontinued in 2015 due to lack of funding for the flow gage.

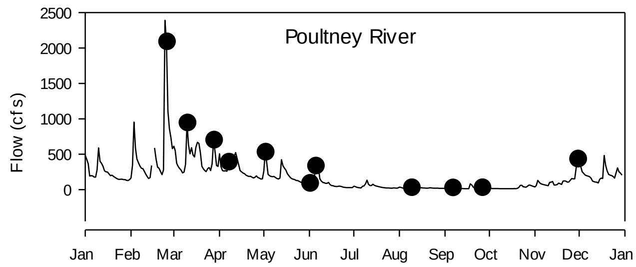
Table 2. Number of samples collected and analyzed for each monitoring parameter during 2016.

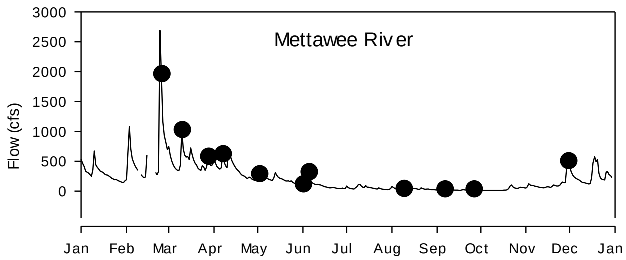
Parameter	Lake	Tributaries	Total
TP	404	329	733
DP	404	251	655
Cl	404	251	655
TN	404	319	723
Ca	67	53	120
SiO2	404	-	404
K	67	53	120
Na	67	53	120
Mg	67	53	120
Alkalinity	67	56	123
DO (Winkler)	60	-	60
Chl-a	297	-	297
TSS	-	247	247
Temperature	-	248	248
Conductivity	-	248	248
pH	-	247	247
Secchi depth	273	-	273
Multiprobe depth profiles	264	-	264
Zebra mussel veligers	102	-	102
Zebra mussel settled juveniles	4	-	4
Mysids	126	-	126
Zooplankton	144	-	144
Phytoplankton	136	-	136
Spiny waterflea	477	-	477

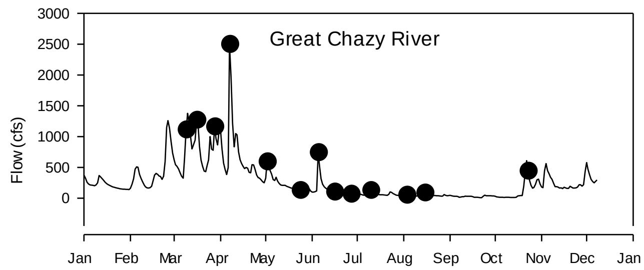
Figure 1. Sampling dates during 2016 in relation to daily flows at each tributary station. Daily flows are shown by lines, and sampling dates are shown by dots.

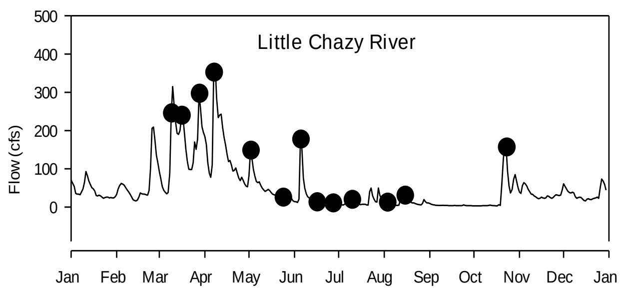


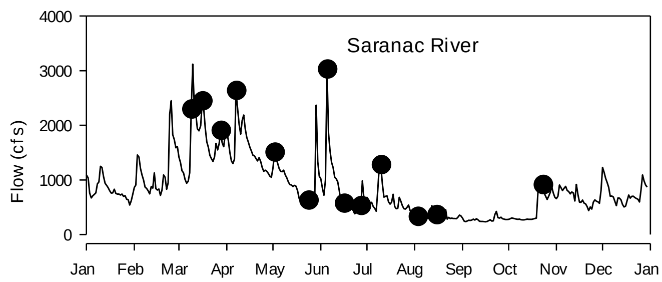

Otter Creek
Flow (cfs)
0
2000
4000
6000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

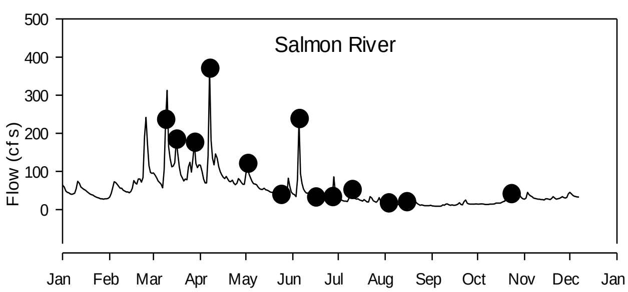

Poultney River
Flow (cf s)
0
500
1000
1500
2000
2500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

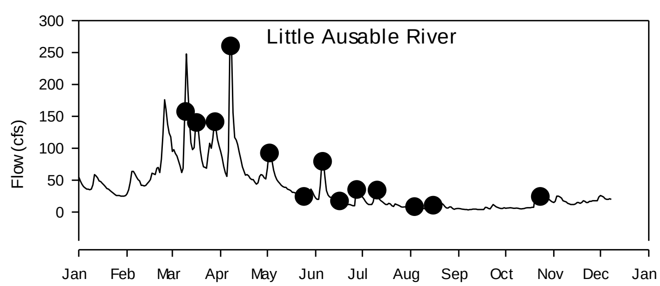

Mettawee River
Flow (cfs)
0
500
1000
1500
2000
2500
3000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

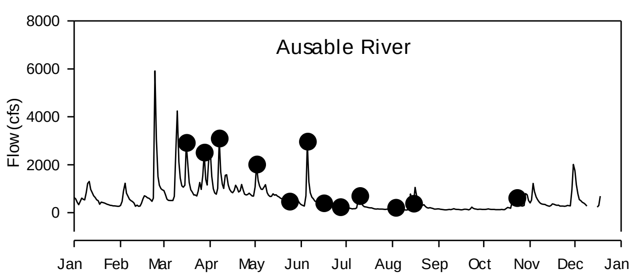

Great Chazy River
Flow (cfs)
0
500
1000
1500
2000
2500
3000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

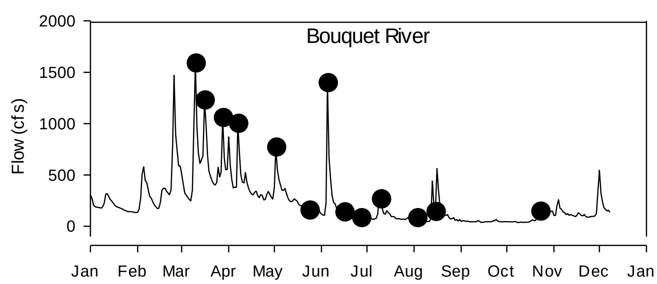

Little Chazy River
Flow (cfs)
0
100
200
300
400
500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

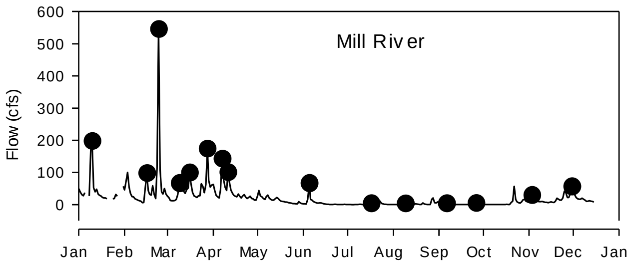

Saranac River
Flow (cf s)
0
1000
2000
3000
4000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Salmon River
Flow (cf s)
0
100
200
300
400
500
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Little Ausable River
Flow (cf s)
0
50
100
150
200
250
300
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Ausable River
Flow (cfs)
0
2000
4000
6000
8000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Bouquet River
Flow (cfs)
0
500
1000
1500
2000
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan



Data Quality Assurance Results

As described in the program's Quality Assurance Project Plan, field equipment blanks and field duplicate samples are obtained on each sampling run. The results for the blank samples are summarized in Table 3. Eleven of the 236 blank samples analyzed during 2016 (4.6%) had concentrations above the analytical detection limits. Although this is better than the 8.5% of blanks that were above detection in 2014, we will continue to strive to be more diligent in 2017 and beyond to reduce blanks samples that are above the detection limit. Results for field duplicate samples are summarized in Table 4 for the chemical analyses.

The results from laboratory and field duplicate analyses run on phytoplankton samples obtained during 2011-2015 are shown in Table 5. Phytoplankton data are not yet finalized for 2016.

Table 3. Field equipment blank results during 2016 for lake and tributary samples.

Test	Detection Limit	Units	Number of Blanks Obtained	Number of Blanks Above Limit	High Blank Values
Alk	1.0	mg/l	6	0	
Cl	2.0	mg/l	33	0	
TN	0.1	mg/l	37	0	
TP	5.0	µg/l	38	5	5.36 5.66 6.29 7.24 8.0
DP	5.0	µg/l	33	4	5.36 5.42 6.49 6.92
Chl-a	0.5	µg/l	13	1	.86
TSS	1.0	mg/l	18	0	
SiO2	0.2	mg/l	16	0	
Al	20	µg/l	6	0	
Fe	50	µg/l	6	0	
Ca	0. 1	mg/l	6	1	.145
Na	0.5	mg/l	6	0	
K	0.5	mg/l	6	0	
Mg	0.02	mg/l	6	0	
Mn	5	µg/l	6	0	
Total			236	11	

Table 4. Field duplicate results for chemical tests during 2016 showing the number of duplicates obtained (N) and the mean relative percent difference (RPD) between duplicate pairs.

Test	N	Mean RPD
Chl-a	15	25.6
Cond	--	--
Cl	36	2.3
DP	36	8.4
pH	--	--
Alk	2	.4
TN	38	8.3
TP	38	9.9
TSS	18	8.9
SiO2	17	7.8
Al	6	6.9
Ca	6	2.1
Fe	5	5.9
K	6	2.2
Na	6	1.8
Mg	6	1.6
Mn	5	6.2

Phytoplankton and Zooplankton Database

All phytoplankton data from 2006-2015 have been incorporated into the main Lake Champlain Monitoring Program database. Zooplankton data are currently available for the project period of 1993-2013. The data available for download from the web interface include phytoplankton cell densities and biovolumes, and zooplankton densities grouped by major taxonomic category. Counts by individual taxa will eventually be added to the web page, but are currently available only by request.

Table 6. Phytoplankton duplicate results for 2011–2015, the most recent sampling data, showing the number of pairs (N) and the mean relative percent difference (RPD) between pairs.

Test	Year	N	Sample Type	Mean RPD
Field Duplication	2011	11	Biovolume	44.4
			Cell Density	44.8
	2012	12	Biovolume	42.3
			Cell Density	55.4
	2013	8	Biovolume	27.9
			Cell Density	33.4
	2014	8	Biovolume	37.8
			Density	35.3
	2015	10	Biovolume	53.0
			Density	71.5
Lab Duplication	2011	15	Biovolume	32.1
			Cell Density	39.3
	2012	19	Biovolume	28.3
			Cell Density	27.5
	2013	12	Biovolume	26.9
			Cell Density	37.1
	2014	13	Biovolume	48.2
			Cell Density	51.7
	2015	14	Biovolume	32.6
			Density	30.3

Wastewater Phosphorus Discharge Data

The project workplan requires an annual compilation of wastewater phosphorus discharge data for all treatment facilities in the Vermont and New York portions of the Lake Champlain Basin. Data on annual mean flow, total phosphorus concentration, and phosphorus load at each facility have been compiled for 2016 along with data from previous years, and are available electronically in spreadsheet form on request. The total loads and flows from Vermont and New York wastewater treatment facilities during 2007-2016 are summarized in Table 6

Table 6. Total phosphorus load to Lake Champlain from wastewater treatment facilities in Vermont and New York from 2007-2016.

State	Number of Facilities	Year	Total Phosphorus Load (mt/yr)	Total Flow (mgd)
Vermont	60	2007	20.9	43.5
	60	2008	21.1	45.1
	60	2009	20.3	40.5
	60	2010	18.4	39.7
	59	2011	19.3	45.5
	59	2012	16.9	37.6
	59	2013	17.1	40.6
	59	2014	18.8	40.7
	59	2015	13.6	38.5
	59	2016	11.7	36.5
New York	29	2007	28.5	33.2
	29	2008	26.5	34.3
	29	2009	20.9	31.5
	29	2010	22.0	32.8
	29	2011	23.0	34.4
	29	2012	22.6	30.4
	29	2013	22.9	30.3
	29	2014	24.7	30.3
	29	2015	23.7	29.6
	29	2016	22.2	30.2

Rock River Monitoring Project

A Rock River Watershed Targeted Best Management Practice (BMP) Implementation Project was initiated in 2010 with funding provided by the Lake Champlain Basin Program (LCBP) and with oversight provided by a coordinating committee including the U.S. Natural Resource Conservation Service (NRCS), the Vermont Agency of Agriculture, Food, and Markets (AAFM) and the Vermont Department of Environmental Conservation (DEC). The purpose of the project is to demonstrate water quality improvements from a focused agricultural BMP implementation effort in a small watershed where very high rates of phosphorus loading to Lake Champlain have been documented. Most of the identified BMP implementation projects were expected to begin in 2013 or 2014.

In order to document water quality improvements resulting from the targeted BMP implementation in the Rock River watershed, the Vermont DEC established monitoring stations immediately upstream and downstream of the BMP implementation area in late 2010, and funded the construction and operation of a U.S. Geological Survey (USGS) stream flow gage at the downstream site. The DEC issues grants to the Friends of Northern Lake Champlain (FNLC) to support sample collection activities by trained local residents, and the DEC Laboratory conducts the sample analyses. The LCBP financially supports the laboratory analytical efforts, and supported the stream gaging through September 2014. The State of Vermont now supports the Rock River stream gage through a cooperative agreement with the USGS.

The area targeted for BMP implementation is approximately 13.5 km^2 in size on the upper Rock River in the towns of Highgate and Franklin, VT. Nearly all of the BMP implementation area is contained within the catchment area between the upstream monitoring station (RR20) and the downstream station (RR14). The implementation area occupies about 90% of the 15.1 km^2 drainage area between the upstream and the downstream stations. A USGS continuous stream flow gage is co-located with the downstream sampling station (RR14).

Samples are obtained manually as grab samples from the center of the river on each date for analysis of total phosphorus (TP), total dissolved phosphorus (DP), and total suspended solids (TSS). Sampling is conducted biweekly year-round except during the winter months when snow and ice in the river make sampling impossible. Additional sampling is conducted during high-flow events.

The study was designed as an upstream/downstream, before/after analysis, which is a type of a paired watershed design (Clausen and Spooner, 1993). It was originally anticipated that Analysis of Covariance (ANCOVA) would be used to test for statistically significant differences in TP, DP, PP, and TSS concentrations at the downstream station before vs. after BMP implementation (Meals, 2004). However, agricultural BMP implementation did not occur during a discrete, short-term time interval that would allow for a clear distinction between pre and post-implementation periods. Consequently, regression analysis of continuous temporal trends was used in place of the original ANCOVA design.

The sampling results from the upstream station were used to provide a partial control on background factors not related to BMP implementation that might influence the water quality results. The differences in $\log_{10}$-transformed TP, DP, PP, and TSS concentrations between the upstream and downstream stations sampled concurrently were used to indicate BMP treatment effects on water quality.

The differences between the upstream and downstream concentrations were often strongly dependent on the stream flow rate at the time of sampling. To avoid bias in the trends analysis caused by different flow conditions being sampled over time, the concentration differences were flow-normalized by obtaining residuals from regressions using $\log_{10}$-transformed concentration difference as the dependent variable and $\log_{10}$ average daily flow rate as the independent variable. In cases where these regressions were statistically significant, the regression residuals were used in the subsequent trends analysis to represent flow-normalized concentration differences. In cases where these regressions were not statistically significant, the non-normalized concentration differences were used for trends analysis. Time in decimal years was used as the independent variable to analyze temporal trends in water quality.

There have been 317 upstream/downstream paired samples collected and analyzed for TP, DP, and TSS through 2016. This total includes some samples obtained during 2008-2009 by Vermont DEC as part of a previous study. The numbers of paired samples obtained each year are shown in Table 7. The project site map is show in Figure 2. Estimated BMP implementation progress is shown in Figure 3 and Table 8.

Table 7. Numbers of paired samples obtained.

Year	Number of sample pairs
2008	10
2009	2
2010	18
2011	66
2012	55
2013	55
2014	51
2015	27
2016	33
Total	**317**

Figure 2– Rock River Monitoring Project site map

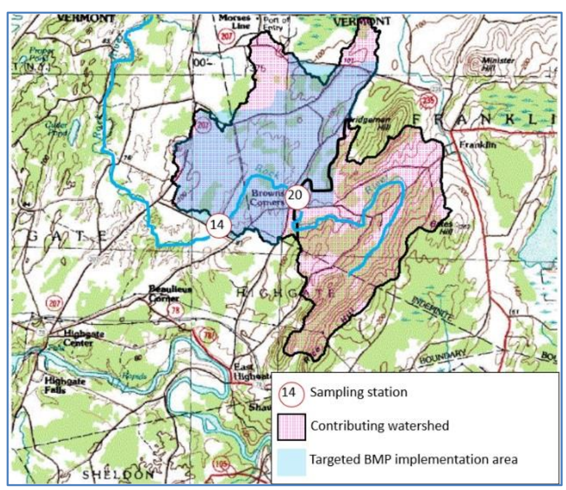


Figure 3. Summary of estimated BMP implementation activity in the target watershed. Data from NRCS and LCBP. Note that there is no requirement to report activities such as cover cropping and rotation after the initial grant-funded implementation, so there is likely more activity than shown here.

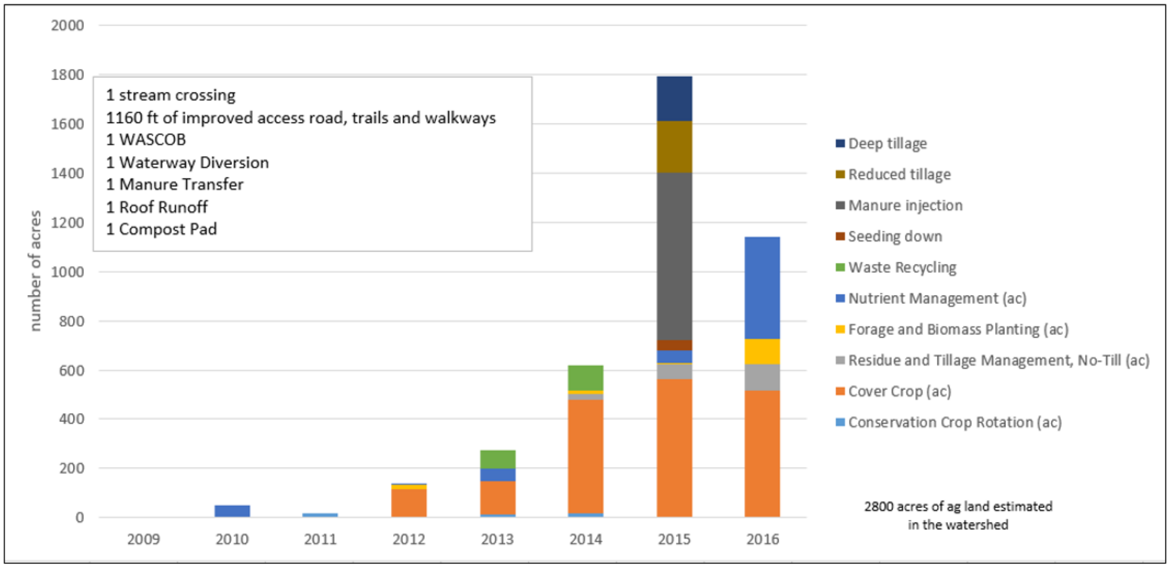


Table 8. BMP implementation projects funded by VAAFM in the Rock River watershed. Note that these activities include but are not limited to, the target watershed.

BMP Description	2010	2012	2013	2014	2015	Total
Agricultural Fuel Secondary Containment Facility		1				1
Animal Trails and Walkways	1					1
Diversion				1		1
Heavy Use Area Protection			1			1
Roof Runoff Management			1			1
Waste Facility Cover			1			1
Waste Storage Structure			1			1
Waste Transfer				1	2	3
Waste Treatment - Silage			1	1		2
Total	**1**	**1**	**5**	**3**	**2**	**12**

Data analysis continues to show there are no significant changes in phosphorus, particulate phosphorus or total suspended solids concentrations since BMP implementation began (Figure 4). Contrary to expectations, dissolved phosphorus concentrations have a significant increasing trend (p=0.004).

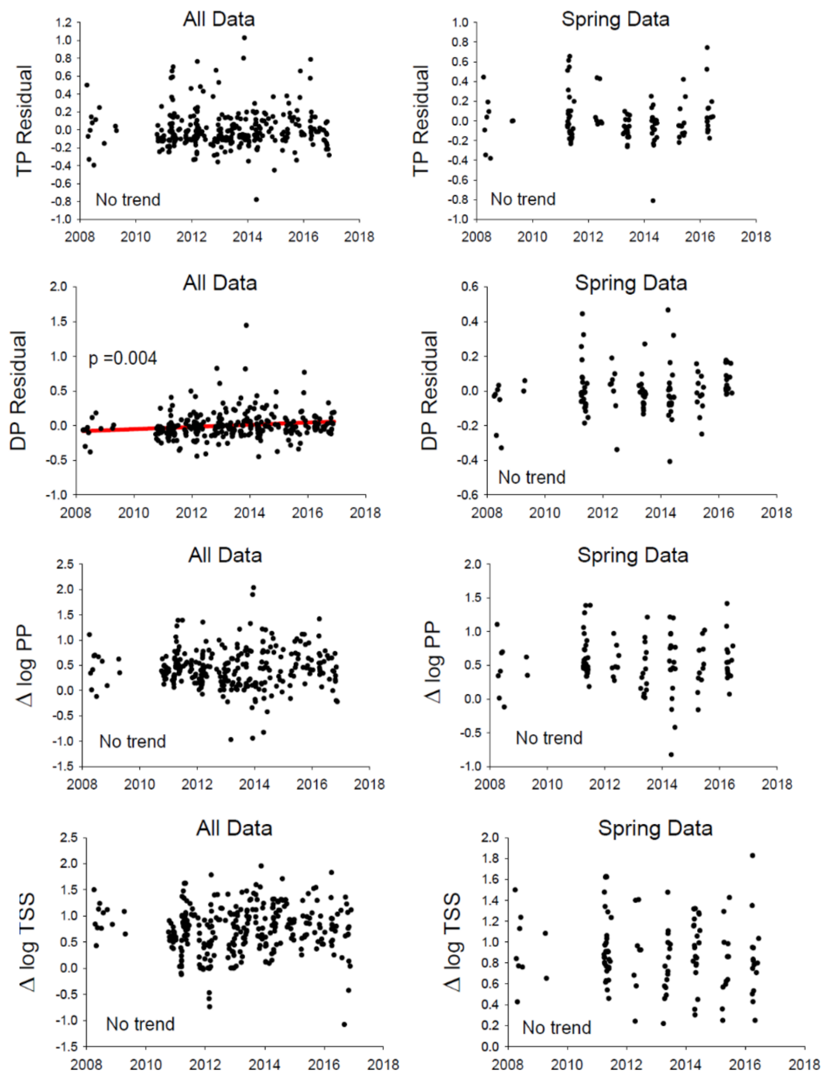


Figure 4. Results of regression analyses for the Rock River sites. Concentrations have been flow-normalized for TP and DP. Data for PP and TSS showed no response to flow and have not been normalized.

Invasive Species Monitoring
Lake Champlain

A total of 477 zooplankton samples were scanned for *Bythotrephes longimanus* (spiny waterflea) from monitoring stations on Lake Champlain in 2016 (Table 9, Figure 5). Whole water vertical tows were taken at each monitoring station using a 250 µm mesh 50 cm plankton net. In addition to the whole water tows, a epilimnion tow was collected at sites 7, 9, 19, 25, 34 and 36 for each sampling event. If the sites were isothermic, epilimnion tows were taken at 2x Secchi depth or 1m from the bottom. Samples were then visually scanned in the laboratory under a dissecting microscope to determine population densities. All samples were also scanned for other potential invasive invertebrates including *Hemimysis anomala* and *Cercopagis pengoi.* Based on whole water vertical tows, densities of *B. longimanus* peaked in June in the 2016 (Figure 6A, 6B, 6C) season earlier than it did in 2015 (August) and 2014 (October).

Table 9. Spiny water flea (SWF) monitoring stations in the Lake Champlain.

Station	**Lat**	**Long**	**# of sample events**	**# samples**
62			6	36
51	45.0410	73.1290	9	18
50	45.0130	73.1740	9	18
46	44.9480	73.3400	10	20
40	44.7850	73.1620	10	20
36	44.7560	73.3350	10	30
34	44.7080	73.2270	10	30
33	44.7010	73.4180	10	20
25	44.5820	73.2810	10	30
21	44.4740	73.2320	10	21
19	44.4710	73.2990	10	84
16	44.4250	73.2220	10	21
10	44.3000	73.3214	6	36
9	44.2420	73.3340	10	30
7	44.1260	73.4120	10	31
4	43.9540	73.4050	8	16
2	43.7140	73.3830	8	16
			Total # of Samples	477

Figure-5 Lake Champlain
LTM Sampling Locations