2013 Report:

Blue Mountain Lake

Chemistry of Museum and Potter Brooks

Adirondack Watershed Institute

Paul Smith's College

P.O. Box 265

Paul Smiths, NY 12970

Report No. PSCAWI 2014-69

Paul Smith's College
THE COLLEGE OF THE ADIRONDACKS

Acknowledgements

The Adirondack Watershed Institute (AWI) is a program of Paul Smith's College that conducts research and service work broadly focused on conservation and protection of water resources. The narrative and results presented in this report were produced by Daniel L Kelting, Executive Director, and Corey Laxson, Research Associate, both with the AWI. Laboratory work on samples was conducted by Corey Laxson, Elizabeth Yerger, Sean Patton, Brandon Morey, and Dan Kelting. Sean Regalado produced watershed maps in GIS. This project was supported with funding from Blue Mountain Lake Water Watch. Paul Smith's College provided office and laboratory space.

Paul Smith's College
THE COLLEGE OF THE ADIRONDACKS®

Please cite this report as:

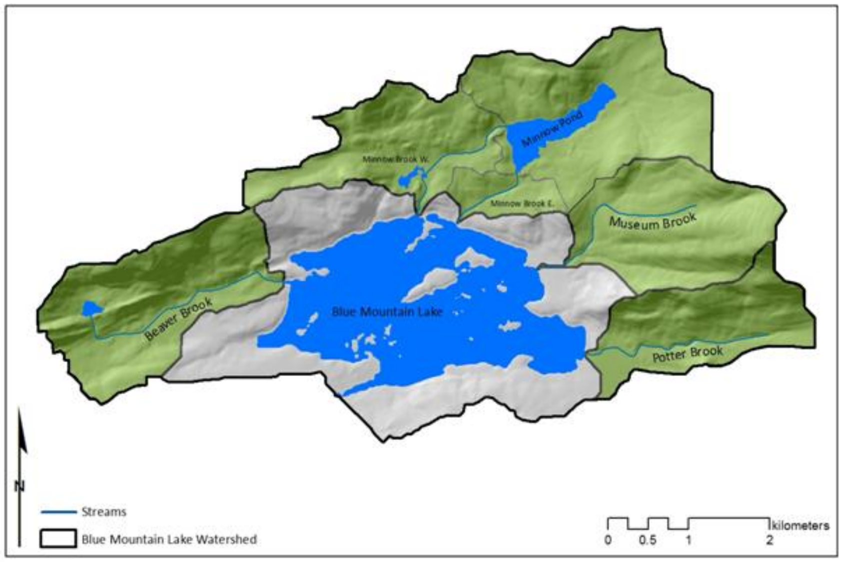
Kelting*, D.L., and C.L. Laxson. 2014. Chemistry of Museum and Potter Brooks: 2013 Report, Blue Mountain Lake. Adirondack Watershed Institute of Paul Smith's College. Report No. PSCAWI 2014-69. 27p.

*Corresponding author Dan Kelting at dkelting@paulsmiths.edu

Cover Photo: Eckford Chain of Lakes taken from Blue Mountain. Photo credit to Marc Wanner.

Table of Contents

Quick Facts – Museum and Potter Brooks



Museum Brook	
Area (ha)	321
% of Watershed	11

Potter Brook	
Area (ha)	256
% of Watershed	9

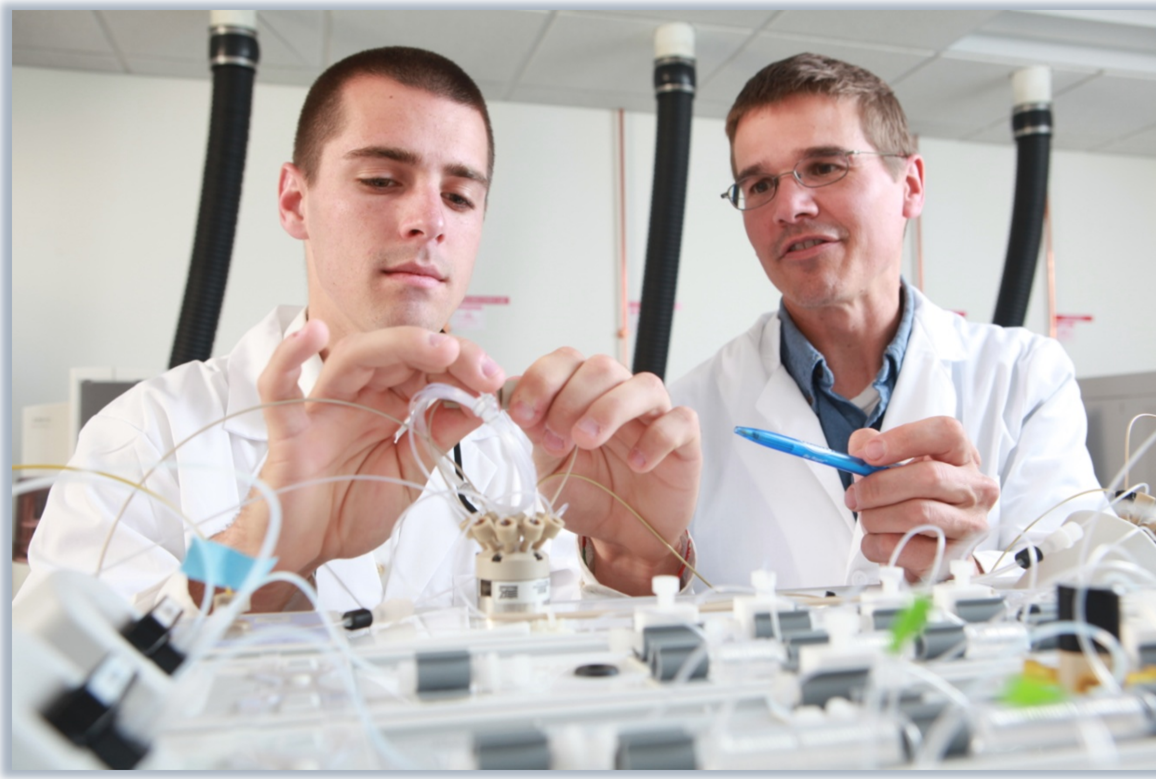
2013 Chemistry (Museum Brook)

Analyte	Value
pH	5.37
Alkalinity (mg/L)	6.5
Total Phosphorus (µg/L)	14.5
Calcium (mg/L)	3.5
Sodium (mg/L)	16.0
Nitrate (µg/L)	215
Chloride (mg/L)	23.0
Conductance (µS/cm)	98.6
Color (Pt-Co)	79

2013 Chemistry (Potter Brook)

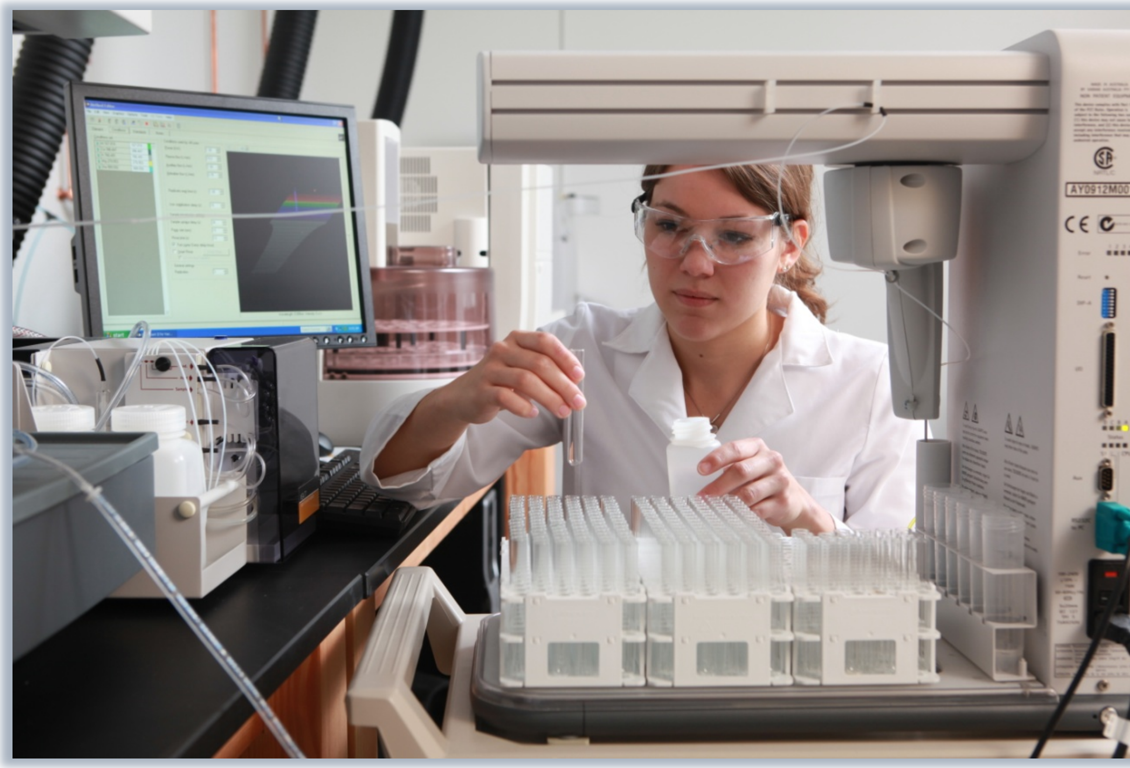
Analyte	Value
pH	5.63
Alkalinity (mg/L)	10.6
Total Phosphorus (µg/L)	5.5
Calcium (mg/L)	4.3
Sodium (mg/L)	11.8
Nitrate (µg/L)	208
Chloride (mg/L)	16.4
Conductance (µS/cm)	83.2
Color (Pt-Co)	41

List of Tables



Preparing the Lachat to analyze water samples for chloride and sulfate via ion chromatography in the AWI Environmental Research Lab.

List of Figures



Transferring water samples to sample cups in preparation for determining metal concentrations via inductively coupled plasma optical emission spectroscopy in the AWI Environmental Research Lab.

Executive Summary

A tributary monitoring program was initiated in the 1990s within the Blue Mountain Lake watershed. The main purpose of this monitoring program is to identify and understand factors that influence the water quality of the lake itself. Two tributaries were monitored in 2013, Museum Brook and Potter Brook. A grab sample of stream water was obtained at each of 11 stream monitoring stations (4 along Museum Brook and 7 along Potter Brook) at five separate times roughly one month apart spanning May to September. Highlights from this report include:

- Total phosphorus and nitrate concentrations were higher at downstream locations in Museum Brook and were higher at the outlet than the majority of observations from least impacted streams in other regions of the Adirondacks.
- There were no trends in total phosphorus or nitrate concentrations moving downstream in Potter Brook. Total phosphorus concentrations were generally within the range of concentrations observed for least-impacted streams in other regions of the Adirondacks, while nitrate concentrations were generally higher than the majority of observations from these least impacted streams.
- Total phosphorus load estimates averaged 0.12kg/ha/yr for Museum Brook and 0.11kg/ha/yr for Potter Brook, with no trends apparent in the estimates. Load estimates for both tributaries were within the range of total phosphorus loads reported for a least impacted stream in the Adirondacks, but the estimates for Museum Brook and Potter Brook were highly variable.
- Fecal coliform counts exceeded various thresholds for samples collected from both tributaries, with thresholds exceeded at both least impacted and impacted sampling locations.
- Sodium and chloride concentrations and conductivity at the outlets of Museum Brook and Potter Brook were substantially higher than values for least impacted streams in other regions of the Adirondacks. Values for these analytes upstream of paved roads in Museum Brook and Potter Brook were within the range of values for least impacted streams in other regions of the Adirondacks.

Elevated total phosphorus and nitrate concentrations at downstream locations in Museum Brook were likely from pollutant inputs. Though total phosphorus loading estimates for Museum Brook suggested that loads were still within expected values for least impacted streams, high variation reduced our confidence in these estimates as well as in those for Potter Brook. The lack of downstream trends in total phosphorus and nitrate concentrations in Potter Brook suggested that development has not had measureable impacts on nutrient inputs to this stream. The substantially elevated sodium and chloride concentrations observed in both streams below paved roads were clearly from road salting, which has had a significant impact on the chemistry of both streams and the lake.

As was stated previously, the main purpose of this monitoring program is to identify and understand factors that influence the water quality of the lake itself. Yet, Museum Brook and Potter Brook collectively drain only 20% of the total watershed area of Blue Mountain Lake and thus most of the watershed is not currently monitored. Thus, we recommend expanding the stream monitoring program to include all major streams. We recommend further that the outlets of each stream be instrumented with conductivity and stage sensors to obtain the high resolution data necessary to observe impacts and to estimate nutrient and salt loads with greater confidence.

Introduction

Blue Mountain Lake is a 697ha lake located in Hamilton County in the Town of Indian Lake. The lake has been monitored by the Adirondack Lake Assessment Program and the Adirondack Watershed Institute (AWI) since 1998. The lake historically has oligotrophic characteristics and is clearer than 95% of lakes in the ALAP dataset (Kelting and Laxson 2014b). Lake residents would like to preserve the oligotrophic character and clarity of Blue Mountain Lake.

A number of lake residents became concerned in the early 1990s with a proposed local residential development (now known as the Woodlands) and the potential impact this new development would have on the character of the lake. Water Watch was formed in 1993 partly in response to this concern. But it was also recognized that no group or government agency regularly studied the water quality of Blue Mountain Lake and its tributaries in such a manner as to understand and preserve its quality. As a result, a disciplined, authoritative database for decision making was lacking and thus Water Watch was also formed to fill that void.

Water Watch initiated a monitoring program in 1993 to provide valuable information about the water in the lake and the streams flowing into it. While Water Watch recognizes the intrinsic value in the streams being of high quality, the main goal in monitoring the streams is to further understand the water quality of the lake itself. With this data in hand, it is Water Watch's intent to use the information to influence those who have an effect on water quality (such as builders, property owners and local officials) and, when necessary, to help set a course for remedial actions.

The monitoring program has been conducted most years with only a few exceptions and minor changes. The program has two major components, the "Brooks Tests" which monitor Museum and Potter Brooks, and the "Adirondack Lake Assessment Programs (ALAP) Tests" which focus on the lake itself. The Brooks Tests have been conducted in a somewhat different manner and time cycle from the ALAP Tests and results have been reported separately. All tests have been made possible by the financial support of Water Watch members, significant volunteer efforts in the gathering of samples and a close partnership with the Adirondack Watershed Institute.

This report presents the water chemistry results for Museum Brook and Potter Brook from the 2013 monitoring season. Total phosphorus loading estimates are also provided for both tributaries spanning the period from 1998 to 2013. Interpretations of the 2013 water chemistry and loading estimates are provided within the limits of the data. These numbers are also compared to values from least impacted streams monitored by AWI in other watersheds. The purpose of these comparisons is to provide benchmarks against which to evaluate the water quality of Museum Brook and Potter Brook. Lastly, recommendations are provided to improve the tributary monitoring program to meet the main goal of understanding the water quality of the lake itself.

Lake and Watershed Characteristics

Blue Mountain Lake is located in the central Adirondacks (Figure 1) in Hamilton County in the Town of

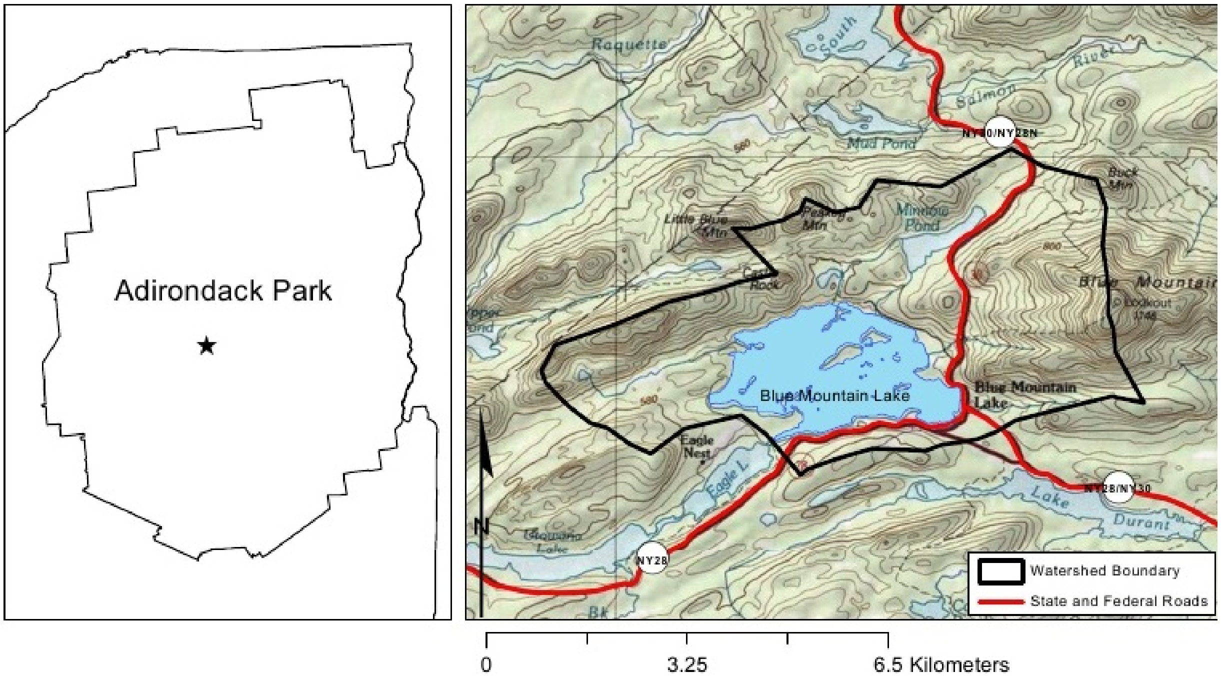


Figure 1. Location and watershed for Blue Mountain Lake.

Indian Lake (Table 1). The lake is 697ha in surface area and has 44km of shoreline. The maximum depth is 30.5m, total volume is 75,725,176m^3, and the lake flushes about 0.3 times per year. The Blue Mountain Lake watershed is 2,972ha, 22% of which is surface water. The watershed is dominated by forest cover, with 62% deciduous, 7% evergreen, and 7% mixed forests. The watershed contains 4.0km of local roads (county, town, and local) and 9.0km of state roads (state and US highways). There are five major tributaries within the Blue Mountain Lake watershed (Figure 2). The drainage area for Minnow Pond represents the largest tributary watershed within the Blue Mountain Lake watershed (Table 2). Minnow Pond has two outlets at East and West Minnow Brooks (Figure 2), with the watershed for West

Table 1. Lake and watershed characteristics for Blue Mountain Lake.

Location	County:	Hamilton	Latitude:	43.8612
	Town:	Indian Lake	Longitude:	-74.4579
Lake Characteristics	Lake Area (ha):	697	Z-max (m):	30.5
	Lake Perimeter (km):	44	Volume (m^3):	75,723,176
			Flushing Rate (T/Y):	0.3
Watershed Characteristics	Watershed Area (ha):	2,972	Residential (%):	0
	Surface Water (%):	22	Agriculture (%):	0
	Deciduous Forest (%):	62	Commercial (%):	0
	Evergreen Forest (%):	7	Local Roads (km):	4.0
	Mixed Forest (%):	7	State Roads (km):	9.0
	Wetlands (%):	0		

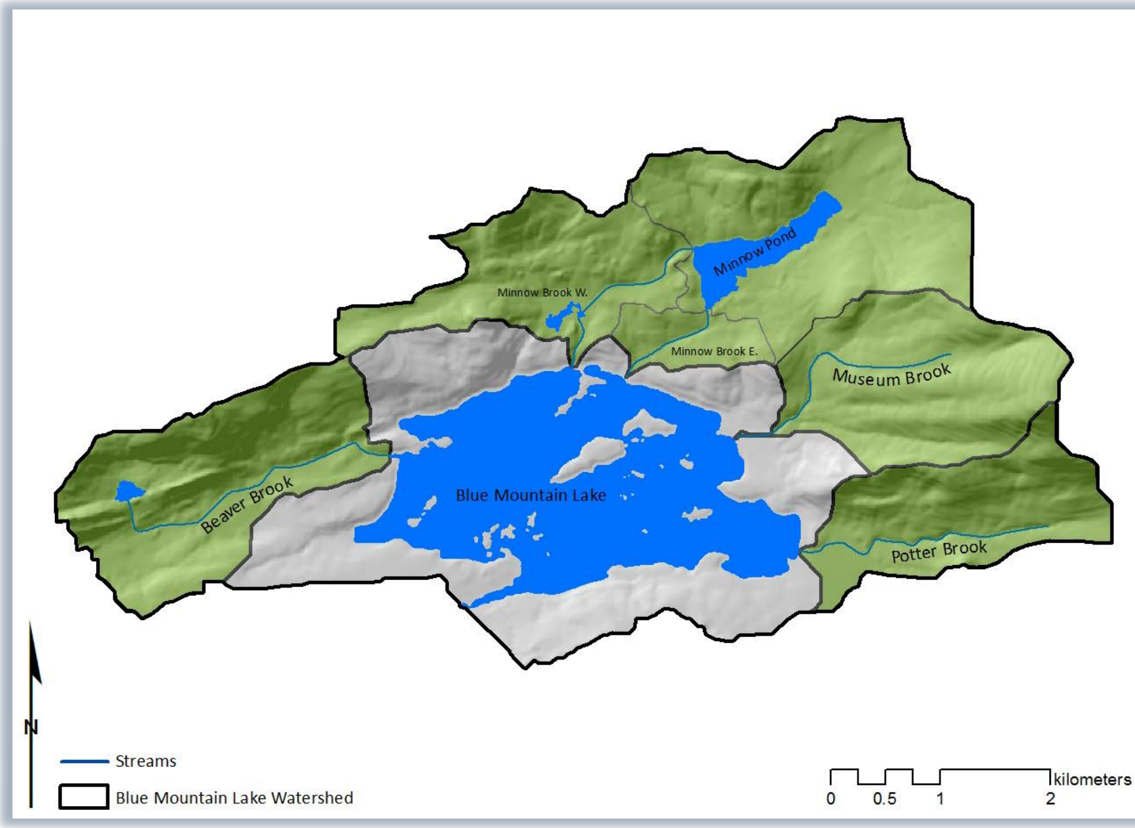


Figure 2. Major tributaries of the Blue Mountain Lake watershed.

Minnow Brook being the larger of the two (Table 2). Collectively the Minnow Pond and Brook watersheds drain 737ha of land, which constitutes 25% of the total watershed area (Table 2). The second largest tributary watershed is Beaver Brook, which drains the western portion of the watershed (Figure 2). Museum and Potter Brooks are the smallest tributary watersheds, constituting 11 and 9% of the total watershed area, respectively. Fifteen percent of the watershed is *not* drained by a tributary, which constitutes the shoreline and adjacent uplands shown in gray on Figure 2.

Table 2. Tributary watershed area and percent of Blue Mountain Lake watershed occupied by each tributary.

Tributary	Area (ha)	Percent
Minnow Pond and Brooks	737	25
• Minnow Pond	411	14
• East Minnow Brook	66	2
• West Minnow Brook	260	9
Beaver Brook	374	13
Museum Brook	321	11
Potter Brook	256	9

Methodology

Monitoring Locations

Two tributaries of Blue Mountain Lake were monitored in 2013, Museum Brook and Potter Brook. These two tributaries collectively drain 20% of the total watershed area. The Museum Brook watershed is the larger of the two, draining 321ha of land, while the Potter Brook watershed drains 256ha of land (Table 2). Tributary maps in previous reports were not drawn to scale, which made it difficult to properly interpret the monitoring data. Thus the roads and tributaries were digitized from color infrared ortho-photos and the position of each sampling station along each tributary was accurately positioned on new location maps in GIS (Figure 3). These new maps provide a different perspective, particularly for Museum Brook wherein the distances between each sampling station and the geographic proximity of each sampling station to cultural features in the watershed are properly shown.

Four stream monitoring stations were sampled along Museum Brook (Figure 3). Sampling station #1 was located upstream of all houses on Wells Road and was selected to serve as the least-impacted condition against which to benchmark downstream samples. Sampling station #2 was located adjacent to the overflow parking lot for the Adirondack Museum, which was also adjacent to State Route 28. Sampling station #3 was located downstream of the filtration field outfall, State Route 28, the Adirondack Museum, and Maple Lodge Road at the access road to the waste water treatment plant for the museum. It is important to note that an un-monitored tributary enters Museum Brook between stations 2 and 3. The fourth station was positioned near the outlet of Museum Brook in flowing water upstream of lake influence.

Seven stream monitoring stations were sampled along Potter Brook (Figure 3). Sampling station #1 was positioned near the outlet of Potter Brook in flowing water upstream of lake influence. Sampling station #2 was located just south of a convenience store and between State Routes 28 and 30. Sampling station #3 was located upstream of State Route 30, but within the area influenced by road runoff from the highway. Potter Brook splits about 80m upstream of sampling station #3. Sampling stations were located on both the left and right branches of Potter Brook just upstream of the split. Sampling station #4 located on the left branch captures some of the influence of adjacent residential development, while sampling station #7 also located on the left branch was positioned upstream of the development to serve as a benchmark of least-impacted conditions. Sampling station #5 located on the right branch of Potter Brook captures some of the influence of residential development, a sand pit, and the site of an old sawmill. Sampling station #6 also located on the right branch was positioned upstream of residential development and downstream of the sand pit and old sawmill site.

Field Sampling and Lab Analysis

A grab sample of stream water was obtained at each of the 11 stream monitoring stations at five separate times roughly one month apart spanning May to September. All grab samples were kept on ice after collection and chemically preserved or stored at 4°C in the laboratory until analysis could be completed. Samples were analyzed for pH, conductivity, alkalinity, total phosphorus, calcium, sodium,

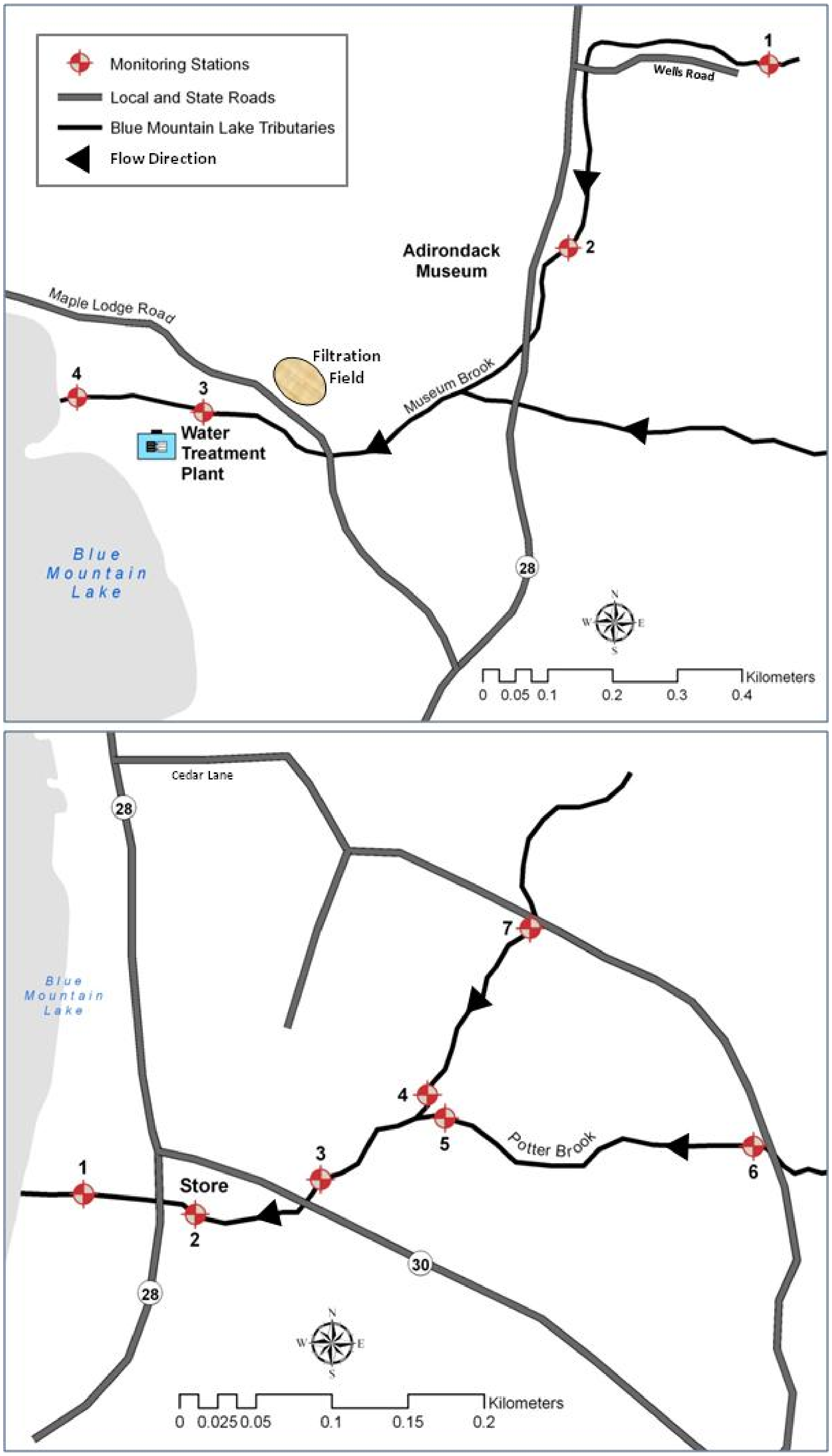


Figure 3. Locations of water sampling stations in Museum Brook (top panel) and Potter Brook (bottom panel). Note the panels have different scales.

nitrate, chloride, and color at the AWI Environmental Research Lab following the analytical methods described in Table 3.

Table 3. Analytical methods performed in the AWI Environmental Research Lab.

Analyte	Method Description	Reference
Lab pH	Mettler Toledo standard pH electrode	APHA
Conductivity	Conductivity at 25° C via Mettler Toledo conductivity cell	APHA 2510 B
Apparent Color	Single wavelength method with PtCO standards	APHA 2120 C
Total Phosphorus	Acid-persulfate digestion, automated ascorbic acid reduction	APHA 4500-P H
Nitrate + Nitrite	Automated cadmium reduction	APHA 4500-NO_3 I
Alkalinity	Automated methyl orange method	EPA 301.2
Chloride	Automated ion chromatography	EPA 300.0
Metals	Inductively coupled plasma optical emission spectroscopy	EPA 200.7

Separate grab samples of stream water were collected for fecal coliform analysis. This sampling was done under the direction of a representative from Water Watch. AWI staff collected the samples and transported them to Endyne Inc., a commercial laboratory located in Plattsburgh, NY, for analysis that same day. Endyne Inc. determined coliform and e coli numbers using the SM 9223 Quantitary method.

Data Analysis

Average 2013 values for each analyte were calculated from the lab data and reported along with the raw data by sampling date for the outlet of each tributary (see Tables 4 and 5). Line graphs were constructed for total phosphorus, conductivity, alkalinity, nitrate, sodium, and chloride to show the seasonal trend and variation between sampling locations for each tributary (see Figures 4 and 6). To evaluate longer term differences in stream chemistry between sampling locations, box plots were constructed using all of the data collected from 2010 to 2013 by location for each tributary, but only for total phosphorus, nitrate, and chloride (see Figures 5 and 7). Average 2013 analyte values for the outlets of Museum Brook and Potter Brook were also compared to values for least-impacted streams monitored by AWI for the same time period.

In previous reports annual phosphorus loads were estimated based on measured stream discharge, by multiplying average discharge by average stream phosphorus concentration. This is the generally accepted method for estimating nutrient loads; however this approach results in large errors when based on infrequent sampling. We took a step towards improving the phosphorus load estimates by using an annual discharge estimate derived from total precipitation captured by each watershed. Precipitation data was obtained from the National Climate Data Center for Tupper Lake, summed by year, and multiplied by watershed area to obtain the total precipitation captured. We then assumed that 50% of this precipitation was discharged from each watershed. This approach was used to estimate annual phosphorus loads for 1998 to 2013. Additionally, 95% confidence intervals for phosphorus load were calculated by year based on the within year variation in total phosphorus concentration (see Figure

8). These confidence intervals provide a sense of the level of uncertainty surrounding each estimate. Trend analysis was conducted for total phosphorus load using Kendall tau[1] to test the hypothesis "there is no relationship between the indicator and time", with the hypothesis rejected at alpha ≤ 0.05.

Results and Discussion for Museum Brook

Acidity (pH) ranged from 4.45 to 5.67 and averaged 5.37 at the outlet in 2013 (Table 4). Museum Brook was considerably more acidic than the least impacted streams, with pH values of Museum Brook generally in the lowest 25% of the distribution (Table 6). Alkalinity ranged from 1.5 to 12.8mg/L and averaged 6.5mg/L at the outlet in 2013. Alkalinity at the outlet of Museum Brook was within the range of values for the least impacted streams. Total phosphorus ranged from 7.0 to 25.4µg/L and averaged 14.5µg/L at the outlet in 2013. Total phosphorus concentrations at the outlet of Museum Brook were higher than 75% of the samples from least impacted streams. Calcium ranged from 2.6 to 4.8mg/L and averaged 3.5mg/L at the outlet in 2013. Calcium concentrations at the outlet of Museum Brook were within the range of values for the least impacted streams. Sodium ranged from 8 to 24.3mg/L and averaged 16.0mg/L at the outlet in 2013. Sodium concentrations at the outlet of Museum Brook were over ten times greater than values for the least impacted streams. Nitrate ranged from 93 to 457µg/L and averaged 215µg/L at the outlet in 2013. Nitrate concentrations at the outlet of Museum Brook were higher than 50% of the samples from least impacted streams. Chloride ranged from 11.6 to 33.8mg/L and averaged 23.0mg/L at the outlet in 2013. Chloride concentrations at the outlet of Museum Brook were about fifteen times greater than values for the least impacted streams. Conductance ranged from 55.6 to 149.8µg/L and averaged 98.6µg/L at the outlet in 2013. Conductance at the outlet of Museum Brook was about three times greater than values for the least impacted streams. Color ranged from 56 to 130Pt-Co units and averaged 79Pt-Co units at the outlet in 2013. Color at the outlet of Museum Brook was darker than 50% of the samples from least impacted streams.

Table 4. Chemistry of water samples collected at the outlet of Museum Brook in 2013.

Analyte	Sampling Date					Average
	5/29	6/18	7/25	8/12	9/25	
pH	5.53	5.55	4.45	5.67	5.65	5.37
Alkalinity (mg/L)	1.5	4.6	4.0	9.4	12.8	6.5
Total Phosphorus (µg/L)	7.0	9.3	10.7	20.3	25.4	14.5
Calcium (mg/L)	2.6	3.1	2.6	4.3	4.8	3.5
Sodium (mg/L)	12.0	15.2	8.0	20.5	24.3	16.0
Nitrate (µg/L)	93	102	116	309	457	215
Chloride (mg/L)	19.4	23.8	11.6	26.5	33.8	23.0
Conductance (µS/cm)	73.4	94.9	55.6	119.5	149.8	98.6
Color (Pt-Co)	72	60	130	56	78	79

[1] Kendall tau is a widely used statistic for evaluating trends in water quality. It is a non-parametric hypothesis test for dependence between two variables, in our case the dependence of a water quality indicator on time.

There was a general trend of increasing total phosphorus concentration at the four sampling locations in Museum Brook from May through September in 2013 (Figure 4A). Total phosphorus concentrations at the four sampling locations were similar in late May, but a clear separation was observed by mid-summer wherein the total phosphorus concentrations at stations 3 and 4 were higher than at stations 1 and 2. Total phosphorus concentrations at the least-impacted location (station #1) were well within the range of concentrations observed for other least-impacted streams, while total phosphorus concentrations downstream of station 2 were higher than 75% of observations for other least impacted streams (Table 6).

There was a general trend of increasing conductivity at the four sampling locations in Museum Brook from May through September in 2013 (Figure 4B). The lowest conductivity was observed at the least-impacted location (station #1), followed by station #2. Conductivity was higher at stations 3 and 4 for all five sampling dates. A noticeable dip in conductivity was observed in July at stations 2, 3 and 4. Conductivity values at the least-impacted location (station #1) were well within the range of values observed for other least-impacted streams, while conductivity values downstream of station 1 were considerably higher than observations for other least impacted streams (Table 6).

There was a general trend of increasing alkalinity at the four sampling locations in Museum Brook from May through September in 2013 (Figure 4C). The lowest alkalinity was observed at the least-impacted location (station #1), followed by station #2. Alkalinity was higher at stations 3 and 4 for all five sampling dates. A noticeable dip in alkalinity was observed in July at all stations. Alkalinity values at stations 2, 3, and 4 were well within the range of values observed for other least-impacted streams, while alkalinity values at station 1 were considerably lower than observations for other least impacted streams (Table 6).

There was a general trend of increasing nitrate at stations 2, 3 and 4 in Museum Brook from May through September in 2013 (Figure 4D). The lowest nitrate was observed at the least-impacted location (station #1), followed by station #2. Nitrate was higher at stations 3 and 4 for all five sampling dates, particularly later in the summer. A noticeable dip in nitrate was observed in July at stations 2, 3 and 4. Nitrate values at stations 1 and 2 were well within the range of concentrations observed for other least-impacted streams, while nitrate values at stations 3 and 4 in August and September were higher than 75% of observations from other least impacted streams (Table 6).

There were general trends of increasing sodium and chloride concentrations at stations 2, 3 and 4 in Museum Brook from May through September in 2013 (Figure 4E and 4F). The lowest sodium and chloride concentrations were observed at the least-impacted location (station #1). Sodium and chloride concentrations were higher at stations 2, 3, and 4 for all five sampling dates, with concentrations at station 2 being roughly one-half of those observed at stations 3 and 4. Noticeable dips in sodium and chloride concentrations were observed in July at stations 2, 3 and 4. Sodium and chloride concentrations at the least-impacted location (station #1) were well within the range of observations for other least-impacted streams, while concentrations downstream of station 1 were considerably higher than observations for other least impacted streams (Table 6).

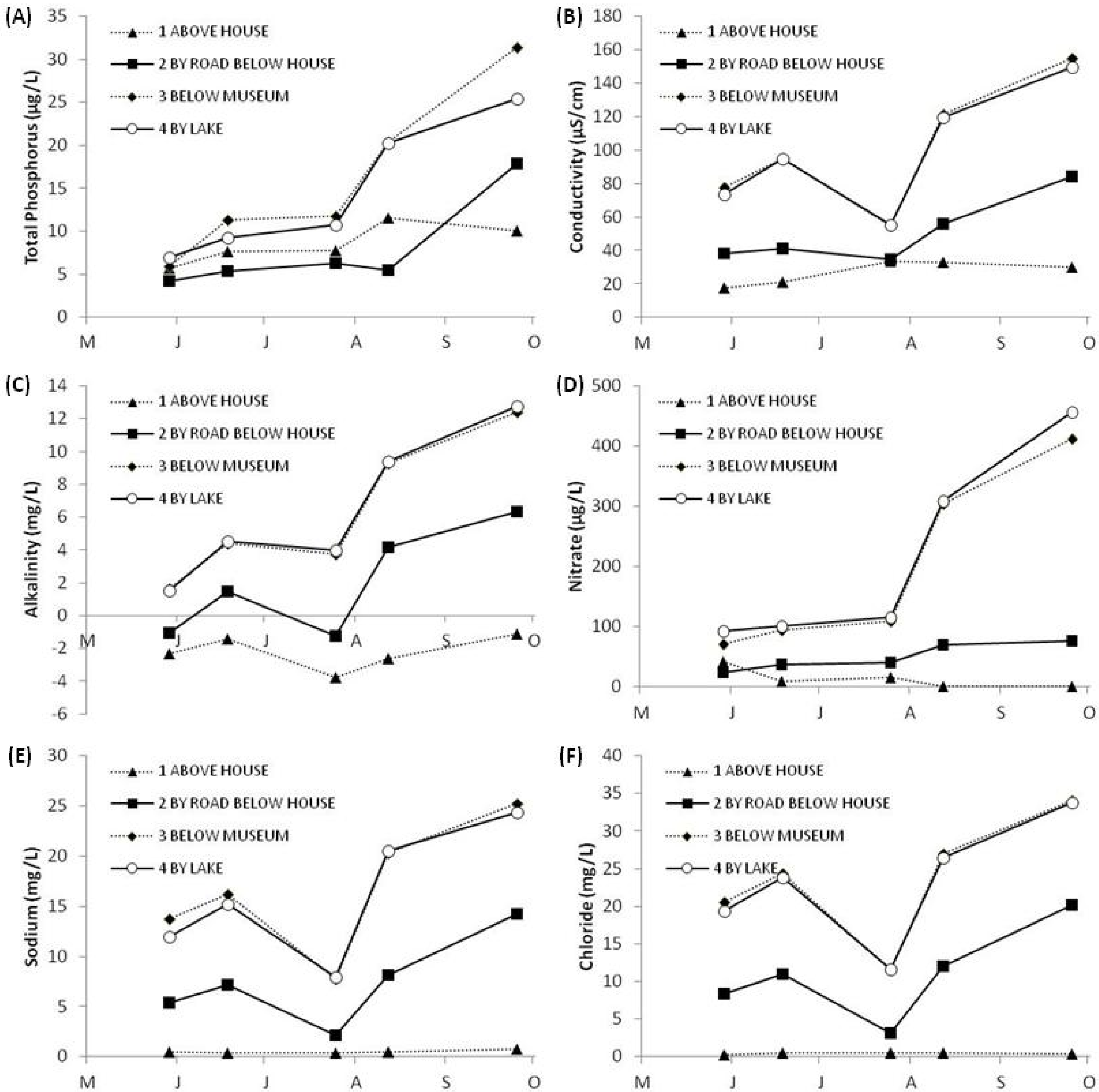


Figure 4. Chemistry of water samples collected at four sampling stations along Museum Brook in 2013.

Total phosphorus nitrate, and chloride were chosen for display in box plots since the first two are important limiters of lake productivity and the remaining analytes all follow the same trend as chloride. The box plots show the same basic trends for all three analytes between sampling stations as the 2013 data (Figure 5). The shaded area in each box contains 50% of the data, the horizontal line within each box represents the median value, the vertical bars denote the data range, and the black circles are the means. Mean concentrations of all three analytes increased moving downstream from the least impacted location at station 1 (above house) to station 3 (below museum). But, for total phosphorus and nitrate the box plots showed a high degree of similarity between stations 1 and 2 (by road below house), and also between stations 3 and 4 (by lake). The box plots for chloride also showed a high degree of similarity between stations 3 and 4, but unlike total phosphorus and nitrate there was a distinct difference between stations 1 and 2 for chloride. There was a large amount of variation in analyte concentrations. For example, total phosphorus at station 3 ranged from 5 to 72µg/L and chloride concentration at this same station ranged from 6 to 67mg/L.

The increasing trends observed through time for the analytes shown in Figure 4 were likely in response to decreasing stream flow through the summer. The noticeable dips observed in July were likely in response to an increase in stream flow in response to rainfall events, which would have diluted the analytes: the weather station at Tupper Lake reported about 7cm of rainfall in the 10 days preceding the July sampling date. The higher total phosphorus and nitrate concentrations observed at stations 3 and 4 were likely from residential sources (e.g. septic systems) and permitted discharge from the outfall for the filtration field located just upstream of station 3. Elevated values for the other analytes below station 1 were largely a result of road salting, though a portion of the higher conductivity may be attributed to other pollutants (e.g. septic runoff and fertilizer). Conductivity is a surrogate measure of dissolved ions in water and thus the pattern observed in conductivity largely reflects the increased concentrations of sodium and chloride from road salting (Daley et al. 2009). The sodium and chloride concentrations measured at station 1 were both less than 1mg/L, and within the expected range for least-impacted watersheds in the Adirondacks (Kelting et al. 2012). The increased concentrations of these ions at station 2 and the further increase observed at station 3 reflects higher road salt loads as more road length is included in the watershed. If the Adirondack Museum uses salt on its surfaces as well, then this would be another significant source of sodium and chloride loads to Museum Brook below station 2. The fact that higher sodium and chloride concentrations were also observed in May suggests further that salt has accumulated in the watershed. The pattern of increased alkalinity from station 1 to 4 is also likely explained by road salt, as these ions plus others displaced from soils by salt increase alkalinity (Rosfjord et al. 2007).

Fecal coliform samples were collected at stations 1 and 2 on July 24th. The coliform count was 29colonies/100mL at station 1 and 150colonies/100mL at station 2. Station 2 was sampled again on 9/25 and the coliform count was 8colonies/100mL. Station 3 was also sampled on 9/25 and the coliform count was 5colonies/100mL. Samples did exceed various thresholds for designated uses, even the least impacted location at station 1. This stands to reason, since humans are only one of many sources of fecal coliform. These results show that fecal coliform is highly variable in space and time, which makes it difficult to interpret the data.

Monitoring Recommendations

The results clearly show that stations 3 and 4 are very similar. This finding makes sense given that station 4 is located only about 200m downstream of station 3 and there is marginal watershed input between these stations. Thus we recommend dropping one of these stations. We further recommend that the currently un-monitored tributary that discharges between stations 2 and 3 be sampled in 2015 to determine if this tributary contributes any pollutants to Museum Brook. Water Watch should also

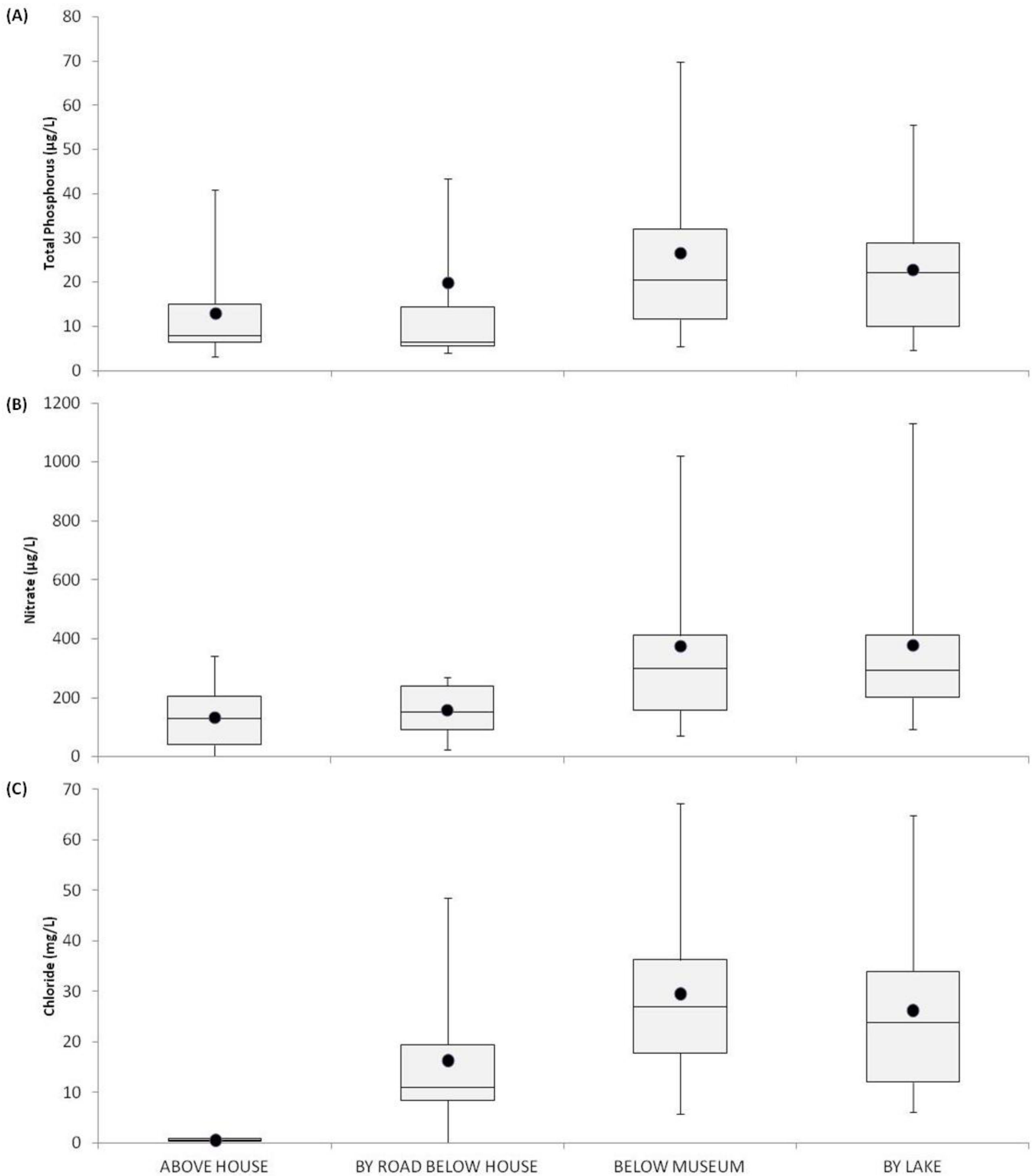


Figure 5. Box plots for total phosphorus (A), nitrate (B), and chloride (C) concentrations from water samples collected from 2010 to 2013 at four sampling stations along Museum Brook.

find out if the Adirondack Museum uses salt. Variation in analyte concentrations results from a combination of natural seasonal changes associated with weather and biogeochemical processes overlaid by human impacts within the watershed. This variation can make it difficult to observe impacts if samples aren't collected at the right time. Thus we further recommend that conductivity and stage sensors be installed near the outlet of Museum Brook to obtain the high resolution data necessary to observe impacts. Lastly, we don't support continued monitoring of fecal coliform in this tributary as this data is very difficult to interpret (e.g. sources?) and a significantly greater sampling effort would be needed to yield meaningful results.

Results and Discussion for Potter Brook

Acidity (pH) ranged from 4.64 to 6.00 and averaged 5.63 at the outlet in 2013 (Table 5). Potter Brook was considerably more acidic than the least impacted streams, with pH values of Potter Brook generally in the lowest 25% of the distribution (Table 6). Alkalinity ranged from 4.4 to 20.9mg/L and averaged 10.6mg/L at the outlet in 2013. Alkalinity at the outlet of Potter Brook was in the upper third of the range of values for the least impacted streams. Total phosphorus ranged from 1.3 to 9.4µg/L and averaged 5.5µg/L at the outlet in 2013. Total phosphorus concentrations at the outlet of Potter Brook were within the range of values for the least impacted streams. Calcium ranged from 2.7 to 6.8mg/L and averaged 4.3mg/L at the outlet in 2013. Calcium concentrations at the outlet of Potter Brook were within the range of values for the least impacted streams. Sodium ranged from 5.5 to 25.0mg/L and averaged 11.8mg/L at the outlet in 2013. Sodium concentrations at the outlet of Potter Brook were over ten times greater than values for the least impacted streams. Nitrate ranged from 120 to 248µg/L and averaged 208µg/L at the outlet in 2013. Nitrate concentrations at the outlet of Potter Brook were higher than 50% of the samples from least impacted streams. Chloride ranged from 8.3 to 33.8mg/L and averaged 16.4mg/L at the outlet in 2013. Chloride concentrations at the outlet of Potter Brook were about fifteen times greater than values for the least impacted streams. Conductance ranged from 42.7 to 166.8µg/L and averaged 83.2µg/L at the outlet in 2013. Conductance at the outlet of Potter Brook was about 2.5 times greater than values for the least impacted streams. Color ranged from 2 to 75Pt-Co units and averaged 41Pt-Co units at the outlet in 2013. Color at the outlet of Potter Brook was within the range of values for the least impacted streams.

There was a weak overall negative trend in total phosphorus concentration at the seven sampling locations in Potter Brook from May through September in 2013 (Figure 6A). Total phosphorus concentrations at the seven sampling locations were similar in late May. This was followed by some separation in the summer and then a general decline in concentration to convergence of all stations in September, with the exception of stations 4 and 7 which were dry. Total phosphorus concentrations at all stations but station 4 were within the range of concentrations observed for other least-impacted streams (Table 6). In fact the September concentrations were below the laboratory detection limit.

There was a general trend of increasing conductivity at the seven sampling locations in Potter Brook from May through September in 2013 (Figure 6B). The lowest conductivity was observed at the least-impacted locations (stations 6 and 7), followed by stations 4 and 5. Conductivity was higher at stations 1 and 2 for all five sampling dates and at station 3 in September. A slight dip in conductivity was observed in July at stations 1, 2, and 3. Conductivity values at the least-impacted locations (station 6 and 7) and at stations 4 and 5 were well within the range of values observed for other least-impacted streams. Conductivity values downstream of stations 4 and 5 were considerably higher than observations for other least impacted streams (Table 6).

Table 5. Chemistry of water samples collected at the outlet of Potter Brook in 2013.

Analyte	Sampling Date					Average
	5/29	6/18	7/25	8/12	9/25	
pH	5.92	6.00	4.64	5.81	5.76	5.63
Alkalinity (mg/L)	4.4	5.5	7.9	14.0	20.9	10.6
Total Phosphorus (µg/L)	3.3	9.4	9.1	4.5	1.3	5.5
Calcium (mg/L)	2.8	2.7	4.2	5.0	6.8	4.3
Sodium (mg/L)	5.6	5.5	8.4	14.5	25.0	11.8
Nitrate (µg/L)	235	120	248	196	241	208
Chloride (mg/L)	9.0	8.3	11.5	19.4	33.8	16.4
Conductance (µS/cm)	45.4	42.7	63.8	97.5	166.8	83.2
Color (Pt-Co)	17	69	75	40	2	41

There was a general trend of increasing alkalinity at the seven sampling locations in Potter Brook from May through September in 2013 (Figure 6C). The lowest alkalinity was observed at station 6. The highest alkalinity values were observed at stations 1, 2, and 3. A slight dip in alkalinity was observed in July at most stations. Alkalinity values at stations 5, 6 and 7 were well within the range of values observed for other least-impacted streams, while alkalinity values at the other stations were generally higher than observations for other least impacted streams (Table 6).

There was no trend apparent in nitrate concentrations in Potter Brook in 2013 (Figure 6D). Stations 1, 2, 3, 5, and 6 had similar nitrate concentrations, which fluctuated between 125 and 280µg/L. Nitrate concentrations in May at stations 4 and 7 were similar to the other stations, but then dropped to about 50µg/L in August, when the last sample was collected before the left branch dried out. Nitrate concentrations at stations 1, 2, 3, 5, and 6 were higher than 75% of observations from other least impacted streams, while nitrate concentrations at stations 4 and 7 were within the range observed for least impacted streams (Table 6).

There were general trends of increasing sodium and chloride concentrations at stations 1, 2, and 3 in Potter Brook from May through September in 2013 (Figure 6E and 6F). No trends in sodium or chloride were apparent at the other stations. Sodium and chloride concentrations were higher at stations 1 and 2 for all five sampling dates. Sodium and chloride concentrations at station 3 where similar to the upstream stations in May and June and then rose steadily through the summer to about one-third of the concentrations observed at stations 1 and 2. Slight dips in sodium and chloride concentrations were observed in July at stations 1, 2, and 3. Sodium and chloride concentrations upstream of station 3 were within the range of observations for other least-impacted streams, while concentrations at stations 1, 2 and 3 were considerably higher than observations for other least impacted streams (Table 6).

Total phosphorus nitrate, and chloride were chosen for display in box plots since the first two are important limiters of lake productivity and the remaining analytes all follow the same trend as chloride. The box plots show the same basic trends for all three analytes between sampling stations as the 2013 data (Figure 7). The shaded area in each box contains 50% of the data, the horizontal line within each box represents the median value, the vertical bars denote the data range, and the black circles are the means. There were no trends in mean concentrations of total phosphorus and nitrate moving downstream from stations 6 (Dirt Road) and 7 (Logging Road) to the Potter Brook outlet at station 1 (By Lake). The box plots also showed that the concentrations of these analytes were similar down through the watershed. It is particularly interesting to note the high degree of similarity in total phosphorus between station 4 (Left Branch) and station 7, with station 7 being the least-impacted location monitored in the brook. It is also interesting to note that station 4 had consistently lower nitrate than the other stations. Chloride concentrations increased downstream of stations 4 and 5 (Right Branch) and were very similar upstream of station 3 (RT 28/30 Culvert). The box plots for chloride showed a high degree of similarity between stations 1 and 2. There was a large amount of variation in analyte concentrations. For example, total phosphorus at station 7 ranged from 1 to 340µg/L and nitrate concentration at this same station ranged from 50 to 475µg/L.

The increasing trends observed through time for the analytes shown in Figure 6 were likely in response to decreasing stream flow through the summer. The noticeable dips observed in July for some analytes were likely in response to an increase in stream flow in response to rainfall events, which would have diluted the analytes: the weather station at Tupper Lake reported about 7cm of rainfall in the 10 days preceding the July sampling date. Note the dips observed in Potter Brook were less obvious than the dips observed in Museum Brook. Museum Brook is likely to be more responsive to rainfall than Potter Brook, since the Potter Brook watershed contains fewer impervious surfaces and more wetlands than the Museum Brook watershed. The lack of downstream trends in total phosphorus and nitrate concentrations suggests that development in the Potter Brook watershed did not have a measureable impact on nutrient inputs. Elevated values for the other analytes downstream of stations 4 and 5 were largely a result of road salting, though a portion of the higher conductivity may be attributed to other pollutants (e.g. septic runoff and fertilizer). Conductivity is a surrogate measure of dissolved ions in water and thus the pattern observed in conductivity largely reflects the increased concentrations of sodium and chloride from road salting (Daley et al. 2009). The sodium and chloride concentrations measured at stations 4 to 7 were both less than 1mg/L, and within the expected range for least-impacted watersheds in the Adirondacks (Kelting et al. 2012). The increased concentrations of these ions at station 3 and the further increases observed downstream at stations 1 and 2 reflects higher road salt loads as more road length is included in the watershed. The fact that higher sodium and chloride concentrations were also observed in May at stations 1 and 2 suggests further that salt has accumulated in the watershed. The pattern of increased alkalinity at stations 1 and 2 is also likely explained by road salt, as these ions plus others displaced from soils by salt increase alkalinity (Rosfjord et al. 2007).

Fecal coliform samples were collected at stations 2, 3, 4, and 6 on July 24th. The coliform count was 340colonies/100mL at station 2, 250colonies/100mL at station 3, 250colonies/100mL at station 4, and 200colonies/100mL at station 6. Station 2 was sampled again on 9/25 and the coliform count was 12colonies/100mL. Station 3 was also sampled on 9/25 and the coliform count was 15colonies/100mL. Station 6 was also sampled on 9/25 and the coliform count was 15colonies/100mL. Samples did exceed various thresholds for designated uses, even the least impacted location at station 6, which was located downstream of beaver ponds. These results show that fecal coliform is highly variable in space and time, which makes it difficult to interpret the data.

Monitoring Recommendations

The results clearly show that stations 1 and 2 are very similar. This finding makes sense given that station 1 is located only about 75m downstream of station 2. State Route 28 does cross the stream between these stations, this explains the generally higher concentrations of sodium and chloride at station 1 compared to station 2. But, despite picking up the influence of the road the additional insight provided by station 2 is marginal and thus we recommend dropping this station. As was previously stated, variation in analyte concentrations results from a combination of natural seasonal changes associated with weather and biogeochemical processes overlaid by human impacts within the watershed. This variation can make it difficult to observe impacts if samples aren't collected at the right time. Thus we further recommend that conductivity and stage sensors be installed near the outlet of Potter Brook to obtain the high resolution data necessary to observe impacts. Lastly, we don't support continued monitoring of fecal coliform in this tributary as this data is very difficult to interpret (e.g. sources?) and a significantly greater sampling effort would be needed to yield meaningful results.

Table 6. Comparison of average analyte concentrations in Museum Brook and Potter Brook to the range of concentrations observed in four least impacted Adirondack streams during the same time period in 2013.

Analyte	Blue Mtn. Streams		Least Impacted Adirondack Streams				
	Museum	Potter	Min	Q 1	Median	Q 3	Max
pH	5.37	5.63	5.18	6.25	6.58	6.85	7.21
Alkalinity (mg/L)	6.5	10.6	1.7	4.4	7.7	10.1	15.8
Total Phosphorus (µg/L)	14.5	5.5	0.5	3.6	7.1	11.5	29.6
Calcium (mg/L)	3.5	4.3	1.5	2.8	3.5	4.0	5.6
Sodium (mg/L)	16.0	11.8	0.5	0.7	0.9	1.1	1.4
Nitrate (µg/L)	215	208	6	35	99	149	300
Chloride (mg/L)	23.0	16.4	0.1	0.3	0.5	0.7	1.5
Conductance (µS/cm)	98.6	83.2	11.3	18.5	22.2	30.1	38.3
Color (Pt-Co)	79	41	0	21	43	72	169

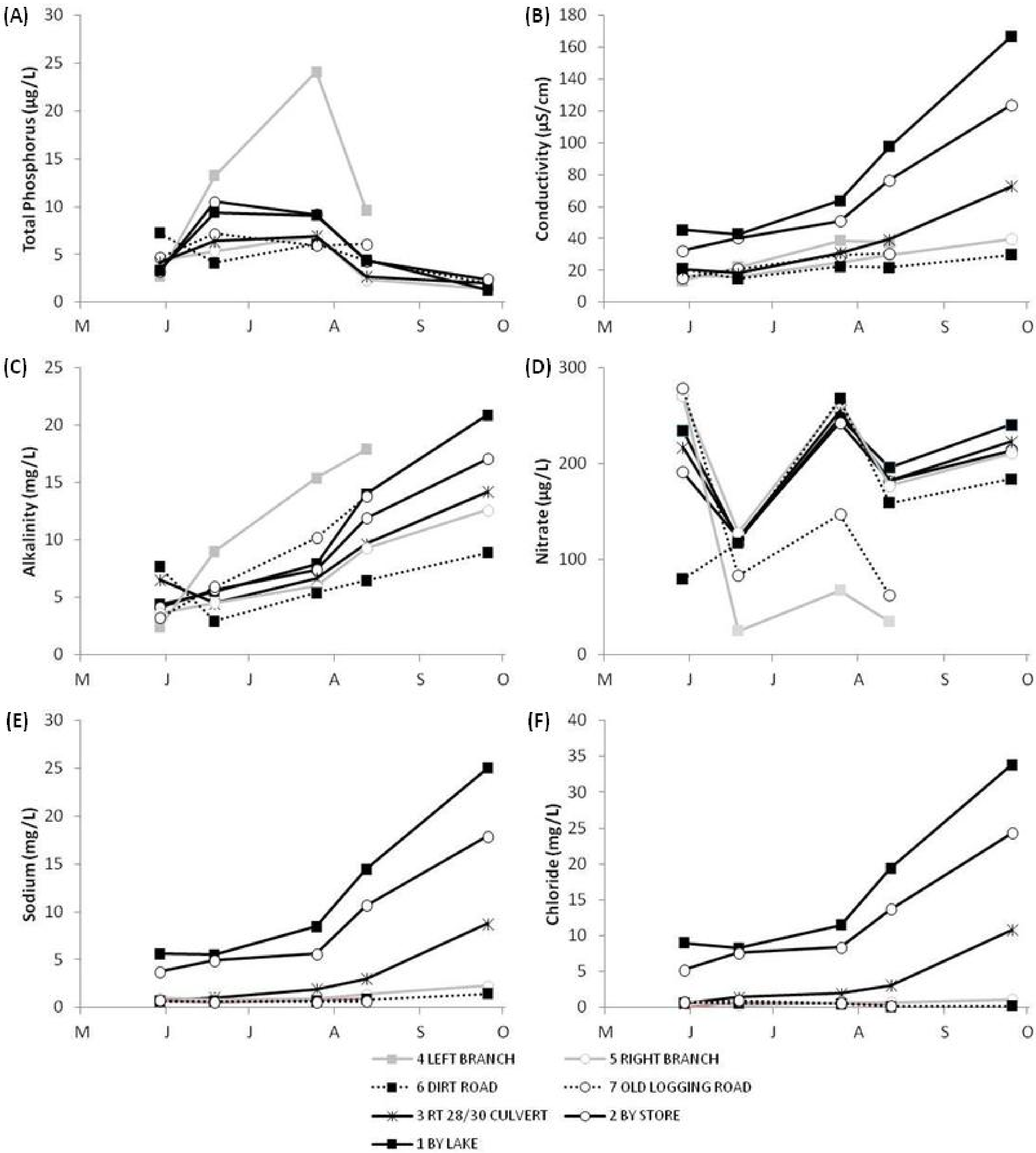


Figure 6. Chemistry of water samples collected at seven sampling stations along Potter Brook in 2013.

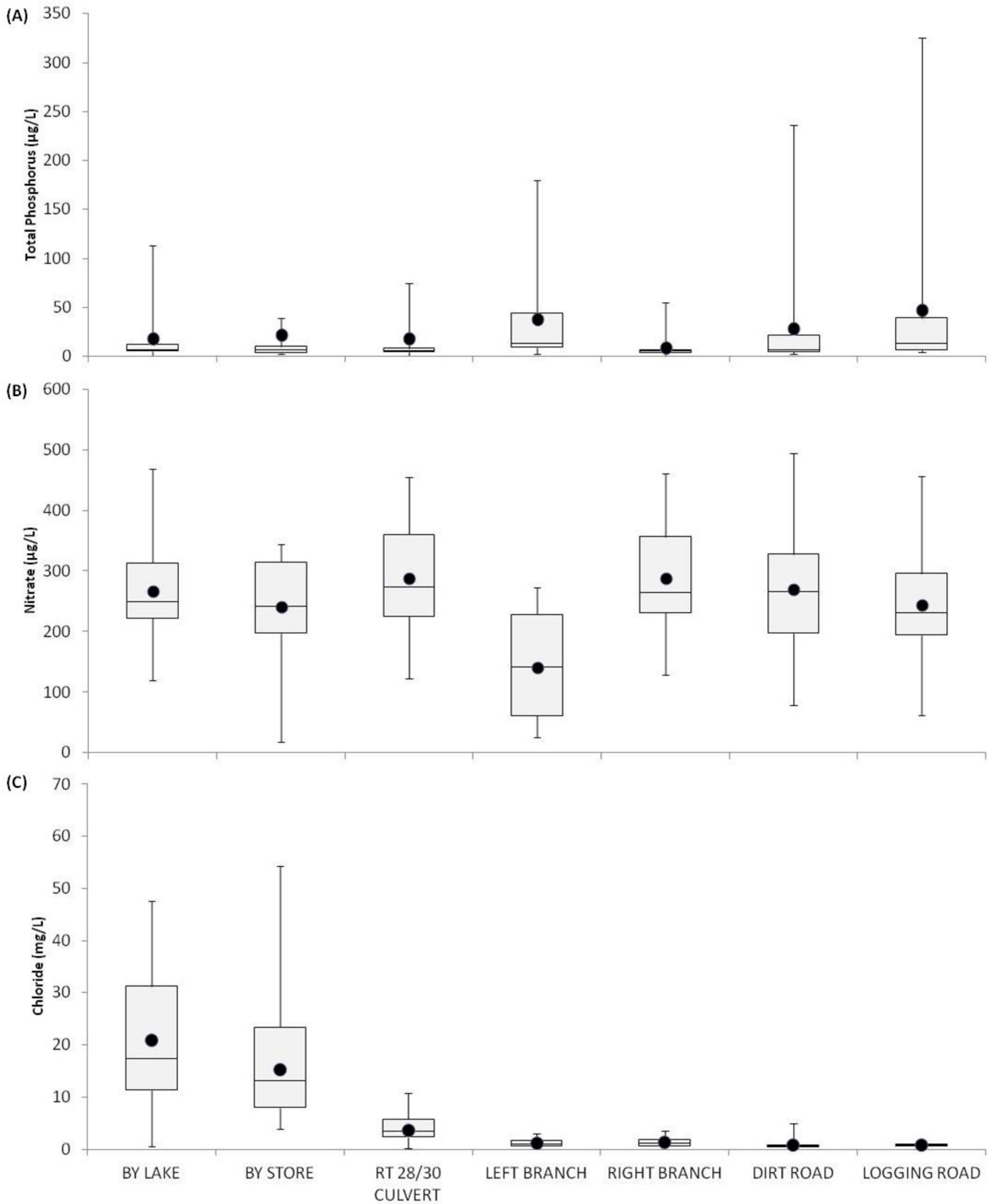


Figure 7. Box plots for total phosphorus (A), nitrate (B), and chloride (C) concentrations from water samples collected from 2010 to 2013 at seven sampling stations along Potter Brook.

Phosphorus Load Estimates

Average total phosphorus loads from Museum Brook ranged from 0.07 to 0.17kg/ha/yr from 1998 to 2013 (Figure 8), with no significant positive or negative trend in the estimates (p=0.121). Total phosphorus load averaged 0.12kg/ha/yr across all years for Museum Brook. Average total phosphorus loads from Potter Brook ranged from 0.03 to 0.26kg/ha/yr from 1998 to 2013, with no significant positive or negative trend in the estimates (p=0.206). Total phosphorus load averaged 0.11kg/ha/yr across all years for Potter Brook. The degree of confidence in the annual total phosphorus load estimates varied greatly by year for both streams, as illustrated by the variation in widths of the 95% confidence intervals. For example, the 95% confidence intervals on the 2001 loading estimates ranged from 0.02 to 0.33kg/ha/yr for Museum Brook and from -0.14 to 0.67kg/ha/yr for Potter Brook. In fact, the confidence intervals bracketed zero for Potter Brook in three years and were close to bracketing zero in two years.

We have been monitoring total phosphorus loads in least impacted streams the Upper Saranac Lake watershed since 2007. Our total phosphorus loading estimates in these least impacted streams ranged from 0.14 to 0.23kg/ha/yr over this period (Kelting and Laxson 2014a). During this same period total phosphorus loading estimates ranged from 0.07 to 0.15kg/ha/yr for Museum Brook and from 0.03 to 0.22kg/ha/yr for Potter Brook (Figure 8). This comparison suggests that developed areas within the Museum Brook and Potter Brook watersheds do not contribute additional phosphorus beyond what should be expected from least impacted streams. However, a local least impacted benchmark stream and significantly better stream discharge and nutrient concentration data would be needed to have confidence in this statement for Blue Mountain Lake.

Conclusions and Recommendations

The Blue Mountain Lake stream monitoring program was established primarily to understand the water quality of the lake itself. We observed elevated concentrations of total phosphorus and nitrate in Museum Brook at stations located downstream of the developed portion of the watershed. The sources of these elevated concentrations likely include a combination of permitted and septic discharge. Despite the elevated concentrations of these nutrients, total phosphorus loads from Museum Brook were within the range of data available for least impacted streams, which suggested no cause for concern. However, given the large amount of variation in the loading estimates and the lack of a local least impacted benchmark stream, a strong conclusion cannot be made. The same holds for Potter Brook which had even more variation in the loading estimates. The one strong conclusion is that road salting has altered the chemistry of both brooks and by extension the lake. The drainage areas for Museum Brook and Potter Brook represent only 20% of the total watershed area of Blue Mountain Lake, thus a significant portion of the watershed is not currently monitored. We recommend expanding the stream monitoring program to include the five major streams depicted in Figure 2. Inclusion of Beaver Brook provides the local least impacted stream needed to benchmark the other streams. We recommend further that the outlets of each stream be instrumented with conductivity and stage sensors to obtain the high resolution data necessary to observe impacts and to estimate nutrient and salt loads.

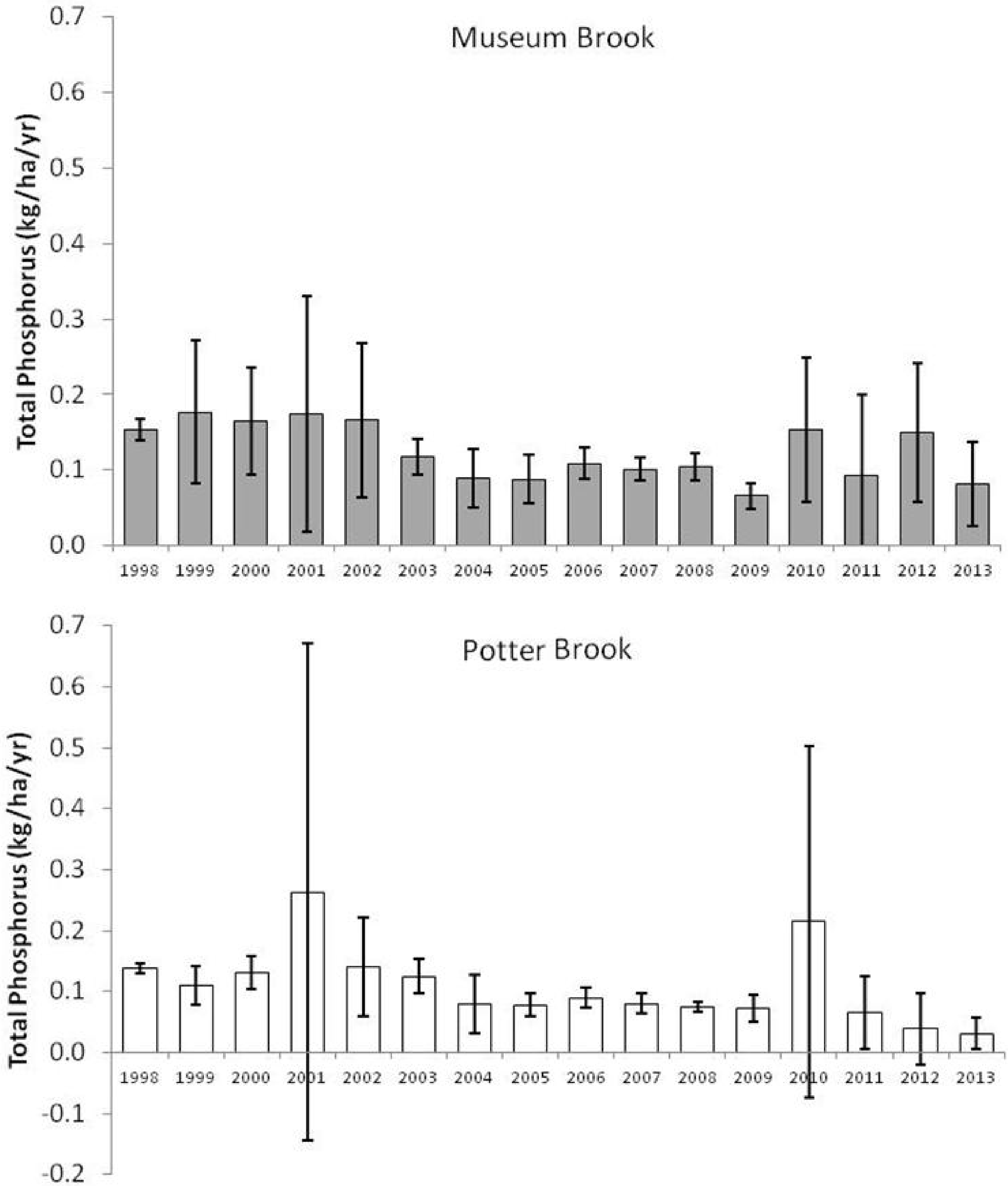


Figure 8. Annual total phosphorus load estimates for Museum Brook (top panel) and Potter Brook (bottom panel). Vertical bars represent 95% confidence intervals for the estimated loads.

Literature Cited

Daley, M.L., J.D. Potter, and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: effects of road salt and hydrologic variability. Journal of the North American Benthological Society, 28(4):929–940.

Kelting, D.L., C.L. Laxson, and E.C. Yerger. 2012. A regional analysis of the effect of paved roads on sodium and chloride in lakes. Water Research, 46(8):2749-2758.

Kelting, D.L., and C.L. Laxson. 2014a. Upper Saranac Lake: 2013 Water Quality Report. Adirondack Watershed Institute of Paul Smith's College. Report No. PSCAWI 2014-67. 44p.

Kelting, D.L., and C.L. Laxson. 2014b. Adirondack Lake Assessment Program: 2013 Report, Blue Mountain Lake. Adirondack Watershed Institute of Paul Smith's College. Report No. PSCAWI 2014-59. 23p.

Rosfjord, C.H., K.E., Webster, J.S., Kahl, S.A., Norton, I.J., Fernandez, and A.T. Herlihy. 2007. Anthropogenically driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acid deposition. Environmental Science and Technology 41(22), 7688-7693.