



NYSERDA

A Long-Term Monitoring Program for Evaluating Changes in Water Quality in Selected Adirondack Waters

Program Summary

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A Long-Term Monitoring Program for Evaluating Changes in Water Quality in Selected Adirondack Waters

Program Summary Report 2013

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Notice

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About the Adirondack Lakes Survey Corporation

The Adirondack Lakes Survey Corporation (ALSC) was established in 1983 to undertake comprehensive biological and chemical surveys of Adirondack waters; to study the water quality and the effect of acid rain; and to disseminate this information and contribute to scientific understanding through studies and reports. For over 30 years, the ALSC has carried out this scientific and technical mission by conducting monitoring of surface water chemistry and fish; making these data available to the public and scientific community; and contributing to studies regarding acidification in the Adirondacks. The ALSC operates out of the New York State Department of Environmental Conservation (NYSDEC) Region 5 headquarters in Ray Brook, NY. To conduct its mission, the ALSC receives support from three sources: the New York State Energy Research and Development Authority (NYSERDA), NYSDEC, and the United States Environmental Protection Agency (USEPA).

The ALSC remains current and responds to the needs of the scientific community through improvements in its field, laboratory, and data processing capabilities. Field sampling is conducted year-round throughout the Adirondack Park under a variety of field conditions. Staff is experienced in the collection of fish, sediment cores, and water samples for routine chemistry and ultra-clean sampling for mercury analysis. The laboratory is equipped to analyze over 20 chemical parameters. The data processing department is skilled in the analysis and delivery of a wide range of digital products.

Acknowledgments

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Acronyms and Abbreviations

$\mu\text{eq L}^{-1}$	microequivalent per liter
$\mu\text{g kg}^{-1}$	microgram per kilogram
$\mu\text{g m}^{-2}$	microgram per square meter
$\mu\text{mol C L}^{-1}$	micromole carbon per liter
$\mu\text{mol L}^{-1}$	micromole per liter
$\mu\text{S cm}^{-1}$	microsiemens per centimeter
AEAP	Adirondack Effects Assessment Program
AI IM	inorganically complexed aluminum
AI OM	organically complexed aluminum
ALS	Adirondack Lakes Survey (1980s)
ALSC	Adirondack Lakes Survey Corporation
ACLP	Adirondack Cooperative Loon Project
AEAP	Adirondack Effects Assessment Program
AERP	Adirondack Episodic Response Project
AI TD	total dissolved aluminum
AI TM	total monomeric aluminum
ALTM	Adirondack Long Term Monitoring Program
AMMP	Adirondack Manipulation and Modeling Project
ANC_{calc}	Acid Neutralizing Capacity by calculation
ANC	Acid Neutralizing Capacity by gran titration
APA	Adirondack Park Agency
ASRC	Atmospheric Sciences Research Center
BCS	base cation surplus
C_A	summed concentration of acid anions
Ca^{2+}	calcium ion
CaCl_2	calcium chloride
CASTNET	Clean Air Status and Trends Network
CB	summed concentration of base cations
CEC	cation exchange capacity
Chl a	Chlorophyll a
Cl^-	chloride ion
$\text{cmol}_{\text{sc}} \text{kg}^{-1}$	centimoles of charge per kilogram
DDRP	Direct/Delayed Response Project
DIC	Dissolved Inorganic Carbon
DOC	Dissolved Organic Carbon
ECASS	East-Central Adirondack Stream Survey (see WASS)
ELS	Eastern Lakes Survey
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency (U.S.)

eq	equivalent
eq ha ⁻¹ yr ⁻¹	equivalent per hectare per year
eq L ⁻¹	equivalent per liter
ERP	Episodic Response Project
F ⁻	fluoride ion
g	grams
GLAD PBT	Great Lakes Acid Deposition persistent, bio-accumulative toxic
GIS	Geographic Information System
H ⁺	hydrogen ion
ha	hectare
Hg	elemental mercury
IMAl	inorganic monomeric aluminum
K ⁺	potassium ion
kg	kilogram
km	kilometer
LAB pH	laboratory pH
LAMP	Lakes Acidification Mitigation Project
LTM	Long Term Monitoring Program
LWC	liquid water content
m	meter
MADPro	Mountain Cloud Acid Deposition Program
MDN	Mercury Deposition Network
MeHg ⁺	methylmercury
mg L ⁻¹	milligrams per liter
mg L ⁻¹ -C	milligrams per liter as carbon
mg m ⁻³	milligrams per cubic meter
Mg ²⁺	magnesium ion
mL	milliliter
mm	millimeter
mmol L ⁻¹	millimole per liter
na	not available
Na ⁺	sodium ion
NAAQ	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
NAPAP	National Acid Precipitation Assessment Program
ng g ⁻¹	nanograms per gram
NH ₄ ⁺	ammonium ion
NO _x	oxides of nitrogen
NO ₃ ⁻	nitrate ion
NOAA	National Oceanic and Atmospheric Administration

NTN	National Trends Network
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSERDA	New York State Energy Research and Development Authority
pH	negative logarithm of hydrogen ion concentration
Pt Co	platinum cobalt
RILWAS	Regional Integrated Lake-Watershed Acidification Study
SCONDUCT	specific conductivity
SiO ₂	silica
SO _x	oxides of sulfur
SO ₂	sulfur dioxide
SO ₄ ²⁻	sulfate ion
ST	Speckled trout
SUNY-ESF	State University of New York College of Environmental Sciences and Forestry
SUVA ₂₅₄	specific ultraviolet absorbance at 254nm
TIME	Temporally Integrated Monitoring of Ecosystems
TOC	total organic carbon
TP	total phosphorus
TRUECOLOR	color defined on the platinum cobalt scale
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UVA	ultraviolet absorbance
WASS	Western Adirondack Stream Survey
Water year	The period between October 1 st of one year and September 30 th of the next
YP	yellow perch

Program Overview

The goal of the Adirondack Long Term Monitoring Program (ALTM) is to provide surface water chemistry data in the Adirondack region in response to changes in atmospheric deposition of acid rain precursors. The ALTM provides for increased understanding of the processes involved in lake and stream acidification recovery in several ways, including: the interpretation of the chemistry trends across lake classes; additional snowmelt sampling; periodic fisheries surveys; and other biological measurements. It also provides for participation in more intensive investigations at some sites by acquisition of supplemental data and/or by conducting additional field sampling. The monitoring objectives of the current component of the ALTM are: continued sampling and analysis of 52 lakes on a monthly basis; periodic lake fisheries resurveys; annual summer sampling 43 lakes as part of a cooperative project with USEPA under the Temporally Integrated Monitoring of Ecosystems (TIME); stream monitoring at four locations on a bi-weekly basis as part of a cooperative project with USGS; summer cloud water sampling and analysis from measurements made at the summit of Whiteface Mountain; weekly wet deposition sampling at Wanakena, NY; and analysis of selected lake samples for regional fisheries management. We also briefly report on major additional stream sampling conducted with the USGS during the years 2003-2011. Stream results are reported at water year intervals (i.e. Oct 1 - Sept 30) in contrast with lakes results that are reported on calendar year (i.e. Jan 1- Dec 31) intervals.

Data are posted on the ALSC website (www.adirondacklakessurvey.org), following appropriate quality assurance checks and clearance by the ALSC Program Manager and the NYSDEC Research Manager. This report describes the major core areas of work contained in the 2007–2013 program plan and the data available through December 2012. This report is intended as an update on the ongoing ALTM work that will include updated datasets. Still, there is an inherent time lag in the analysis of the data and the reporting of the data. For each program element, site selection and sampling design as well as highlights of recent results are provided along with key references. Questions on this report can be directed to:

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Adirondack Long Term Monitoring (ALTM) Lakes

The Adirondack Long Term Monitoring (ALTM) program was initiated in 1982 to evaluate monthly chemistry of 17 Adirondack lakes. The lakes were selected from the Regionalization of the Integrated Lake Watershed Acidification Study (RILWAS) (Driscoll and van Dreason 1993). From 1984 to 1987 an intensive chemical and biological survey of 1469 lakes within the Adirondack Park was undertaken by the Adirondack Lakes Survey Corporation (ALSC). Following the completion of the interpretive analysis the ALTM was expanded to 52 lakes to provide a better representation of lakes across the region (Figure 1) (Baker et al. 1990). The expanded lake set was, in part, based on the lake classification system developed by Newton and Driscoll (1990). Monthly sampling of the 52 lakes began in June 1992 (Table 1).

Figure 1. Location of 52 ALTM lakes sampled monthly by the ALSC



Table 1. ALTM lake characteristics and identification of lakes included in: the original 17 ALTM lakes (Record Start 1982); lakes sampled during the Adirondack Lakes Survey (1984–1987)(ALS survey); and the EPA TIME/LTM project cross over lakes (TIME)

Ref #	ALTM Pond Name	Record Start 1982	Classification	DOC ^a	Lake Elev (m)	Surface Area (ha)	ALS Survey	Limed	TIME	Outlet Pair	Snowmelt
050684	Arbutus Lake	X	Medium Till Drainage	low	516	48.9					
050707	Avalanche Lake		Thin Till Drainage	low	873	4.4	A				
040905	Barnes Lake	X	Mounded Seepage	high	395	2.9	A	L			
020059	Big Hope Pond		Medium Till Drainage	high	517	8.9	A		T		S
040752	Big Moose Lake	X	Thin Till Drainage	low	558	512.5					
030255	Black Pond Stream	X	Thick Till Drainage	low	495	29.0	A			O	
040874	Brook Trout Lake		Thin Till Drainage	low	724	28.7	A				
040748	Bubb Lake Stream	X	Thin Till Drainage	low	554	18.2	A			O	S
050669	Carry Pond		Mounded Seepage	low	652	2.8	A				
040747	Cascade Lake Stream	X	Medium Till Drainage	low	557	40.4	A			O	
050458	Clear Pond	X	Thick Till Drainage	low	584	70.4	A				
040777	Constable Pond Stream	X	Thin Till Drainage	low	580	20.6	A			O	
040750	Dart Lake	X	Thin Till Drainage	low	537	51.8	A				
020138	East Copperas Pond		Thin Till Drainage	high	480	3.6	A				S
070859	G Lake		Thin Till Drainage	low	620	32.2					
030171	Grass Pond		Mounded Seepage	high	381	1.6	A				
040706	Grass Pond		Medium Till Drainage	low	549	5.3	A				
020264	Heart Lake	X	Medium Till Drainage	low	661	10.7	A				S
040852	Indian Lake		Thin Till Drainage	low	654	33.2	A		T		
050259	Jockeybush Lake		Thin Till Drainage	low	599	17.3	A				
050706	Lake Colden		Thin Till Drainage	low	843	15.4	A				
040739	Lake Rondaxe	X	Thin Till Drainage	low	524	90.5	A				
040826	Limekiln Lake		Medium Till Drainage	low	575	186.9	A				
030172	Little Clear Pond		Mounded Seepage	low	381	1.9	A	L			
020126	Little Echo Pond	X	Mounded Seepage	high	482	0.8					S
020058	Little Hope Pond		Medium Till Drainage	high	517	2.8	A				
060182	Little Simon Pond		Medium Till Drainage	low	546	58.1	A	L			
050649	Long Pond		Thin Till Drainage	high	574	1.7	A				
040186	Loon Hollow Pond		Thin Till Drainage	low	605	5.7	A				
040887	Lost Pond		Thin Till Drainage	high	717	4.4	A				
020265	Marcy Dam Pond		Thin Till Drainage	low	720	1.2	A				
040707	Middle Branch Lake		Thin Till Drainage	low	496	17.0	A				
020143	Middle Pond		Carbonate Influenced	high	483	24.3	A				S
040704	Middle Settlement Lake		Thin Till Drainage	low	526	15.8	A				
040746	Moss Lake	X	Medium Till Drainage	low	536	45.7	A				S
050577	Nate Pond		Medium Till Drainage	high	613	8.3	A				
041007	North Lake		Thin Till Drainage	low	555	176.8	A		T		
070728	Otter Lake Stream	X	Thin Till Drainage	low	505	14.8				O	
020233	Owen Pond		Thick Till Drainage	low	514	7.6	A				S
060329	Queer Lake		Thin Till Drainage	low	597	54.5	A				
060315A	Raquette Lake Reservoir		Medium Till Drainage	high	564	1.5	A				S
060313	Sagamore Lake		Medium Till Drainage	high	580	68.0	A				S
020197	Sochia Pond		Mounded Seepage	low	495	1.6	A				
041004	South Lake		Thin Till Drainage	low	617	197.4			T		
040754	Squash Pond Stream	X	Thin Till Drainage	high	653	3.3	A			O	
040850	Squaw Lake		Thin Till Drainage	low	646	36.4	A		T		
020188	Sunday Pond		Mounded Seepage	low	495	4.0	A				S
040753	West Pond Stream	X	Thin Till Drainage	low	581	10.4	A			O	S
050215	Willis Lake		Medium Till Drainage	low	400	14.6	A				
040210	Willys Lake (Horseshoe)		Thin Till Drainage	low	632	24.3	A		T		
040750A	Windfall Pond Stream	X	Carbonate Influenced	low	591	2.4	A			O	
040576	Woods Lake		Thin Till Drainage	low	605	24.7		L			

^a Dissolved Organic Carbon

Site Description

Descriptions of the Adirondack region, the ALTM study sites, sample collection and analytical procedures are available in Driscoll and van Dreason (1993), Driscoll et al. (2003), and Chen and Driscoll (2005). Eight of the original 17 lakes (1982) were sampled, not directly on the lake outlet, but at varying distances downstream in proximity to an access road. In June 1993, sampling was initiated at the upstream lake outlet sites at these eight locations. Seven of the 52 ALTM lakes (Little Echo Pond, Woods Lake, Big Moose Lake, South Lake, Arbutus Lake, Otter Lake, and G Lake) were not part of the intensive survey performed in 1984–1987 but were added or remained either because they were part of the original 17 ALTM lakes or due to other intensive studies. Within this 52 lake set, the NYSDEC regional fisheries staff actively manage fish stocks in about half of these waters (ALSC 2003). Four lakes (Barnes Lake, Woods Lake, Little Simon Pond, and Little Clear Pond) have a recent history of lake liming and are not included in time series analysis of chemistry data. Table 1 provides a summary of selected lake characteristics, management and sampling information.

The Adirondack region is also one of the USEPA lake water chemistry study areas in the TIME program (Stoddard et al. 2003) described in a separate section of this report. Under this program, the ALSC conducts summer sampling of 43 lakes of which six lakes are common between TIME and ALTM. These are Big Hope Pond, Indian Lake, North Lake, South Lake, Squaw Lake, and Willys Lake (see Table 1). Some of these 43 lakes are also part of the NYSDEC fisheries management lakes.

Sampling Design

The ALTM lakes are sampled monthly. Lakes with no outlets and those accessed by helicopter are sampled at a deep part of the lake at a depth of 0.5 m with a Kemmerer sampler. All other sites are sampled at the outlet by surface grab method. All samples are collected in high density polyethylene bottles. Samples are transported from the field in chilled coolers to the ALSC laboratory in Ray Brook, NY (ALSC 2002a and 2002b).

Samples are analyzed for the following parameters: pH, ANC, specific conductance, color, nitrate, sulfate, chloride, fluoride, calcium, magnesium, potassium, sodium, silica, ammonium, dissolved organic carbon, dissolved inorganic carbon, total dissolved aluminum, total monomeric aluminum, total organic monomeric aluminum, total inorganic monomeric aluminum (calculated), and starting in October 2008, for total phosphorus and chlorophyll a. Analytical procedures follow USEPA standards developed and described elsewhere (Morrison et al. 1991; ALSC 2002a; Driscoll and van Dreason 1993; Burns et al. 2006).

In 2013, budgetary reduction necessities required NYSERDA, NYSDEC, and EPA to re-evaluate the level of support to the ALSC for the Adirondack lakes monitoring effort. The reduced sampling design, which began in January 2014, was based on a NYSERDA report (Levine and Yanai, 2012), and subsequent evaluation and discussion with USEPA, NYSERDA, and NYSDEC regarding the relative value of data types, frequencies, and locations. With a nearly 20-year monthly record, it was determined that sampling frequency could be reduced at some locations while retaining the integrity and value of the data record and the lake monitoring program. Details of the modified schedule are provided in Appendix A.1. In summary, the lake schedule changes were as follows:

- Fifteen lakes were changed to annual sampling during the summer (July or August): Barnes, Carry, Grass (03), Little Hope, Long, Middle, Nate, Owen, Sochia, Sunday, Willis, Windfall and Windfall Stream;
- Nineteen lakes were changed to six times per year (February, April, May, July, September and November): Avalanche, Black Pond, Bubb and Bubb Stream, Cascade and Cascade Stream, Clear Pond, Lake Colden, Dart, East Copperas, G Lake, Limekiln, Loon Hollow, Marcy Dam, Middle Branch, Middle Settlement, Otter and Otter Stream, and Queer;

- Twenty-five remaining lakes will continue on a monthly basis based on several criteria including a) capturing a range of DOC, ANC (pH surrogate), and NO_3^- ; b) strongly increasing DOC sites; and c) involvement in ongoing intensive research projects.

Results

Since baseline monitoring was initiated in 1982, several lake chemistry time series analyses were conducted with the idea of evaluation of changes in atmospheric deposition. These evaluations are a snapshot of changes in chemistry that are attributed, for the most part, to changes in the acidic precursor emissions based upon the potential need for additional action for improvement from a policy framework. The following represents a synopsis of published ALTM chemistry results. These analyses and others were the foundation for assessing acid deposition effects to lake chemistry in the Adirondack region in recent decades. Responses are evaluated relative to lake classes and relationships among parameters. Depending on the length of the time period evaluated, trends in lake chemistry were found to vary as deposition patterns changed.

Chemistry Trends Reported Based Upon 1982 to 1997 Sampling (17 lakes)

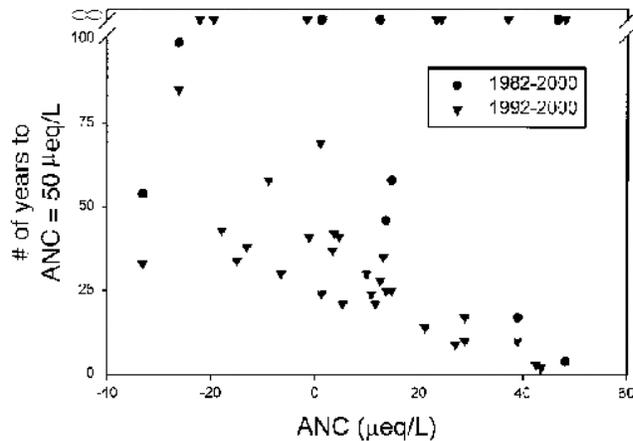
A total of three time periods were analyzed for the original 17 lakes and the results are summarized in this section. The first time series conducted for the period 1982 to 1991 found most lakes exhibiting declines in sulfate concentrations consistent with decreases in SO_2 emissions and SO_4^{2-} in precipitation. ANC levels were continuing to decline in several lakes thought to be due to increasing concentrations of NO_3^- (Driscoll and van Dreason 1993). The next time series conducted for 1982–1994 found continued decline in lake sulfate concentrations, but at rates considerably less than the rate of decline anticipated from atmospheric deposition. The delays in sulfate response were thought to be due to the release of stored sulfate in watershed soils. Lake nitrate concentrations did not show significant trends. No systematic increases in pH or ANC were detected (Driscoll et al. 1995). Similar patterns were observed in time series analysis on the same lakes during 1982–1997. The limited response of lake water ANC and pH were thought to be attributable to several factors, including: the depletion of base cations in soils; additional inputs of sulfate; elevated leaching of nitrates; and/or pH buffering associated with elevated levels of aluminum (Driscoll et al. 1998).

Chemistry Trends 1992–2000 (48 lakes)

The first time series analysis on the expanded 48 ALTM lakes for the 1992–2000 time period found all lakes exhibiting significant decreases in sulfate concentrations that coincided with decreases in atmospheric sulfur deposition. Although atmospheric nitrogen deposition did not change over this period, some lakes exhibited decreases in nitrate concentrations. These declines contributed to increases in ANC and pH in over half of the lakes. Increasing DOC concentrations were observed in 20% of the lakes. In some lakes, monomeric aluminum shifted from toxic inorganic species to less toxic organic forms. Nevertheless, in 2000, 16 out of 48 lakes showed inorganic monomeric aluminum concentrations above $2 \mu\text{mol L}^{-1}$, a value known to be toxic to many organisms including juvenile forms of Adirondack fish. Extrapolation of rates of lake ANC increase (Figure 2) suggested that the time frame of chemical recovery is on the order of decades at current rates of decrease in acidic deposition (Driscoll et al. 2003).

Figure 2. Time for ANC to reach critical value of 50 $\mu\text{eq L}^{-1}$

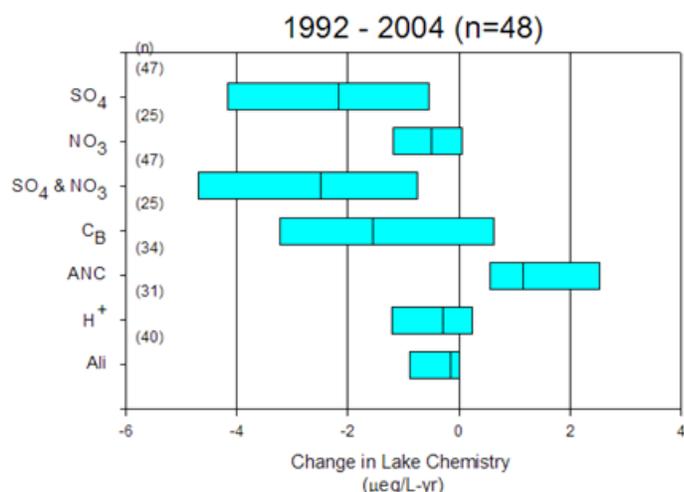
Time for lakes to reach ANC values of 50 $\mu\text{eq L}^{-1}$ as a function of ANC value in the year 2000. These values are extrapolated based on the slope of ANC change from time series analysis assuming a linear rate of change. The extrapolation was done for two intervals, 1982–2000 (six lakes) and 1992–2000 (28 lakes) for those waters where ANC trends were significant. Lakes with 50 $\mu\text{eq L}^{-1}$ or greater in 2000 are not shown here. The rates of ANC increase were generally greater when calculated over the later interval (example Big Moose Lake long interval rate is approximately 45 years, but over the shorter record is only 25 years to achieve 50 $\mu\text{eq L}^{-1}$).



Chemistry Trends 1992–2004

Four years later, time series showed continued decreases in precipitation sulfate and hydrogen ions and decreases in lake water sulfate continuing at an average 2.2 $\mu\text{eq L}^{-1} \text{yr}^{-1}$. This rate is similar to values reported in eastern North America and Europe. The lake sulfate decreases were not uniform over the monitoring period coinciding with reduced rates of SO_2 emissions and wet sulfate deposition. Lake nitrate concentrations are declining in 27 lakes and increasing in three. The mechanism contributing to the apparent increase in lake watershed nitrogen retention is not evident. ANC and pH are increasing in 34 and 31 lakes, respectively. Base cations are decreasing in half of the lakes, largely due to decreases in calcium concentrations (Figure 3). Decreases in monomeric aluminum concentrations are largely occurring in thin till lakes. DOC changes are less distinct decreasing in 15 lakes while increasing in four lakes (Driscoll et al. 2007).

Figure 3. Mean rates of change in solute concentrations 1992–2004



Chemistry Trends 1992–2008 and Ongoing

In 2013, the ALTM program conducted Seasonal Kendall tests (SKT) on all lake water solute concentrations according to methods described in Raynal et al. 2004. This was done in collaboration with C.T. Driscoll and K.M. Driscoll. Appendix A provides results of SKT time-series analysis for the 48 ALTM lakes through 2000 and 2004 and annually to 2012. The values are expressed as a rate of change (median slope as $\mu\text{eq L}^{-1} \text{yr}^{-1}$; for aluminum, DIC, DOC, SiO_2 as $\mu\text{mol L}^{-1} \text{yr}^{-1}$). Only statistically significant trends ($p < 0.05$) are reported. The 2000 and 2004 results cover the time period from June 1992 to December, tracking the published papers. The annual updates beginning in 2005 cover the time period from June 1992 to May of the following year. Generally, the time series patterns have been consistent over recent years, however the rates of change have been declining (e.g. sulfate, nitrate and ANC). The number of lakes with significant levels of increasing DOC increased from 18 in 2009 to 30 lakes in 2011 and 27 lakes in 2012 (Appendix A). Table 2 contains a summary of trends (1992 - 2012) for selected parameters.

Table 2. Summary of trends (1992-2012) for selected parameters (n = 48 lakes)

Parameter	Lakes		Range		Mean	Units
	Increasing	Decreasing	Low	High		
Sulfate		48	-0.89	-4.08	-2.51	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
Nitrate		31	-0.02	-1.10	-0.33	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
CB		42	-0.30	-2.73	-1.44	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
CB	1		0.27	0.27	0.27	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
ANC	41		2.07	0.29	0.96	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
Lab pH	32		0.04	0.00	0.02	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
AL IM		42	0.00	-0.63	-0.12	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
AL TM		32	-0.02	-0.62	-0.17	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
DOC		4	-1.31	-11.17	-5.47	$\mu\text{eq L}^{-1} \text{yr}^{-1}$
DOC	27		12.35	1.97	5.08	$\mu\text{eq L}^{-1} \text{yr}^{-1}$

Plots of selected chemical parameters for Big Moose Lake are provided (Figure 4). The plots are updated through December 2013 and include weekly data (red) collected during snowmelt (March and April). In 2009, despite the lowest concentrations of sulfate and nitrate observed since the onset of sampling in 1982, the ANC values remain below 20 and pH below 6 for the first half of the year, which coincides with the detection of toxic inorganic monomeric aluminum. However, recent data show the monthly and the weekly snowmelt values (red) have been chemically more benign to biota with pH staying mostly above 5.5 and IMAI levels around or below 2 $\mu\text{mol L}^{-1}$. Snowmelt nitrate peaks are near 30 $\mu\text{eq L}^{-1}$ and late summer base flow concentrations are nearing detection limits.

Lake Outlet Paired Sampling

Eight of the original 17 lakes used as part of the ALTM have water quality sampling locations at substantial distances downstream from the physical lake outlet (Table 3). These original eight sites were historically sampled by Syracuse University from 1982 to 1992. All sampling locations were chosen at the most accessible sites to allow completion of sampling within a 1–2 day interval.

Figure 4. Monthly time series plots for Big Moose Lake. Values in $\mu\text{eq L}^{-1}$ except total and inorganic monomeric aluminum, which are in $\mu\text{mol L}^{-1}$. Shaded area represents most recent (2013) data

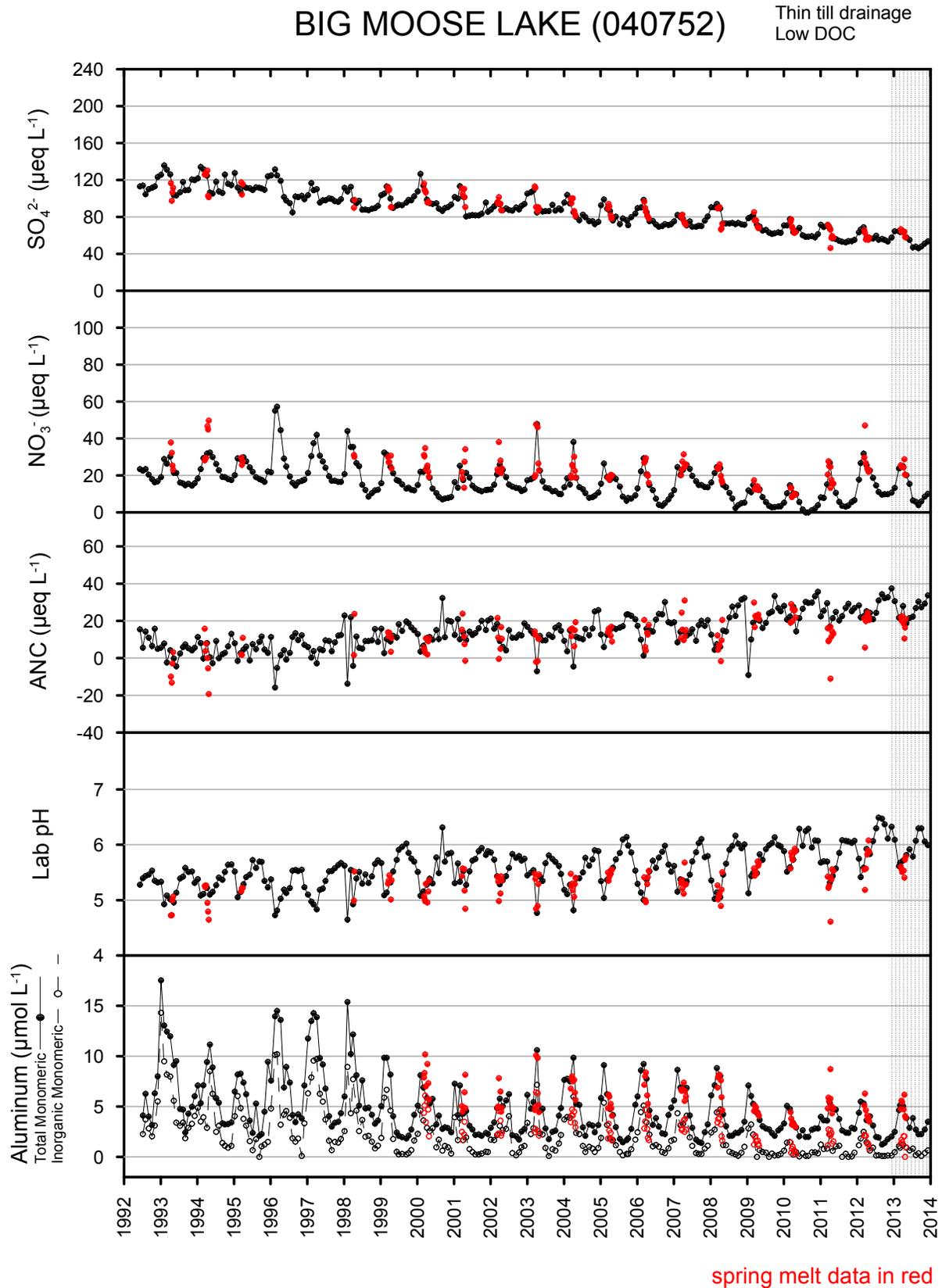


Table 3. ALTM lakes with paired outlet/pond sampling sites

Pond Number	Pond Name	Lake Type	Distance Between Sampling Pairs (km)
030256	Black Pond	Thick till drainage low DOC	0.3
040748	Bubb Lake	Thin till drainage low DOC	1.1
040747	Cascade Lake	Medium till drainage low DOC	2.0
040777	Constable Pond	Thin till drainage low DOC	2.7
070729	Otter Lake	Thin till drainage low DOC	0.5
040754	Squash Pond	Thin till drainage high DOC	0.6
040753	West Pond	Thin till drainage low DOC	0.3
040750A	Windfall Pond	Carbonate influenced	2.0

In July 1993, with respect to the eight original Syracuse sites, the ALSC established additional sampling locations at each lake. The intention was to standardize the sampling locations of all 52 lakes, with the goal of conducting sampling at the paired locations for a period of time sufficient to evaluate if there are site differences or locational dependence in chemistry of these waters.

In 2006, a comparison of monthly data at these eight paired sampling sites during 1993-2004 found that the Black Pond and Black Pond Outlet sites were statistically similar and therefore one of the sites could be discontinued. As a result, the upstream site was discontinued in December 2006 (Cirmo et al. 2007). Because the seven additional, unique sites are being continued, the names of the original downstream sites have been augmented with the addition of STREAM in the name label (Appendix A). In their preliminary white paper, Cirmo and others make paired statistical comparisons of 21 surface water parameters for each of the eight study areas. They discuss a strategy to analyze underlying causes in watershed features (e.g. geology, wetlands, elevation) where differences in chemistry are strongest. Topographic maps of the sampling pairs are included. The white paper is available upon request.

Base Cation Surplus

In 2012, the ALSC calculated base cation surplus (BCS) results to the parameters reported for the ALTM lakes (Lawrence et al. 2013). Researchers may use BCS along the same lines they use ANC, such as critical load discussions and evaluating ecosystem recovery from acid deposition. As with various critical ANC limits used by state and federal agencies, the BCS threshold of $0 \mu\text{eq L}^{-1}$ provides a critical limit, which corresponds to harmful biological effects. Furthermore, the effects of variable DOC concentrations on the mobilization of toxic aluminum can be addressed through the BCS, a chemical index that explicitly includes strongly acidic organic anions (Lawrence et al. 2013, Lawrence et al. 2008a). Like ANC and ANC_{Calc} , the BCS relates closely to IMAI below a threshold value, but unlike ANC and ANC_{Calc} , the BCS threshold of $0 \mu\text{eq L}^{-1}$ doesn't shift with varying DOC concentrations (Lawrence et al. 2013, Lawrence et al. 2008b, Lawrence et al. 2007). Values of BCS above zero provide a measure of base-cation availability and indicate how close a water is to the toxic Al mobilization threshold. Therefore, similar to using ANC as an ecological indicator of overall health of an ALTM lake (United States Environmental Protection Agency 2009), the BCS result provides a useful reference point for evaluating acidification recovery in the presence of increasing DOC concentrations (Lawrence et al. 2013).

In 2012, average annual BCS results were higher than 1994 results in all ALTM waters, except Barnes Lake. Additionally, nearly 60% of ALTM waters had an average BCS below $0 \mu\text{eq L}^{-1}$ in 1994, whereas in 2012, approximately 30% of the waters showed values below this critical threshold. This comparison suggests that ALTM lakes have become considerably less acidic since 1994 (Lawrence et al. 2013).

Snowmelt Sampling

In 1993, weekly sampling was initiated in a few ALTM lakes to capture more chemistry during snowmelt. The purpose of collecting more frequent data during the snowmelt period is to assess worse-case conditions to biota during this typically most acidic time of year. The intent was to sample more frequently each spring a total of 10 to 12 waters on a rotating basis from year to year. Sampling commenced at the onset of snowmelt, ended with the disappearance of the snowpack, lasted anywhere from three to eight weeks, and was adjusted with staff availability. Beginning in 2002, the lakes and sampling periods were standardized. The same 12 lakes were sampled each year: Little Echo; East Copperas, Middle, Sunday, Owen, Heart, Moss, Bubb, Big Moose, West, Sagamore; and Raquette Lake Reservoir (Table 1). Sampling begins in the first week of March and ends in the first week of May. All 12 lakes are sampled on the same day each week. The selected lakes generally represent all lake classes throughout the region at elevations ranging between 482 m (Little Echo) and 661 m (Heart). These lakes are typically within easy access of year-round roads so that they can be sampled with available field staff all in one day. Plots of weekly snowmelt and monthly data for the 12 lakes are updated through 2011 and provided in Appendix C. The weekly snowmelt chemistry data for all lakes (1993 - 2012) were posted to www.adirondacklakessurvey.org in 2013.

In 2011, Dr. Charles Driscoll of Syracuse University, continued an analysis of the influence of snowmelt on ALTM lake chemistry including examinations of the processes that contribute to snowmelt acidification and of trends over all and during the snowmelt period.

ALSC also began a preliminary examination of the 12 individual snowmelt lakes with respect to what additional information was provided by more frequent sampling. About half of the lakes seem to show little additional information with increased sampling (Middle Pond, Owen Pond, Heart Lake, East Copperas Pond, Little Echo Pond, and Sunday Lake). Big Moose Lake also does not show significant additional information with the weekly sampling. The remaining lakes (Moss Lake, Bubb Lake, West Pond, Sagamore Lake, and Raquette Lake Reservoir) show additional acidic depressions during the weekly sampling and provide valuable documentation of biologically stressful conditions during this critical time of year. Plots of weekly snowmelt and monthly data for the 12 lakes are provided in Appendix C. Weekly snowmelt sampling measurements were discontinued as part of the routine sampling after December 2013 in response to NYSERDA's ALTM program restructuring.

Snowpack Sampling

During 1999 and 2000, mass-balance studies at three ALTM lakes (Grass, Constable, and G) by Myron Mitchell with SUNY College of Environmental Science and Forestry included snow core sampling at these watersheds. When measurable snow was present, monthly samples of snowpack were collected and melt water was analyzed by the ALSC laboratory at each of these watersheds.

Snowpack data from January 1999 through March 2012 was released to the website on December 2, 2014. This data release is comprised of three files found at www.adirondacklakessurvey.org. The file 1999-2012ALTM.SNOWPACK.metadata.R.rtf contains description of the snowpack data. The file 1999-2012.ALTM.SNOWPACK.R.xlsx contains the data for the Adirondack Long-Term Monitoring (ALTM) snow core (snowpack) sample sites and site identification information. The support file: 2012-1992.DL.R.xlsx contains detection limit values for chemistry parameters. Snowpack sampling measurements were discontinued as part of the routine sampling after December 2013 in response to NYSERDA's ALTM program restructuring.

Additional Modifications to Lake Monitoring

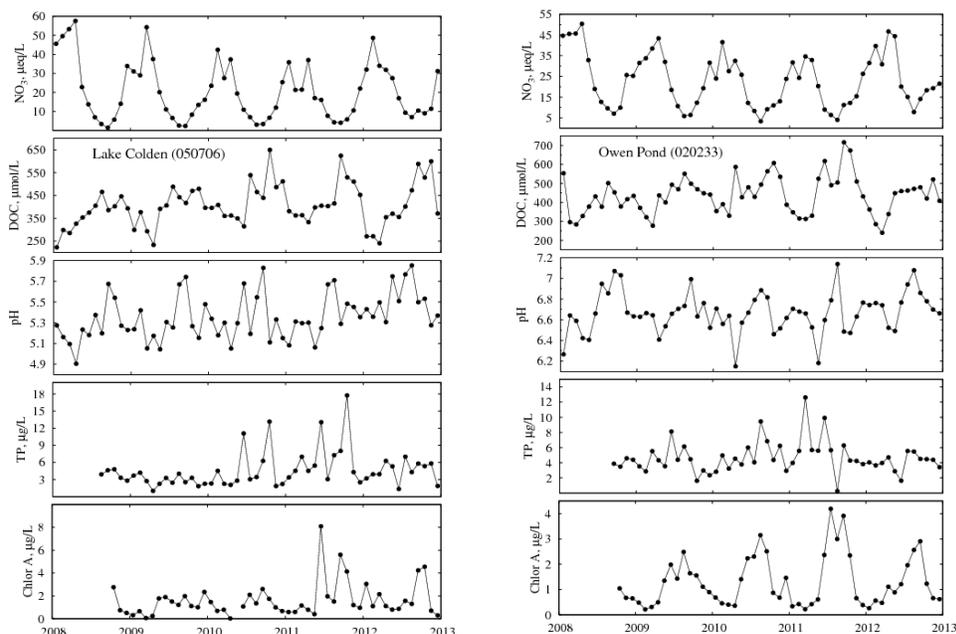
Pilot Study of Specific Ultraviolet Absorbance (SUVA) initiated in August 2013

Recent surface water studies have shown the potential use of specific ultraviolet absorbance (SUVA₂₅₄) and DOC data in streams as a predictor of mercury effects. In 2013, NYS Department of Environmental Conservation Division of Air Resources and ALSC initiated a pilot study to run from August 2013 to March 2014 to test the usefulness of SUVA₂₅₄ as a surrogate for mercury in sensitive Adirondack mountain lakes and streams. The pilot project began in August 2013 with the goal of relating late summer index levels of ultraviolet absorbance (UVA), SUVA₂₅₄, and DOC with recent ALTM lake concentrations of total and methylmercury. These lake mercury data were available from the 2008-2012 fisheries resurvey of ALTM lakes. The start-up and initial eight months of sampling were part of the Great Lakes Acid Deposition persistent, bio-accumulative toxic (GLAD PBT) funds. The pilot program was temporarily continued through July 2015 by NYSERDA under the ALSC work plan for 2015.

Total Phosphorus and Chlorophyll *a* discontinued after December 2013

Improvements in lake chemistry from acidifying emissions reductions are expected to lead to biological recovery (Driscoll et al. 2001). In the mid-1980s, phytoplankton reductions in the Adirondacks were associated with lake acidity and related to nutrient status (Sutherland, 1989). Since then, periodic measurements of biological parameters have been conducted in over half of the ALTM lakes (Momen et al. 2006). Chlorophyll *a* (chl *a*) and total phosphorus (TP) are common indicators of lake productivity and nutrient status. In October 2008, the ALSC began collecting and analyzing both of these as part of the routine monthly sampling of the 52 ALTM lakes. The expectation was that eventual signals of biological response would begin to appear in some of these lakes. Figure 5 show plots of TP, chl *a* and selected acidity parameters during 2008 to 2013 for Lake Colden and Owen Pond. These two lakes are selected to illustrate the challenges of deriving quantitative trends and relationships in chemistry and biology. Owen and Colden are located relatively close to each other in and near the High Peaks Region. They have distinctively different watersheds, chemistry and biota (Roy et al. 2011). TP and chl *a* measurements were discontinued as part of the routine sampling after December 2013 in response to NYSERDA's ALTM program restructuring. The data through 2012 were posted to www.adirondacklakessurvey.org and the complete data will be posted by August 31, 2015. Reinstating TP and chl *a* measurements for selected lakes and time periods remain a future possibility.

Figure 5. Plots of Total Phosphorus (TP), and chlorophyll a (chl a) against selected parameters 2008-2013



Marcy Dam Pond Sampling Discontinued after May 2014

The impoundment at Marcy Dam Pond was damaged significantly during Tropical Storm Irene (August 20-28, 2011). In 2013, NYSDEC decided to dismantle the structure beginning in August 2014. The decision to remove it was based on several factors including Dam Safety regulations, cost, ecological considerations and its Wilderness classification under the Adirondack Park State Land Master Plan. Because the removal of the dam will effectively change Marcy Dam Pond from a lake to a stream system, the site was discontinued as an ALTM chemistry monitoring site in June 2014. Its monthly chemistry record which began in June 1992 (ALSC Pond No. 020265) will be maintained at www.adirondacklakessurvey.org.

ALTM Chemistry Data Reported to Date

Data currently available from this ALTM lake study include the 52 lakes and additional sampling collected at seven outlet pair locations. In 2012, annual mean concentrations of the parameters measured for the 52 lakes from January 1993 through December 2012 and the monthly chemistry data from June 1992 through December 2013 were posted to the ALSC website (<http://www.adirondacklakessurvey.org>). Data from the additional seven outlet pair locations are also included within these files.

Fisheries Surveys in ALTM Lakes

In 1994, the ALSC began fisheries surveys in ALTM waters. Lake chemistry improvements were anticipated from the 1990 Clean Air Act Amendments increasing interest in aquatic biota sampling. The ALSC has extensive experience with fisheries surveys. A majority (n=45) of the ALTM lakes had been surveyed as part of the 1984–1987 ALSC survey. The resurveys were conducted generally following ALSC methods at a rate of 4–8 surveys per year (ALSC 2002a). In 2007, a preliminary analysis of those comparisons indicated that modest changes were detectable in some lakes. As a result, another round of survey was planned for 2008–2012. This new survey also presented an opportunity to evaluate fish tissue mercury concentrations in selected fish populations.

The rationale for fish mercury analysis was based, in part, on the findings of the NYSERDA study conducted during 2003–2005 by NYSDEC in collaboration with ALSC. In their statewide survey of mercury in fish in 131 lakes and reservoirs, Simonin et al. 2008 found the Adirondack and Catskill Park regions containing higher levels of mercury in fish than in other parts of the state. Of the chemical and physical characteristics of lakes examined, lake acidity (pH) was the most important variable associated with high mercury levels in fish. Species sampled included: yellow perch; small and largemouth bass; and walleye. While brook trout are an important sport fish for the Adirondacks, relatively few mercury data are available in part because this species is considered less prone to accumulating mercury.

Sampling Design

The current ALTM fisheries resurvey was concluded in 2012. It included total and methylmercury analysis in yellow perch and brook trout. All fish were analyzed for total mercury, whereas a subset were analyzed for methylmercury. All lake water samples were analyzed for total mercury and methylmercury. The resurvey schedule was based on the interval between the two previous surveys and existing staff levels. Table 4 shows the dates of the surveys, the years between surveys, and the number of target species caught and analyzed for mercury.

Table 4. Five-year schedule of ALTM lakes resurvey 2008–2012

Year	Pond No.	Pond Name	ALS Dates	LTM Dates	Sched- uled Year	Date Sampled	Analyzed		Caught	
			dd/mm/ yyyy	dd/mm/yyyyyyyy		dd/mm/ yyyy	Yellow Perch	Brook Trout	Total YP	Total ST
2008	020059	Big Hope Pond	22/05/1984	17/05/1994	2008	12/11/2008	0	24	0	25
	020233	Owen Pond	13/09/1984	24/05/1994	2008	25/09/2008	0	1	0	1
	030172	Little Clear Pond	09/10/1984	23/05/1994	2008	09/10/2008	0	7	0	7
	030171	Grass Pond	09/10/1984	15/06/1998	2008	09/10/2008	0	0	0	0
	040887	Lost Pond	12/09/1984	23/06/1994	2008	23/10/2008	0	6	0	6
	070859	G Lake		14/06/1994	2008	01/10/2008	0	31	0	32
	050669	Carry Pond	24/09/1987	23/06/1994	2008	16/10/2008	0	24	0	39
	040850	Squaw Lake	18/09/1984	17/10/1994	2008	21/08/2008	0	12	0	12
	040852	Indian Lake	17/09/1984	17/10/1994	2008	15/10/2011	0	1	0	1
2009	020058	Little Hope Pond	22/05/1984	15/05/1995	2009	15/10/2009	0	7	0	7
	020197	Sochia Pond	10/05/1984	22/05/1995	2009	24/06/2009	0	0	0	0
	040748	Bubb Lake	21/05/1986	19/09/1995	2009	24/09/2009	0	8	0	8
	040750A	Windfall Pond	07/06/1985	24/05/1995	2009	12/05/2009	0	0	0	0
	050458	Clear Pond	20/10/1987	24/04/1995	2009	28/10/2009	0	2	0	2
	050259	Jockeybush Lake	02/09/1987	17/07/1996	2009	08/10/2009	0	27	0	36
	040576	Woods Lake		27/05/1997	2009	19/05/2009	0	0	0	23
	020126	Little Echo Pond		28/05/1998	2009	29/06/2009	0	0	0	0
	020138	East Copperas Pond	19/07/1984	27/05/1998	2009	17/06/2009	0	0	0	0
	020143	Middle Pond	16/05/1984	27/05/1998	2009	10/09/2009	22	0	37	0
040754	Squash Pond	29/05/1986	17/06/1998	2009	15/06/2009	0	0	0	0	
040752	Big Moose Lake	25/09/2000	25/09/2000	2009	22/10/2009	25	4	28	4	
040739	Lake Rondaxe	07/10/1986	18/10/2000	2009	18/09/2009	13	4	23	4	

Table 4. continued

Year	Pond No.	Pond Name	ALS Dates	LTM Dates	Sched- uled Year	Date Sampled	Analyzed		Caught	
			dd/mm/ yyyy	dd/mm/yyyyyyyy	dd/mm/ yyyy	Yellow	Brook	Total	Total	
						Perch	Trout	YP	ST	
2010	050649	Long Pond	09/09/1987	15/06/1998	2010	21/06/2010	0	0	0	0
	030256	Black Pond	10/10/1985	15/07/1998	2010	25/10/2010	0	21	0	25
	040706	Grass Pond	18/09/1984	18/05/1999	2010	07/10/2010	0	0	0	0
	040747	Cascade Lake	12/06/1984	16/06/1999	2010	27/09/2010	25	1	82	1
	040753	West Pond	06/06/1985	26/05/1999	2010	23/06/2010	0	0	0	0
	040777	Constable Pond	11/06/1984	24/05/1999	2010	14/10/2010	25	6	109	6
	060329	Queer Lake	22/05/1986	14/06/1999	2010	20/10/2010	0	13	0	13
	070729	Otter Lake		22/07/1999	2010	28/06/2010	0	0	0	0
	040746	Moss Lake	23/09/1986	21/08/2000	2010	26/10/2010	25	0	48	1
	040750	Dart Lake	23/09/1986	27/09/2000	2010	19/10/2010	25	2	40	2
	020188	Sunday Pond	11/10/1984	07/06/2000	2010	09/09/2010	0	14	0	14
	2011	050215	Willis Lake	09/09/1987	21/05/2001	2011	08/09/2011	5	0	14
041004		South Lake	16/09/1986	25/06/2001	2011	27/09/2011	0	20	0	28
041007		North Lake	16/09/1986	25/06/2001	2011	26/08/2011	20	0	119	0
050684		Arbutus Lake	na	27/06/2001	2011	06/10/2011	0	20	0	20
060313		Sagamore Lake	09/10/1986	18/06/2001	2011	15/09/2011	19	10	19	11
		Raquette Lake								
060315A		Reservoir	10/10/1985	19/06/2001	2011	21/09/2011	0	16	0	18
040186		Loon Hollow Pond	18/06/1985	28/05/2002	2011	23/05/2011	0	0	0	0
040905		Barnes Lake	06/09/1985	29/10/2002	2011	19/05/2011	0	0	0	0
020264		Heart Lake	07/05/1985	26/05/2004	2012	13/10/2011	0	15	0	16
050706		Lake Colden	20/10/1987	29/09/2004	2012	13/06/2011	0	0	0	0
050707		Avalanche Lake	22/10/1987	29/09/2004	2012	13/06/2011	0	0	0	0
060182	Little Simon Pond	14/05/1985	19/06/2002	2011	17/10/2011	0	14	0	14	
2012	020265	Marcy Dam Pond	14/05/1985	25/05/2004	2012	10/05/2012	0	12	0	12
		Middle Settlement								
	040704	Lake	18/09/1984	18/06/2003	2012	09/13/2012	0	7	0	7
	040707	Middle Branch Lake	19/09/1984	16/06/2004	2012	09/12/2012	0	3	0	3
	040826	Limekiln Lake	15/10/1985	06/10/1997	2012	10/18/2012	20	22 ^a	29	22 ^a
		Willys Lake (Horse-								
	040210	shoe)	06/06/1984	28/05/2005	2012	05/07/2012	0	0	0	0
050577	Nate Pond	28/10/1987	18/10/2005	2012	09/26/2012	0	8	0	8	
040874	Brook Trout Lake	29/06/1984	26/06/2002	2012	10/17/2012	0	19	0	18	

^a Splake

As part of this effort, a lake water chemistry sample and other field parameters are also collected at the time of the fish survey (fall or spring). In July a more extensive lake water sample was collected from all waters scheduled for fish survey for that calendar year. All mercury water samples collected for mercury analyses were taken according to “Clean Hands/Dirty Hands” protocol. Samples are kept cool and shipped overnight to Frontier Global Sciences in Seattle, WA for analysis of mercury in lake water.

ALSC follows ALS fisheries survey protocols conducting fish surveys in the spring or fall, with no surveys during July and August. Experimental gill nets are the primary equipment used along with minnow gill nets and minnow traps. The number of gill nets set in each survey is based on the surface area of the lake. Nets are set according to previous surveys for comparability. All sport fish and yellow perch are weighed, have lengths measured, and have scale samples and opercular bones taken for aging individuals. Fish are processed at the NYSDEC laboratory at Hale Creek by ALSC staff according to the NYSDEC Bureau of Habitat Fish Preparation Procedures for Contaminant Analysis (Simonin et al. 2008). The samples are processed, frozen, and shipped to Cebam Analytical, Inc. in Seattle, WA, for analysis of mercury in fish tissue.

Field collections have been completed in all ALTM lakes. Fish and water samples have been analyzed. In all, yellow perch were found in 11 lakes with 224 individuals analyzed for mercury. Brook trout were found in 33 lakes with 381 individuals analyzed for mercury. Fish specimens were processed at the NYSDEC Hale Creek Laboratory and analyzed by Cebam Analytical for total and methylmercury. Water samples were analyzed by Frontier Global Sciences for total and methylmercury.

Seven lakes were surveyed for fish in 2012. Marcy Dam Pond was not surveyed in 2011 due to a dam breach following a high water event, however it was surveyed in 2012. The survey included a mercury water sample in July and brook trout were collected in October by angling. Splake in Limekiln Lake were analyzed for mercury as a surrogate for brook trout. All seven waters had water samples collected in July and analyzed by Frontier Global Sciences, Inc. One yellow perch, five brook trout and one splake population were caught and analyzed for mercury from six of the seven lakes (Table 4). The 2012 fish specimens were processed in November at the NYSDEC Hale Creek Laboratory by ALSC staff and analyzed by Cebam Analytical in December 2012.

Results

Preliminary results indicate that changes in fish populations between 1984–1987 and 1994–2005 are highly variable. There are signs of response/recovery in the number of fish species in some lakes over the average 14-year interval, but they are modest and mixed. Overall, the recent survey netted 169 fish populations compared to 141 populations from the same lakes in the earlier survey (Table 5a). The greatest species gains occurred in moderately sized lakes with pH 5.5 – 6.0. Fish response patterns were generally consistent with ANC, NO_3^- and Al IM trends. Preliminary results were presented at the 2009 NYSERDA EMEP Conference (www.nyserda.ny.gov/Page-Sections/Environmental-Research/EMEP-Conferences/2009-EMEP-Conference.aspx). The median, mean, and maximum number of fish species (populations) per lake and are shown in Tables 5a. Lakes arranged by fish response classes show the greatest changes in medium sized lakes with 5.5–5.7 pH (Table 5b).

Table 5a. Fish population changes in 42 ALTM lakes between 1984–1987 and 1994–2005 survey

Period of Study	Fish Populations			
	Total all Lakes	Median per Lake	Mean	Maximum
1984-1987	141	3	3.36	10
1994-2005	169	4	4.02	12
Change	+28	+1	<1	+2

Table 5b. Changes in fish communities in Adirondack lakes between 1984–1987 and 1994–2005

Category	n	Median pH	Volume (10 ⁴ m ³)	Species Richness		
				1984 - 1987	1994 - 2005	Δ
No fish	10	4.7 - 4.7	46	0	0	0
No change	8	5.3 - 5.5	100	2.0	2.0	0
Only gained	15	5.5 - 5.7	198	4.1	6.0	+1.9
Only lost	4	6.3 - 6.3	56	3.0	1.75	-1.25
Gained and lost	8	6.2 - 6.5	350	7.1	7.0	+0.9

Table 6. Cascade Lake was one of 15 lakes that only gained species between the 1984 and 1999 surveys

Cascade Lake - ALS Survey 1984					Cascade Lake - Resurvey 1999				
pH=6.48					pH=6.73				
Species n=4	Val =1	Val=1-2	Min pH	Serial Number	Species n=8	Val =1	Val=1-2	Min pH	Serial Number
Brown Bullhead	1	1	4.49	2.5	Brown Bullhead	1	1	4.49	2.5
Yellow Perch	1	1	4.53	4.0	Golden Shiner	1	1	4.49	2.5
Brook Trout	1	1	4.64	8.0	Yellow Perch	1	1	4.53	4.0
White Sucker	1	1	4.64	8.0	Pumpkinseed	1	1	4.59	5.0
Total	4	4	18.30	22.5	Brook Trout	1	1	4.64	8.0
Median	—	—	4.59	6.0	Creek Chub	1	1	4.64	8.0
					White Sucker	1	1	4.64	8.0
					Common Shiner	1	1	4.86	14.5
					Total	8	8	36.88	52.5
					Median	—	—	4.62	6.5

During 2011, fisheries analysis continued on a closer examination of fish management records (e.g., stocking), fish community indices (Table 6).

Fish tissue mercury results from 2008-2012 surveys found total mercury concentrations in yellow perch and brook trout ranging from 81 to 3155 ng g⁻¹ and 5 to 1008 ng g⁻¹ on a wet weight basis, respectively (Tables 7a and 7b).

Table 7a. Total mercury concentrations (ng g⁻¹ wet weight) measured during 2008-2012 in the two target fish species collected. Results are aggregated from Adirondack Long Term Monitoring lakes

Species	Total Mercury (ng g ⁻¹)			
	n	Min	Max	Average
Brook Trout	359	5.50	1008.44	220.22
Yellow Perch	215	81.30	3155.95	454.10

Table 7b. Methylmercury concentrations (ng g⁻¹ wet weight) measured during 2008-2012 in the two target fish species collected. Results are aggregated from Adirondack Long Term Monitoring lakes

Species	Methylmercury (ng g ⁻¹)			
	n	Min	Max	Average
Brook Trout	71	4.35	734.17	215.02
Yellow Perch	43	63.92	3039.56	441.98

Data Reported to Date

The fisheries survey data are currently being analyzed. It is anticipated that the data along with the fish tissue mercury results will be available at the end of the project period and reported in the next annual report.

Temporally Integrated Monitoring of Ecosystems (TIME) Lakes

The Temporally Integrated Monitoring of Ecosystems (TIME) program began as part of a northeastern lakes survey in the early 1990s. Under the auspices of the USEPA Environmental Monitoring and Assessment Program (EMAP), TIME was a statistically-based rotating sampling program (Whittier et al. 2002) that collected lake chemistry and biological data on nearly 250 lakes in New England, New York, and New Jersey during 1991–1996 (USEPA 1993a; USEPA 1993b).

The purpose of EMAP was to monitor ecological indicators of U.S. natural resources across a spectrum of issues including eutrophication and acid deposition over several types of landscape features such as forests, wetlands, arid areas, including surface waters (lakes and streams). The approach was statistically based to assess current status, geographic extent, proportion of the resource population affected, the trends and probable causes (Whittier and Paulsen 1992). For lakes, EMAP Surface Waters evaluated biotic integrity, trophic condition, and fishability of lakes and streams. The sampling time frame was every four years. The framework is described (Whittier and Paulsen 1992) as consisting of 40 km² hexagons in a triangular spaced grid representing approximately 12,500 points for the conterminous US. The grid density was increased three-fold in two high elevation acid sensitive areas of the Northeast, the Adirondack Mountain region and the southern Green Mountains/north central Massachusetts/southwestern New Hampshire Uplands subregion (Whittier and Paulsen 1992).

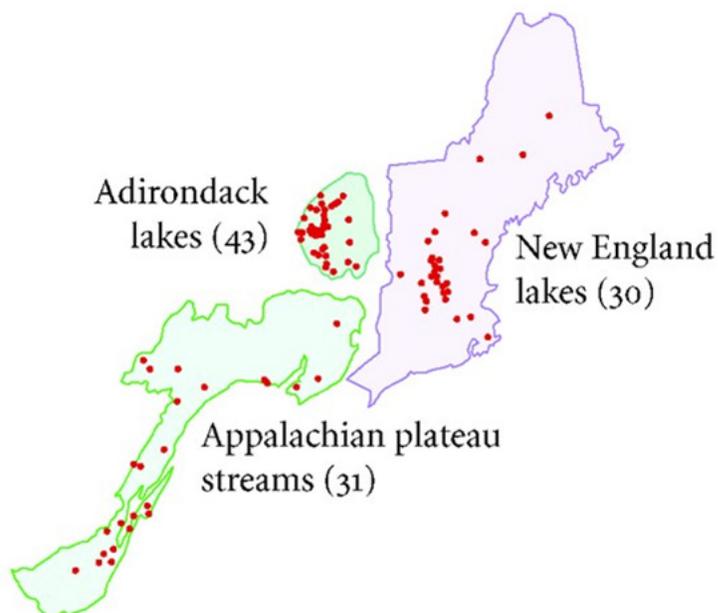
TIME is a statistically based sampling program that enables population estimates of low ANC lakes to be developed from 43 sites in the Adirondacks. There are approximately 1,000 low ANC (less than 100 µeq L⁻¹) lakes in the region out of a total population of 1,830 lakes with a surface area greater than 1 hectare (Stoddard et al. 2003). This monitoring program enables researchers to monitor sensitive lakes over time.

The goal of the program is to track the effectiveness of the 1990 Clean Air Act Amendments in the reduction of acidified surface waters. In addition to the 43 Adirondack lakes sampled once each year in the late summer/early fall, 30 New England lakes and 31 Appalachian streams are sampled by other investigators. An overview of these varied regional monitoring efforts and their relevance to developing scientifically supported national policies to abate atmospheric emissions are provided by EPA (USEPA 1995). The TIME sampling design and tests of its ability to detect trends in ANC and sulfate are provided by Stoddard et al. (1996).

In the eastern US, the core of the EPA acid rain effects monitoring effort are the TIME and Long Term Monitoring (EPA LTM) programs. Both programs are operated in collaboration with academic institutions, state agencies, or other federal agencies (Stoddard et al. 2003). Two aspects of the TIME program include the design based probability sample called the TIME survey sites and the model-based aspect using a non-random group of lakes. The second group of lakes is sampled more frequently (8 – 16 times per year) to build links between chronic and episodic acidification (Stoddard et al. 1996). These long term monitoring (EPA LTM) efforts began in the early 1980s including lakes from Vermont, Maine, and 17 Adirondack lakes that became known as the Adirondack Long Term Monitoring (ALTM) lakes (Figure 6). These provide a characterization of seasonal or episodic acidification. In many of the regions, the sites include some higher ANC sites (i.e., greater than $100 \mu\text{eq L}^{-1}$ ANC) to help separate effects of disturbances (e.g., climate) other than acidic deposition (Stoddard et al. 2003).

This probability-based survey allowed inferences to be made on the entire population of lakes in the Northeast, which numbered 10,381 in New York and New England combined. The survey was conducted in late summer during low flow conditions, so ANC values are expected to be the highest. Lakes were divided into biologically relevant ANC classes where: ANC levels of $< 0 \mu\text{eq L}^{-1}$ are acute concern or chronically acidic; $\text{ANC} > 0$ and $< 50 \mu\text{eq L}^{-1}$ are elevated concern or susceptible to episodic acidification; and ANC values > 50 and $< 100 \mu\text{eq L}^{-1}$ are moderate concern. Results from the Adirondack region representing a population of 1,812 lakes (surface area greater than 1 ha) found 10% had ANC values of $< 0 \mu\text{eq L}^{-1}$ (chronically acidified) and an additional 31% of all lakes were critically acidified with values of $\text{ANC} > 0$ and $< 50 \mu\text{eq L}^{-1}$ bringing the total population of lakes with elevated or acute concern to 41% (Driscoll et al. 2001). A charge-balance technique for evaluating the nature of the acid inputs to these lakes found 83% of the acid sensitive lakes ($\text{ANC} < 50 \mu\text{eq L}^{-1}$) were dominated by inorganic anions with sulfate constituting 82% of the total anionic charge (Driscoll et al. 2001).

Figure 6. TIME Regional Surveys 1991–2000



Site Description

EMAP lake sampling in the Adirondack region began in 1991 with a selection of different lakes each year: 1991 (26 lakes), 1992 (41 lakes), 1993 (23 lakes) and 1994 (27 lakes) for a total 117 lakes. In 1999, one set of 43 lakes was selected for annual sampling, which has been ongoing.

Table 8 identifies TIME/EMAP lake name and identification number, the NYSDEC/ALSC lake name and identification number. The surface area data were derived from the ALSC survey 1984–1987 and from NYSDEC sources for the 13 lakes that were not part of the survey. The lake classification is based on Newton and Driscoll (1990) developed from the ALSC survey. For non-ALSC surveyed lakes, chemistry data from the 1991–1994 EMAP were used. Of these 43 lakes, six are cross-over lakes with the ALTM program (Table 1).

Table 8. Adirondack TIME lake characteristics

EMAP Ref #	ALSC Ref #	TIME/EMAP Pond Name	ALS/DEC Pond Name	Elev. (m)	Classification	Area (ha)
NY012L	020059	Hope Pond	Big Hope Pond	517	Medium till drainage High DOC	8.9
NY250L	030101	Twin Pond (E)	Upper Twin Pond	403	Thin till drainage, Low DOC	6.0
NY033L	030128	Dry Channel Pond	Dry Channel Pond	497	Thin till drainage, Low DOC	27.4
NY297L	030273	Bickford Pond	Bickford Pond	532	Thin till drainage, Low DOC	4.4
NY299L	030276	Pd. Near Spitfire Lake	Unnamed Pond	495	Flow through seepage, High DOC	2.1
NY278L	030331	Parmeter Pond	Parmeter Pond	351	Flow through seepage, High DOC	7.1
NY515L	030360	Wolf Pond	Wolf Pond	451	Thin till drainage, Low DOC	8.9
NY285L	030373	Horseshoe Pond	Horseshoe Pond	466	Thin till drainage, Low DOC	10.4
NY284L	030374	Boottree Pond	Boottree Pond	464	Flow through seepage, Low DOC	6.2
NY527L	040137	Rocky Lake	Rock Lake	424	Thin till drainage, Low DOC	8.2
NY790L	040203	Lower Beech Ridge Pond	Unnamed Pond	630	Thin till drainage, Low DOC	9.3
NY789L	040210	Willys Lake	Willys Lake	632	Thin till drainage, Low DOC	24.3
NY275L	040424	Taylorville Pond	Taylorville Res.	326	Medium till drainage Low DOC	37.5
NY277L	040426	Effley Falls Pond	Effley Falls Res.	354	Thin till drainage, Low DOC	121.5
NY791L	040515	Dismal Pond	Dismal Pond	624	Mounded seepage, Low DOC	21.5
NY792L	040518	No Name	Cat Pond	532	Thin till drainage, High DOC	6.7
NY788L	040528	Witchhopple Lake	Witchhopple Pond	536	Thin till drainage, Low DOC	37.6
NY029L	040566	Little Lilly Pond	Unnamed Pond	596	Thin till drainage, High DOC	6.5
NY280L	040573	Razorback Pond	Razorback Pond	675	Thin till drainage, Low DOC	5.3
NY281L	040579	Snake Pond	Snake Pond	589	Thin till drainage, Low DOC	7.3
NY794L	040620	Payne Lake	Payne Lake	383	Flow through seepage, High DOC	7.0
NY030L	040769	Upper Sister Lake	Upper Sister Lake	590	Thin till drainage, High DOC	32.0
NY014L	040850	Squaw Lake	Squaw Lake	646	Thin till drainage, Low DOC	36.4
NY015L	040852	Indian Lake	Indian Lake	654	Thin till drainage, Low DOC	33.2
NY798L	050607	Little Moose Pond	Little Moose Lake	695	Thin till drainage, Low DOC	11.3
NY282L	041004	South Lake	South Lake	615	Thin till drainage, Low DOC	197.4
NY279L	041007	North Lake	North Lake	555	Thin till drainage, Low DOC	176.8
NY536L	050131A	Miner Mill Vly	Miner Mill Vly	479	Medium till drainage, High DOC	3.3
NY256L	050182	Bennett Lake	Bennett Lake	356	Thin till drainage, Low DOC	14.8
NY505L	050197	Lixard Pond	Lixard Pond	528	Thick till, Low DOC	11.7
NY013L	050298	Second Pond	Second Pond	681	Thin till drainage, Low DOC	18.0
NY526L	050715	Henderson Lake	Henderson Lake	553	Thin till drainage, Low DOC	102.1

Table 8. continued

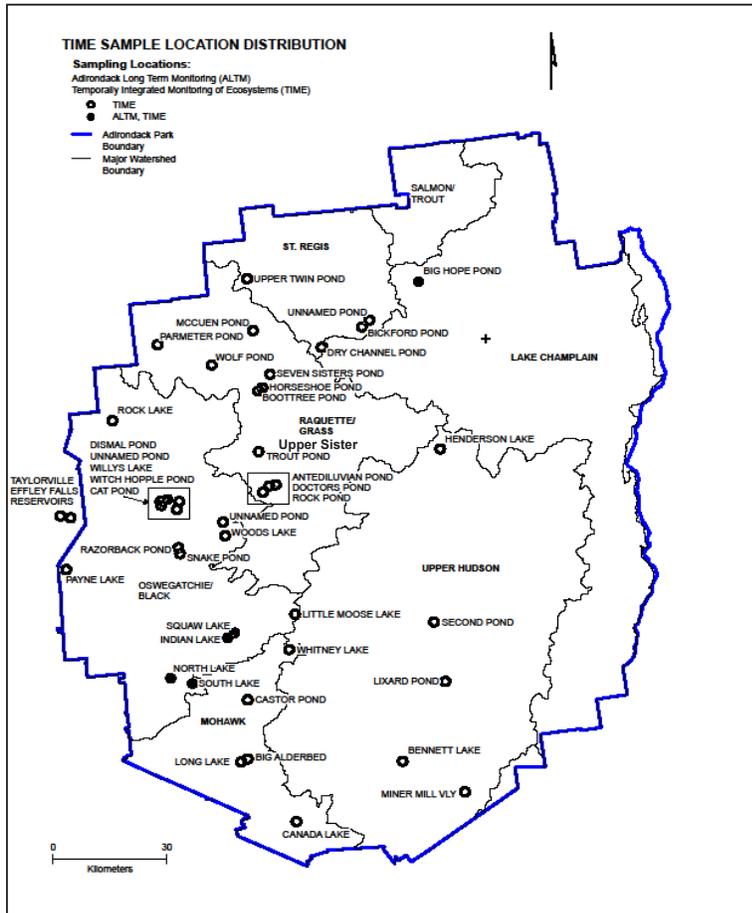
EMAP Ref #	ALSC Ref #	TIME/EMAP Pond Name	ALS/DEC Pond Name	Elev. (m)	Classification	Area (ha)
NY782L	060039	McCuen Pond	McCuen Pond	456	Thin till drainage, High DOC	2.6
NY288L	060074	Seven Sisters Pond	Seven Sisters Pond	469	Mounded seepage, Low DOC	3.0
NY287L	060126	Antediluvian Pond	Antediluvian Pond	532	Thin till drainage, High DOC	5.3
NY291L	060127	Doctors Pond	Doctors Pond	556	Thin till drainage, Low DOC	10.2
NY286L	060129	Rock Pond	Rock Pond	525	Thin till drainage, High DOC	112.2
NY767L	060146	Trout Pond	Trout Pond	545	Thin till drainage, Low DOC	63.4
NY292L	070717	Canada Lake	Canada Lake	472	Salt impacted	217.7
NY017L	070790	Big Alderbed	Big Alderbed	549	Thin till drainage, Low DOC	17.7
NY018L	070823	Long Lake	Long Lake	667	Thin till drainage, Low DOC	21.7
NY507L	070885	No Name	Castor Pond	700	Thin till drainage, High DOC	5.3
NY797L	070936	Whitney Lake	Whitney Lake	752	Thin till drainage, Low DOC	42.6

Sampling Design

TIME sites were selected using methods developed for the EMAP investigation (Hughes et al. 2000). The 43 Adirondack TIME lakes are sampled once in late summer/early fall each year (Figure 7). Samples are collected at a depth of 1.5 m (0.5 m if lake depth is less than 2.0 m), using a Van Dorn sampler. The samples, collected in two 60-mL syringes and two 1-liter Nalgene high density polyethylene bottles, are transported from the field on ice and shipped overnight to the EPA-designated laboratory for analysis (ALSC 2002b). Water samples are also collected in separate bottles for speciated aluminum analysis by the ALSC laboratory since 2006. Samples are delivered directly to the laboratory in Ray Brook, NY.

Samples are analyzed by the EPA-designated laboratory for the following parameters: pH, ANC, specific conductance, color, nitrate, sulfate, chloride, fluoride, calcium, magnesium, potassium, sodium, silica, ammonium, dissolved organic carbon, dissolved inorganic carbon, and total aluminum. The ALSC laboratory provides total dissolved aluminum, total monomeric aluminum, total organic monomeric aluminum, and total inorganic monomeric aluminum (calculated). Analytical procedures follow EPA standards developed and described elsewhere (Morrison et al. 1991; ALSC 2002a; Driscoll and van Drearon 1993; Burns et al. 2006).

Figure 7. TIME and ALTM sample locations



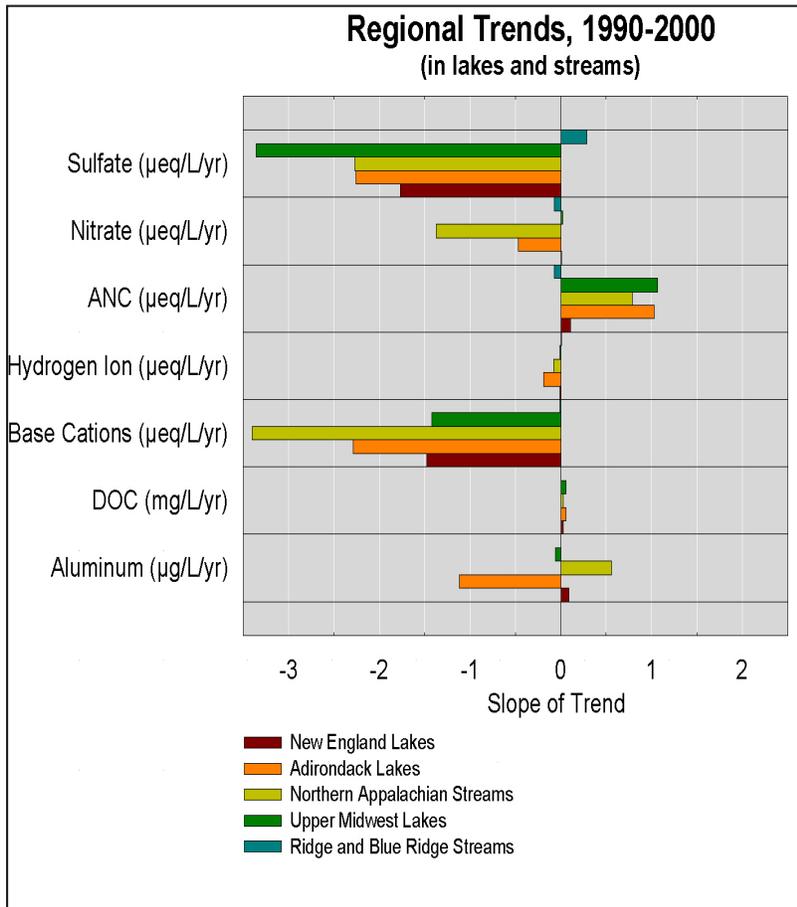
Results

Chemistry Trends 1990–2000

Using EMAP, TIME, and EPA LTM surface water chemistry, Stoddard analyzed regional trends in five sensitive areas of the eastern US over the time period 1990–2000 (Stoddard et al. 2003). The EPA LTM lakes in the Adirondack region are referred to as the ALTM lakes. Trend analysis was conducted on 48 ALTM lakes (non-limed) sampled on monthly basis (Figure 8) and include both drainage and seepage lakes in the ANC range -50 to $100 \mu\text{eq L}^{-1}$ with three lakes in the >100 but $< 200 \mu\text{eq L}^{-1}$ range (Stoddard et al. 2003). In three regions (Adirondacks, Northern Appalachian Plateau, and Upper Midwest), ANC increased at a rate of $1\text{--}2 \mu\text{eq L}^{-1} \text{yr}^{-1}$ despite a decrease in base cations. In the Adirondacks, declines in sulfate occurred in nearly all lakes ($2.5 \mu\text{eq L}^{-1} \text{yr}^{-1}$) and in some lakes declines in nitrates ($0.5 \mu\text{eq L}^{-1} \text{yr}^{-1}$). This combination resulted in pH increases in many lakes (Figure 7). In evaluating lake chemistry responses to atmospheric deposition trends, only sulfate was closely examined because changes in nitrate emissions and deposition were insignificant. During this period 1990–2000, the rate of decline in precipitation sulfate concentrations compared with surface water concentrations varied among the regions. In the Adirondacks, New England, and the Northern Appalachians, declines in precipitation were greater than declines in surface water concentrations, suggesting a lagged response. The five factors identified as important in determining response/recovery in surface water chemistry were: base cations, nitrogen deposition, natural organic acidity, climate fluctuations, and lag in response (Stoddard et al. 2003).

Figure 8. Regional trends in surface water chemistry

Source: Stoddard et al. 2003. *Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990*.



Chemistry Trends 1990–2007 and Ongoing

EPA's 1990–2007 update of regional trends in four sensitive areas of the eastern US found continued sulfate declines in surface water chemistry in three of the regions including the Adirondacks where declines averaged $2.2 \mu\text{eq L}^{-1} \text{yr}^{-1}$. Nitrate declines in some Adirondack lakes occurred at a rate of $0.2 \mu\text{eq L}^{-1} \text{yr}^{-1}$. ANC increases occurred in the same three regions with Adirondack trends averaging $0.77 \mu\text{eq L}^{-1} \text{yr}^{-1}$ (EPA Acid Rain Program 2008 Progress Report; <http://www.epa.gov/airmarkets/progress/arp08.html>). In the Adirondack region, all significant trend slopes (rates of change) have diminished from the previous 1990–2000 assessment.

EPA conducted another assessment during this time period examining 156 northeastern US lakes monitored in the TIME and LTM programs. ANC changes were evaluated between 1992–1994 and 2004–2007. Adirondack lakes were included in this data set. Lakes with ANC levels below $0 \mu\text{eq L}^{-1}$ are considered of acute concern because aquatic biota in these ecosystems are severely compromised. The evaluation found lakes with 3-year average ANC values below $0 \mu\text{eq L}^{-1}$ occurred in 30% of the total population in 1992–1994. The percentage of lakes in the same category had diminished to 18% by 2004–2007 (<http://www.epa.gov/airmarkets/progress/arp08.html>)

The EPA Clean Air Markets Division published a series of reports in 2010 under Acid Rain Program 2009 Progress Reports (<http://www.epa.gov/airmarkets/progress/>). The ALTM lakes data were featured prominently in Environmental Results (October 2010) and Highlights: 15 Years of Results (December 2010). Critical loads for sulfur and nitrogen deposition were established for Northeast and Adirondack lakes. Calculations of critical loads exceedences for two time periods (1989-1991 and 2007-2009) were compared for each region. In the Adirondacks, 37% of lakes with exceedences in the earlier time period no longer were receiving critical loads considered threatening to those lakes. The region, however, remained among the areas with the highest concentration of lakes where acid deposition exceeded the critical loads.

During 2010, two analyses were conducted on Adirondack TIME chemistry, with manuscripts under preparation for both. One was a comparison of the TIME and ALTM results using the six cross-over lakes in common with both projects. Chemistry trends (1992-2008) for sulfate, nitrate, base cations, dissolved organic carbon, hydrogen ion, ANC, and aluminum found sulfate and base cations better represented in the annual TIME data than the other parameters associated with seasonal variability. Seasonal concentrations of total and inorganic aluminum were also examined relative to annual only data. The second analysis involved a broader time series (1991-2007) examination of all the TIME waters with a focus on two measures of ANC and the change in ANC sensitivity classes over the record.

Found at the six crossover lakes (Figure 9) (Big Hope, Squaw, Indian, Willys, South, and North) key chemical parameters paired in time and analyzed by different laboratories generally agreed well (Figure 10) sulfate and ANC plots.

Figure 9. Location of 52 ALTM (black) and 43 TIME (open circles) and the six crossover lakes (red) common to both projects

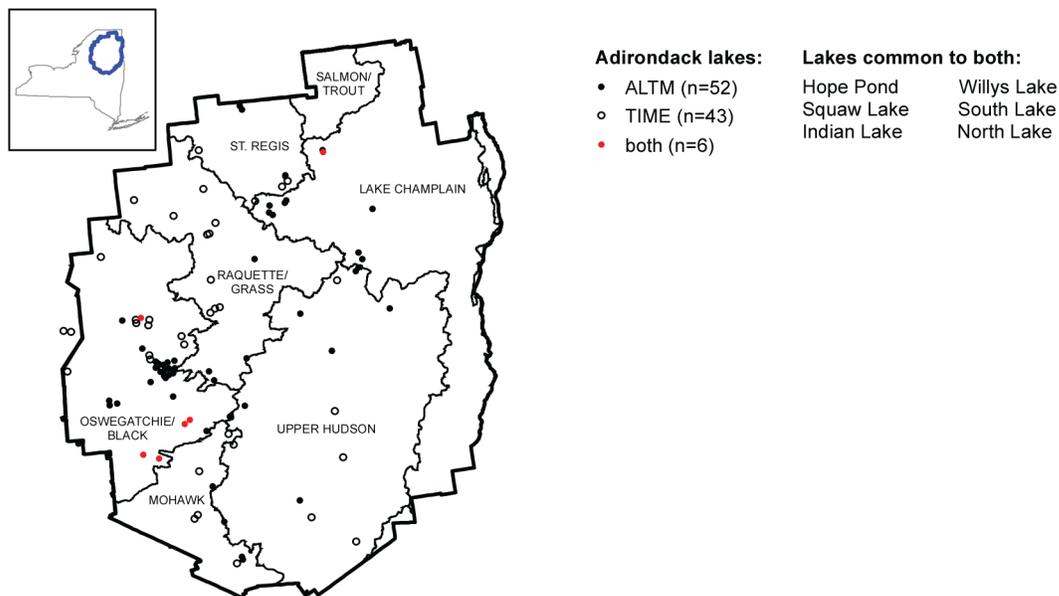
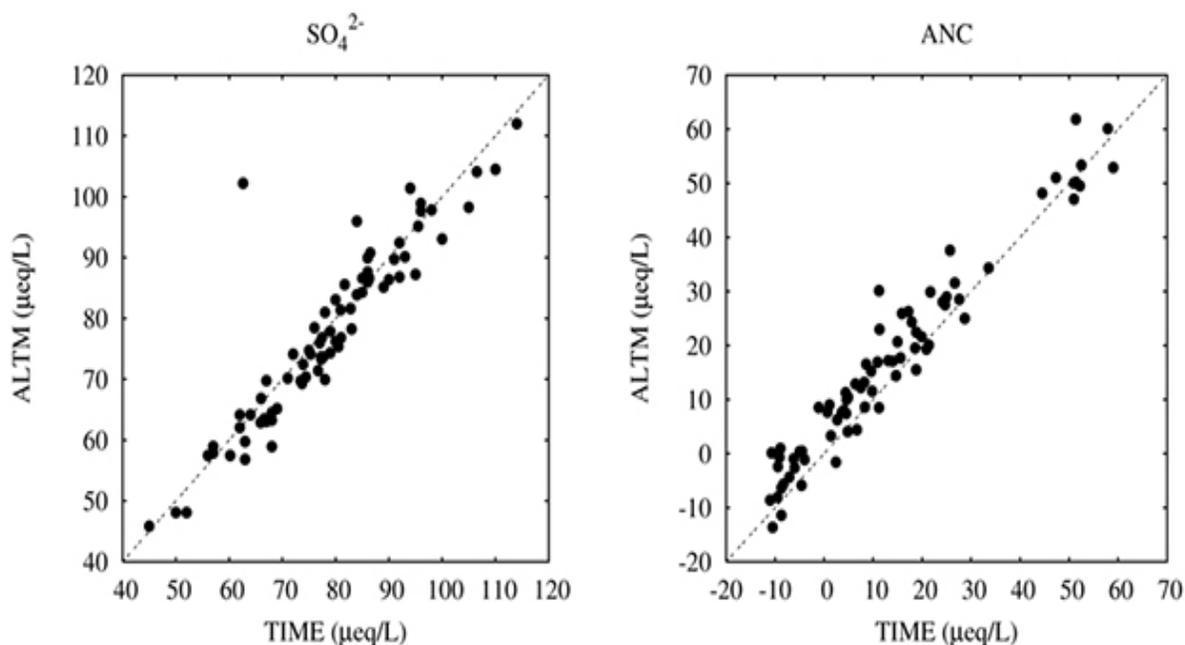


Figure 10. Comparison of sulfate and ANC from TIME and ALTM at six crossover lakes during 1992-2008



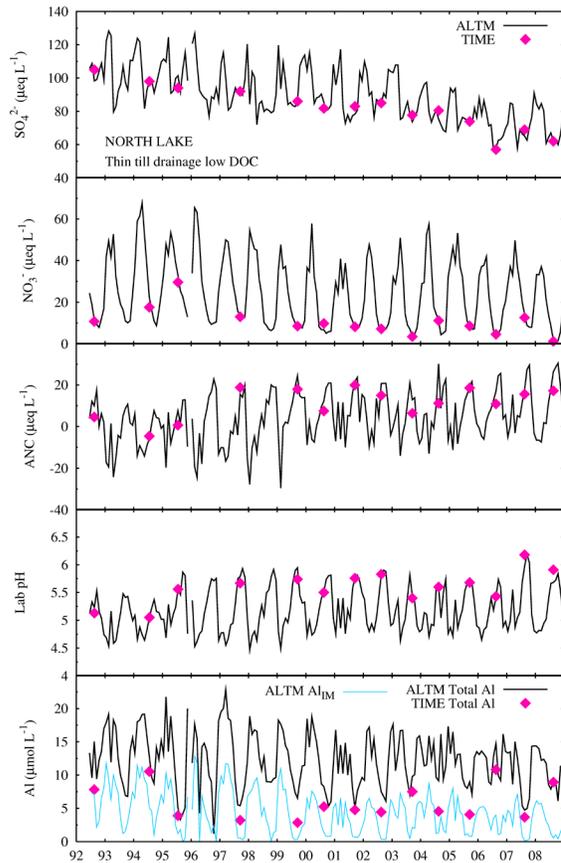
Comparison of monthly ALTM sampling trends with annual TIME trends were consistent for sulfate and the sum of the base cations but not very consistent for ANC and total aluminum (Table 9).

Table 9. The range of long term trends from TIME and ALTM at six crossover lakes using Mann-Kendall for TIME and Seasonal Kendall for ALTM during 1992 - 2008. The number of lakes with significant trends ($p < 0.05$) are shown with the range of slopes

	TIME	ALTM
SO_4^{2-} , $\mu\text{eq L}^{-1} \text{yr}^{-1}$	-3.44 to -2.03 (n=6)	-3.36 to -2.11 (n=6)
ΣCB , $\mu\text{eq L}^{-1} \text{yr}^{-1}$	-2.41 to -1.05 (n=5)	-2.48 to -0.98 (n=5)
NO_3^- , $\mu\text{eq L}^{-1} \text{yr}^{-1}$	-1.16 to -0.81 (n=3)	-1.10 to -0.22 (n=5)
DOC, $\mu\text{mol L}^{-1} \text{yr}^{-1}$	+6.25 to +9.44 (n=2)	+3.60 to +6.74 (n=3)
H^+ , $\mu\text{eq L}^{-1} \text{yr}^{-1}$	-0.17 (n=2)	-0.31 to -0.04 (n=5)
ANC, $\mu\text{eq L}^{-1} \text{yr}^{-1}$	+0.65 to +1.49 (n=2)	+0.70 to +2.08 (n=6)
Total Al, $\mu\text{mol L}^{-1} \text{yr}^{-1}$	Non-significant	-0.56 to -0.17 (n=4)
Al_{IM} , $\mu\text{mol L}^{-1} \text{yr}^{-1}$	N/A	-0.65 to -0.01 (n=5)

ANC, nitrate, DOC and pH exhibited varying degrees of consistency in magnitude and statistical significance of trends (Figure 11). Because these parameters along with aluminum have substantial seasonal variability and are biologically relevant to aquatic biota, the authors concluded that both projects/approaches are needed to assess the full impacts of acidification.

Figure 11. Time series of selected parameters at North lake (1992 - 2008) from ALTM and annual (diamonds) from TIME



Waller et al. (2012) used the NADP NTN and TIME to evaluate response of lake watersheds to changes in sulfur and nitrogen oxides from 1991 to 2007. Decreases in wet sulfate deposition corresponded to decreases in lake sulfate. Lake ANC changes resulted in shifts among lake ANC classes. The percentage of acidic lakes ($ANC < 0 \text{ } \mu\text{eq L}^{-1}$) decreased from 15.5% (284 lakes) to 8.3% (152 lakes) over the period. ANC determined by Gran plot analysis and by calculation of major ion chemistry showed dissimilar values likely due to increases in naturally occurring organic acids. These differences are important to understanding surface water recovery (Waller et al. 2012). The once-per-year population-based TIME study and the monthly ALTM study with seasonal data and aluminum speciation together provide complementary measurements to assess the full impacts of acidification in the Adirondack region.

Recent Regional Trends

The TIME and LTM networks supported by EPA provide information on the chemistry of lakes and streams to indicate how water bodies are responding to changes in SO_2 and NO_x emissions. The key indicators are concentrations of sulfate, nitrate, ANC, base cations and dissolved organic carbon (DOC). The following trends results in these surface water indicators are taken from <http://www.epa.gov/airmarkt/progress/surfacewater.html>

Table 10 shows regional trends in acidification from 1990 (before implementation of the Acid Rain Program) to 2012 in lakes and streams throughout the LTM program. Acidified drainage water mobilizes toxic forms of aluminum from soils and clays, harming fish and wildlife. Five chemical indicators of aquatic ecosystem response to emission changes are presented: trends in sulfate and nitrate anions, base cations, ANC, and DOC. These indicators provide information regarding the surface water sensitivity to acidification and the degree of impact on the aquatic ecosystem. Trends in these measured chemical indicators in drainage waters allow for the determination of whether the water bodies are improving and heading toward recovery or if they are still acidifying.

Table 10. Regional Trends in Sulfate, Nitrate, ANC, Base Cations, and DOC at Long Term Monitoring Sites, 1990–2012

Region	Water Bodies Covered	% of Sites with Improving Sulfate Trend	% of Sites with Improving Nitrate Trend	% of Sites with Improving ANC Trend	% of Sites with Improving Base Cations Trend	% of Sites with Increasing DOC Trend
Adirondack Mountains	50 lakes, NY	100%	54%	76%	88%	62% (29 sites)
New England	26 lakes, ME VT	100%	18%	43%	74%	39% (13 sites)
Catskills / N. Appalachian Plateau	9 streams, NY PA	80%	40%	58%	90%	0% (9 sites)
Central Appalachians	66 streams VA	15%	58%	15%	14%	NA

Notes:

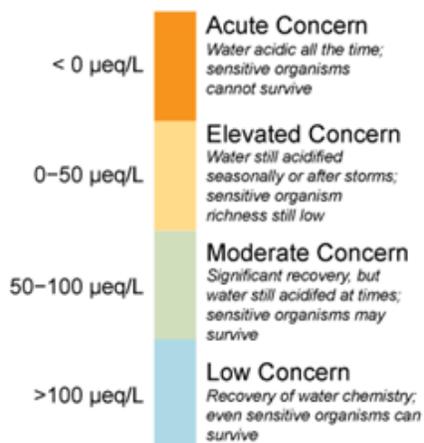
- Trends are determined by multivariate Mann-Kendall tests
- Trends are significant at the 95 percent confidence interval ($p < 0.05$)
- Data for 5 Pennsylvania N. Appalachian Plateau sites is unavailable for 2012
- DOC was only examined in low-ANC waterbodies (ANC less than 25 $\mu\text{eq/L}$)
- DOC is not currently measured in Central Appalachian streams

Trends in ANC Levels of Concern

Figure 12 and Figure 13 are from a recent EPA Progress Report (http://www.epa.gov/airmarkt/progress/ARPCAIR12_02.html). ANC is a measure of overall ability to buffer against acidification, particularly of strong acids that enter aquatic ecosystems. ANC levels have been classified to represent the graduated levels of concern to aquatic organisms (Figure 12). The EPA has examined the shift of ANC over time using ANC concern categories for the TIME lakes in the Adirondacks and New England (Figure 12 and 13).

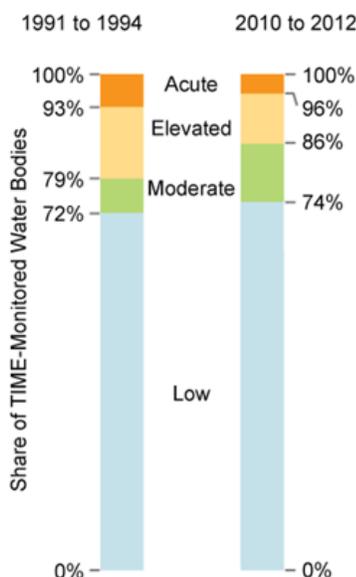
Figures 12. (left) ANC concern levels and Figure 13. (right) TIME lakes by ANC category

Acid Neutralizing Capacity and Aquatic Ecosystem Concern Levels



Source: EPA, 2013

TIME Lakes by ANC Category, 1991–1994 vs. 2010–2012



Source: EPA, 2013

Improving ANC trends are likely the result of reductions in sulfate deposition. Recovery in ANC, however, often lags behind declining surface water sulfate and nitrate concentrations. Dynamics in surface water chemistry are complicated and highly dependent on local factors such as watershed size, geology, and hydrology, which can influence the availability of base cations and DOC, thereby inhibiting ANC recovery. From 1990 to 2012, ANC concentration increased markedly at LTM monitoring sites in the Adirondacks (76 percent), in the Catskills/northern Appalachian Plateau (58 percent), and in New England (43 percent). In contrast, only 15 percent of LTM streams in the Central Appalachians had improving ANC trends, likely due to decreasing base cation levels and the still increasing sulfate concentrations at some sites.

Figure 13 presents a comparison of the average ANC value of the 580 lakes in the Northeast monitored and modeled under the TIME program for the 1991–1994 and 2010–2012 time periods. Seven percent of lakes in the 1991–1994 time period had mean ANC levels below 0 microequivalents per liter (µeq/L) and were categorized as acute concern, but less than 4 percent of lakes were categorized as acute concern in the 2010–2012 time frame. The percentage of lakes in the elevated concern category dropped from 14 percent to 10 percent over the same time frame. Meanwhile, the net percentage of lakes in the moderate concern category increased from 7 percent to 12 percent. These results point to a decrease in acidity, particularly for the subset of TIME lakes in the acute and elevated concern categories.

Critical Loads as a Management Tool

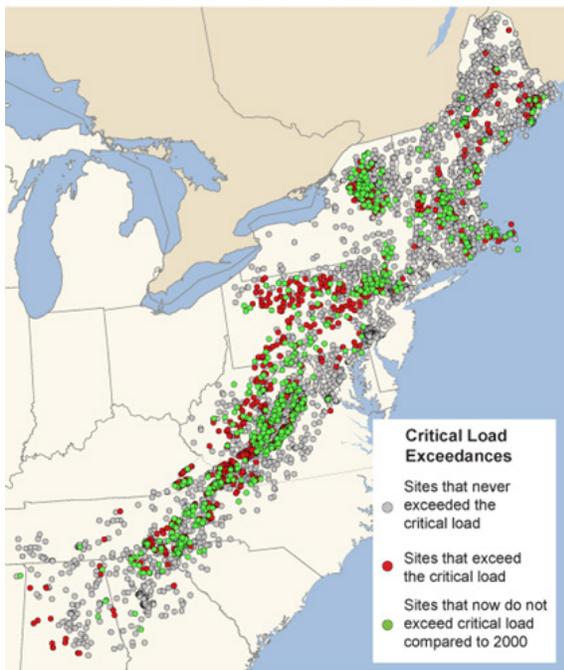
A number of efforts in the last few years examined critical loads as a strategy to assess the effects of sulfur and nitrogen deposition in the Adirondack Region (Lawrence et al. 2011; Sullivan, T.J. 2014). The applications show a reduction in landscapes at risk (Sullivan et al 2014a, Sullivan et al 2014b). On a related course and similar timeline, several federal and regional research efforts focus on improving data types and quality to link air indicators to surface water measurements and indicators (Scheffe et al. 2014; Felton D. 2015).

A recent EPA Progress Report has evaluated the eastern US using these methods. Figure 14 and the following explanations are taken from http://www.epa.gov/airmarkt/progress/ARPCAIR12_02.html#fig_exceedance_map

Figure 14 shows a comparison of the estimated critical load exceedances for waterbodies for the period between 2000–2002 and 2010–2012. For this analysis, the critical load represents the annual deposition load of sulfur and nitrogen to which a lake or stream could be subjected and still support a moderately healthy ecosystem (i.e., having an ANC greater than 50 $\mu\text{eq/L}$). Surface water samples from 4,886 lakes and streams along acid-sensitive regions of the Appalachian Mountains and some adjoining northern coastal plain regions were collected through a number of water quality monitoring programs. Critical load exceedances for those waterbodies were calculated using the Steady-State Water Chemistry model.

Figure 14. Critical Loads

**Lake and Stream Exceedances of Estimated Critical Loads
for Total Nitrogen and Sulfur Deposition for the Period
between 2000–2002 and 2010–2012**



Notes:

- Surface water samples from the represented waterbodies collected through the National Surface Water Survey (NSWS), Environmental Monitoring and Assessment Program (EMAP), Wadeable Stream Assessment (WSA), National Lake Assessment (NLA), Temporally Integrated Monitoring of Ecosystems (TIME), Long Term Monitoring (LTM), and other water quality programs.
- Steady state exceedances calculated in units of $\text{meq/m}^2/\text{yr}$

Source: EPA, 2013

Fisheries Surveys in TIME Lakes

In 2013, six TIME lakes were netted for fish and a fishery management inventory compiled for the time period 1980-2011 for all 43 TIME lakes. The lakes targeted for netting began with the 37 (non-ALTM crossover lakes) then based on a number of factors, including: accessibility (not extremely remote and public land); lack of pre-existing fisheries data; and suitable chemistry (pH 5.2-5.8 and ANC 20-5); and for efficiency of field collections, in proximity to another candidate lake. Ultimately, the six lakes selected included three lakes with no previous fisheries survey or fisheries management information and three lakes with limited historic data. Fish surveys were conducted according to the ALSC fish sampling methods (Adirondack Lakes Survey Corporation, 2002b). The lakes were surveyed either in late June or in late September/early October. A surface water sample was collected for standard analysis at the time of the survey work. Summary table 11 provides the lakes netted with dates, total species caught and the number of yellow perch (YP) and brook trout (ST) captured and preserved (frozen).

Table 11. Summary of fish netted in TIME waters in 2013

TIME ID	ALSC ID	ALSC Name	ALS date mm/yyyy	TIME date dd/mm/yyyy	Total species caught	Total YP	Total ST
NY286L	060129	Rock Pond	na	24/06/2013	7	0	3
NY287L	060126	Antediluvian Pond	na	25/06/2013	3	0	0
NY526L	050715	Henderson Lake	na	10/10/2013	7	22	0
NY788L	040528	Witch Hopple Pond	6/1984, 9/1984	23/09/2013	8	37	9
NY792L	040518	Cat Pond	6/85	24/09/2013	4	12	0
NY798L	050607	Little Moose Pond	7/87	03/10/2013	3	0	3

The number of fish species caught ranged from three to eight. A total of different species were identified. In all a total of 32 fish populations were sampled. This included 3 populations of yellow perch and 3 populations of brook trout. Specimens of these species were frozen for potential future analysis (e.g. mercury concentrations).

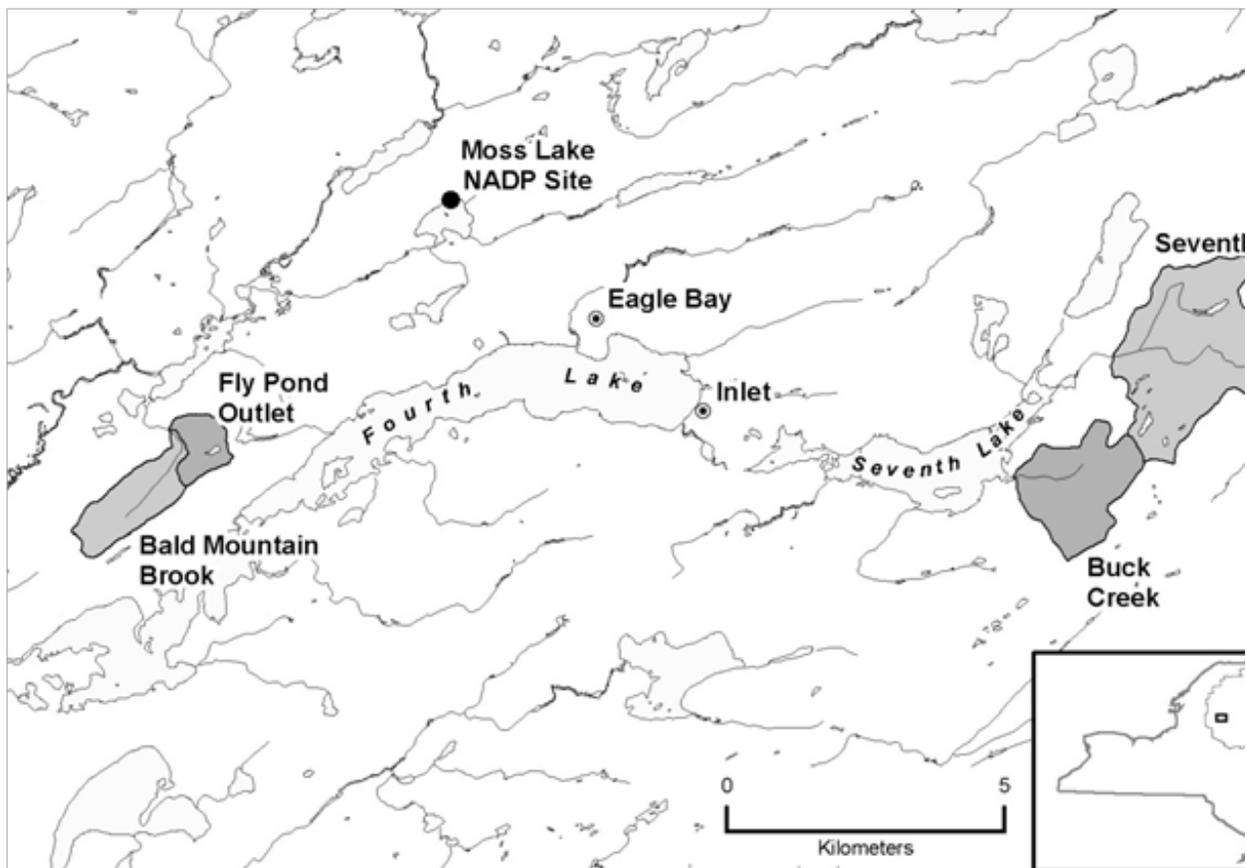
Data Reported to Date

Data currently available from this TIME lake study (this section) include the original EPA EMAP data for the lakes (available at <http://www.epa.gov/emap/html/data/surfwatr/data/nelakes.html>). The EPA LTM/TIME program is responsible for making available the TIME lake chemistry data. Additional chemistry data (i.e., speciated aluminum) analyzed by the ALSC laboratory for the 43 lakes were provided to EPA for the 2006-2013 sampling seasons. The routine TIME water chemistry data are generated from an EPA-designated laboratory. Additional information/data are be available by contacting the NYSDEC ALTM Research Manager.

Stream Chemistry

The streams component of the ALTM program began in June 1992 at the completion of the USEPA Episodic Response Project (ERP). The ERP examined the chemistry and biological effects of episodes, defined as a period of time when ANC values decreased to less than or equal to $0 \mu\text{eq L}^{-1}$, in 13 streams from the fall of 1988 through the spring of 1990 in three study regions: the Catskill and Adirondack Mountains of New York, and the Northern Appalachian region of Pennsylvania. The Adirondacks were represented by four streams: Buck Creek, Bald Mountain Brook, Seventh Lake Inlet, and Fly Pond Outlet. The streams are located in the southwestern highlands area within the Oswegatchie-Black watershed (Figure 15). The bedrock, surficial geology, and soils in these watersheds are considered typical of the region. Fly Pond Outlet is the only stream with a small pond as headwater, and is the reference stream for biological studies (Wigington et al. 1996a).

Figure 15. Stream watersheds of original four ERP streams: Buck Creek, Bald Mountain Brook, Fly Pond Outlet and Seventh Lake Inlet



The ERP investigators produced a series of articles published in *Ecological Applications* (1996, Issue 6). Wigington found none of the Adirondack streams chronically acidic during the study period 1988-1990, however, during high flow, Bald Mountain Brook and Buck Creek exhibited critical chemistry with median ANC values less than $-10 \mu\text{eq L}^{-1}$ (Wigington et al. 1996a). More detailed episodic chemistry was examined by Wigington et al. (1996b). This additional analysis found acid episodes within the 90th percentile with ANC decreases of up to $200 \mu\text{eq L}^{-1}$, decreases of pH of up to one unit, and increases in inorganic monomeric aluminum of up to $15 \mu\text{mol L}^{-1}$. Others reported negative responses of wild brook trout and native forage fish to changes in chemistry (Van Sickle et al. 1996; Baker et al. 1996).

Site Description

The ALSC continued to sample Buck Creek, Bald Mountain Brook, and Fly Pond Outlet on a weekly basis beginning in June 1992. Stream gaging that took place during the ERP was discontinued. Weekly surface grab samples were analyzed for lab pH, air equilibrated pH, ANC, and specific conductivity. In May 1997, the ALSC started analyzing the samples collected during the first week of each month for the full suite of chemical parameters analyzed as they are for the ALTM lakes, namely: lab pH, air equilibrated pH, ANC, specific conductivity, color, nitrate, sulfate, chloride, fluoride, calcium, magnesium, potassium, sodium, silica, ammonium, dissolved organic carbon, dissolved inorganic carbon, total dissolved aluminum, total monomeric aluminum, total organic aluminum, and total inorganic aluminum (calculated).

Following an analysis by Lawrence et al. (2004), in September of 2006 the stream sampling interval was changed to bi-weekly sampling of Buck Creek and Bald Mountain Brook. Sampling at Fly Pond outlet was continued on a monthly basis. All samples are analyzed for full complement chemistry.

Starting in 1998, the United States Geological Survey (USGS) with support from the Adirondack Effects Assessment Program (AEAP), conducted bi-weekly and event-driven chemistry and flow monitoring at two upstream tributaries of Buck Creek referred to as the North Tributary and the South Tributary. Additional sampling started at the main stem of Buck Creek in 2001. All samples were analyzed for the full suite of analytes. At all three locations, USGS collected bi-weekly samples and selected storm event samples collected by automated samplers. The USGS effort included soil temperature and moisture monitoring at a location adjacent to the stream sites. An assessment of episodic acidification in Buck Creek watershed in relation to atmospheric deposition and soil chemistry during 1998–2000 is discussed by Lawrence (2002). Diatom community dynamics and water chemistry were assessed from May 2000 through July 2003 (Passy et al. 2006; Passy 2006). Buck Creek is also one of eight research sites across the Northeast examined in 2000 by the USGS and others (Ross et al. 2004) for patterns of soil nitrogen accumulation. Sampling methods and site characteristics of the Buck Creek watershed are detailed by Lawrence et al. (2002); Ross et al. (2004); Passy (2006); Passy et al. (2006).

In response to funding reductions at the AEAP, in September 2006, the USGS consolidated efforts with the ALSC at Buck Creek and the ALSC assumed responsibility for sample collections at the tributaries and main channel. The ALSC continues bi-weekly sampling at the North Tributary (AB), South Tributary (BB) and the main channel of Buck Creek (BCK). Discharge monitoring also continues at both tributaries and the main channel of Buck Creek, with 5–7 event based samples analyzed each year. Laboratory analysis of the samples collected for these discharge events is based on the guidance of Greg Lawrence (USGS). Bald Mountain Brook and Fly Pond outlet sampling continues on a bi-weekly basis. Chemistry analysis are performed by the ALSC laboratory in Ray Brook.

Buck Creek was a critical calibration site during the Western Adirondack Stream Survey (WASS) conducted during 2003–2005 (Lawrence et al. 2008a; Lawrence et al. 2008b). Buck Creek is the only stream within the Oswegatchie River and Black River drainages monitored for year-round flow and chemistry. During the WASS, Buck Creek served as an index stream to place results within the context of variations throughout the year.

Monitoring of stream discharge and chemistry in the Buck Creek watershed has supported research that has provided valuable information on (1) trends in stream chemistry over the last two decades, (2) methods to improve the ability to distinguish between acid rain effects and natural acidity, and (3) sensitivity of aquatic organisms to low levels of inorganic aluminum. The incorporation of historic vegetation and soil chemistry data and continuation of sampling/analysis at these sites provide critical information on the linkages between (soil acidification) terrestrial condition/status and the hydrologic and aquatic chemistry conditions.

Sampling Design

Descriptions of the stream study sites (Table 12), and laboratory and field methods are provided by Kretser et al. (1992). Through December 2014, surface grab samples are collected in high density polyethylene bottles and analyzed bi-weekly for the following parameters: color, nitrate, sulfate, chloride, fluoride, calcium, magnesium, potassium, sodium, silica, ammonium, dissolved organic carbon, dissolved inorganic carbon, total dissolved aluminum, total monomeric aluminum, organic monomeric aluminum, and inorganic monomeric aluminum (total monomeric Al minus organic monomeric Al). Event-based samples for discharge monitoring are collected in ISCO samplers, maximum of 24 bottles, and analyzed for all of the above parameters except dissolved inorganic carbon, and total dissolved aluminum. Total aluminum is analyzed for event based parameters. As of January 2015, all bi-weekly and episodic samples are analyzed for total aluminum; and total dissolved aluminum will be discontinued from the bi-weekly samples.

Table 12. Physical characteristics of the four ERP study streams in the Adirondack Mountains of New York

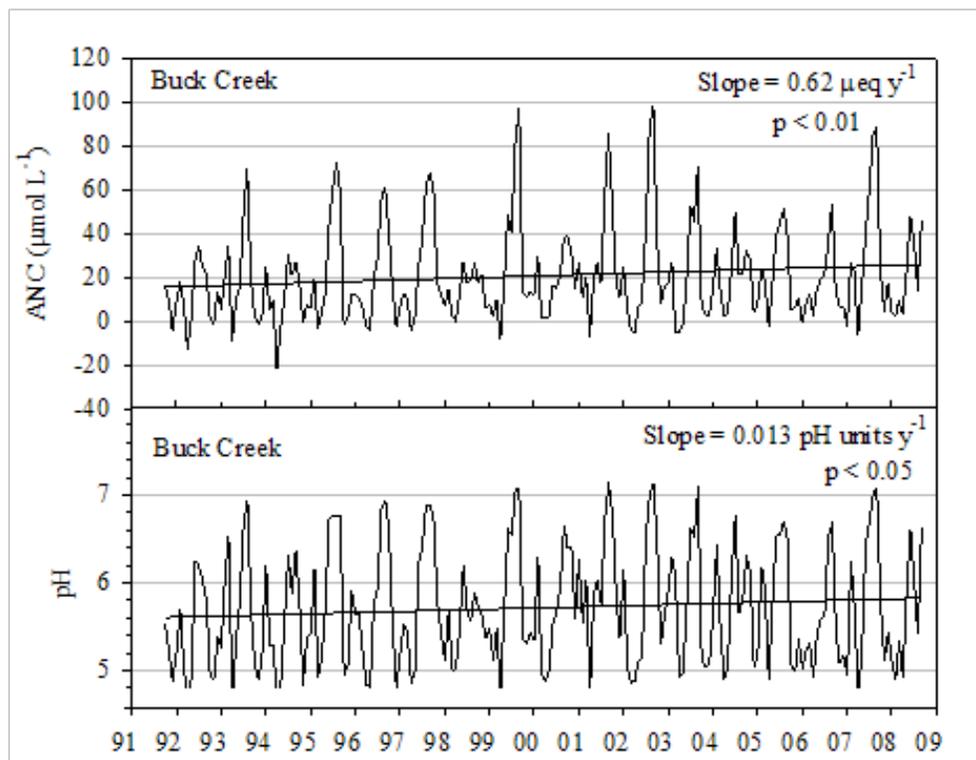
Characteristic	Study Stream Buck Creek ^a	Bald Mountain Brook ^a	Fly Pond Outlet ^b	Seventh Lake Inlet ^c
Stream gage				
Latitude	43° 44' 39" N	43° 45' 03" N	43° 45' 05" N	43° 45' 49" N
Longitude	074° 43' 20" W	074° 54' 39" W	074° 54' 34" W	074° 42' 11" W
Watershed				
Area (km ²)	3.1	1.8	0.9	6.4
Maximum elevation (m)	775	715	710	725
Minimum elevation (m)	560	570	563	570
Lake or pond present	No	No	Yes	Yes
Wetland present	Minor	Yes	Yes	Yes
Soil series	Becket-Lyman	Lyman	Lyman	Lyman
	Becket-Sherry	Becket	Becket	Becket-Sherry
				Becket-Lyman
				Adams Croghan
Stream				
Order	2	1	1	2
Length (km)	2.1	2.2	0.8	3.7
Gradient (m km ⁻¹)	50	25	9	31
a. continued bi-weekly sampling				
b. continued monthly sampling				
c. discontinued after 1991				

Results

Trend Analysis 1991–2001

In 2004, the ALTM Program performed a time series analysis of these three streams, Buck Creek, Bald Mountain Brook, and Fly Pond Outlet, for the period October 1991–September 2001. Examining monthly pH values during these 10 years found that Buck Creek is acidic, Bald Mountain Brook is moderately well buffered, and Fly Pond Outlet is well buffered. Concentrations of DOC were similar among the three streams. Total and inorganic monomeric aluminum concentrations were at or near detection limits in Bald Mountain Brook and Fly Pond Outlet, and higher in Buck Creek. Although similar increasing trends in ANC and pH were found in all three streams, the trends changed uniquely for each stream when the effect of flow variation was removed (Figure 16). In Buck Creek, the increasing trend in ANC was no longer observed if flow effect was removed. In Bald Mountain Brook, a downward trend in ANC from 1991–1995, followed by an upward trend from 1996 to 2001 was evident. In Fly Pond Outlet, ANC increased abruptly in 1997, with no clear trend before or after. These comparisons indicate the importance of long-term flow data for interpreting long term stream chemistry trends (Lawrence et al. 2004).

Figure 16. Trend 1991–2008 Buck Creek



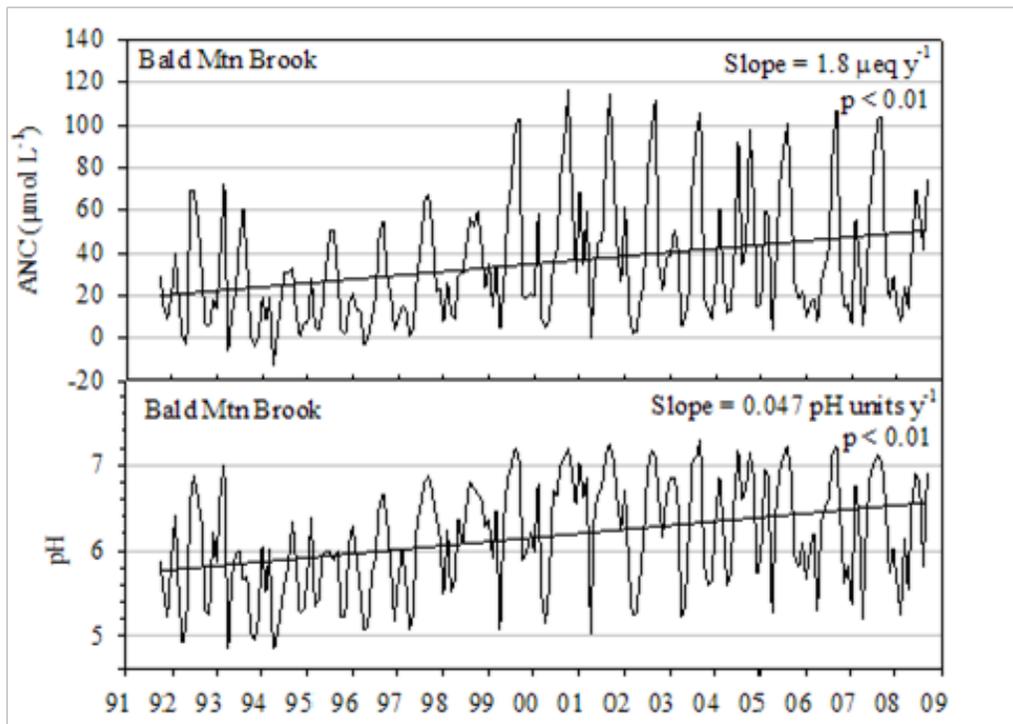
Examination of flow variation within the year identified five periods: the month of April with pronounced snowmelt peak; spring and early summer (May–July); a late summer minimum (August–September) that results from a soil moisture deficit over the course of the growing season; a rise in flow in the fall (October through November) after the growing season; and a relatively stable period (December through March) during the winter months (Lawrence et al., 2004)

Trend Analysis 1991–2008

An updated time series analysis is currently underway for the period October 1991–September 2008. In Buck Creek, measurements of ANC and pH show limited but statistically significant increases over the 17-year period (Figure 15). Extending the average annual rate of increase (slope shown in Figure 16) over the 17 years resulted in a total increase in ANC of $10 \mu\text{eq L}^{-1}$ and a total increase in pH of 0.22 pH units.

In Bald Mountain Brook, measurements of ANC and pH also showed overall increases that were statistically significant (Figure 17). Extending the average annual rate of increase (slope shown in Figure 16) over the 17 years resulted in a total increase in ANC of $31 \mu\text{eq L}^{-1}$ and a total increase in pH of 0.8 pH units. The average annual rate of increase of ANC and pH in Bald Mountain Brook ($1.8 \mu\text{eq L}^{-1} \text{y}^{-1}$, $0.047 \text{ pH units y}^{-1}$, respectively) was approximately 3–4 times the rate of increase of ANC and pH in Buck Creek ($0.62 \mu\text{eq L}^{-1} \text{y}^{-1}$, $0.013 \text{ pH units yr}^{-1}$, respectively). The temporal patterns of both measurements in Bald Mountain Brook show a decrease over the first three years, followed by a pronounced increase over the next 5–6 years, then small to moderate decreases over the final seven to eight years (Figure 17).

Figure 17. Trend 1992–2008 Bald Mountain Brook



With respect to conditions for aquatic biota, in general, values of ANC less than $50 \mu\text{eq L}^{-1}$, pH less than 6.0, and inorganic aluminum concentration greater than $2.0 \mu\text{mol L}^{-1}$ indicate that species are at risk from acidification (Driscoll 2001). The average annual rate of increase of ANC and pH in Bald Mountain Brook suggests a moderate degree of recovery over this period, whereas the rate in Buck Creek suggests relatively minimal recovery. The average annual rate of increase for pH and ANC in both streams is less than the rate reported by Lawrence et al. (2004) for the water year 1992–2001, which indicates that the rate of recovery has slowed over the past seven years. The overall trends for Bald Mountain Brook were considerably stronger than those observed for Buck Creek, but also more erratic. Buck Creek continues to exhibit episodic depressions in ANC ($< 0 \mu\text{eq L}^{-1}$) and pH (< 5.0) at values inhospitable to acid-sensitive aquatic species (Driscoll et al. 2001) (Figure 12).

In summary the updated analysis includes an extension of the 10-year stream monitoring results presented in Lawrence et al. (2004) and includes results from the two tributary streams (North Tributary and South Tributary) within the Buck Creek (Tables 13a-d) watershed that was initiated in 1998. The paper evaluated: the record of Bald Mountain Brook and Buck Creek extended from 10 to 17 years; the 10-year record of the North and South tributaries including a more in-depth evaluation of biogeochemical processes related to recovery; and compared the chemistry of 12 streams sampled in the early 1980s with samples collected in 2003 - 2005 from the same streams. A significant (50%) reduction in atmospheric deposition of sulfur occurred over this period (1998 to 2008). Results for Buck Creek and Bald Mountain Brook are shown in Figures 12 and 13. The North Tributary had high DOC and showed sulfate concentrations decreased at a rate of $2.0 \mu\text{mol L}^{-1} \text{y}^{-1}$. The neighboring South Tributary with low DOC, showed a decrease of only $0.73 \mu\text{mol L}^{-1} \text{y}^{-1}$. In the 12 streams over 23 years, overall increases in pH of only 0.28 and ANC of $13 \mu\text{eq L}^{-1}$ were observed. Although consistent with the range of chemistry changes reported for Adirondack lakes, results from the group of streams presented are highly variable with a more muted recovery response (Lawrence et al. 2011).

Current Trend Analysis Through 2013

During water years 2011 and 2012, the North Tributary of Buck Creek (Table 13a and Table 14a) showed minimal seasonality in measures of acidity (ANC, pH, and BCS), but did exhibit seasonal variations in DOC (highest in spring/summer, late summer and fall) and NO_3^- (highest during winter and snowmelt and lowest during fall). Seasonal patterns were more pronounced in the South Tributary of Buck Creek (Table 13b and Table 14b), Buck Creek (Table 13c and Table 14c) and Bald Mountain Brook (Table 13d and Table 14d), which had the lowest values of ANC, pH and BCS during snowmelt and the highest values during late summer. However, during 2011, BCS values for the Buck Creek tributaries and Buck Creek were negative during all seasons, whereas positive values were measured during all seasons except snowmelt in Bald Mountain Brook. In water year 2012, the North Tributary of Buck Creek remained chronically acidic, but BCS values in Buck Creek and the South Tributary were positive during spring/summer and late summer. Stream chemistry was similar in Bald Mountain Brook during both years, but in the other three streams, 2012 was considerably less acidic. As is normally observed, winter and snowmelt periods tended to be the most acidic period and late summer tended to be the least acidic period.

Table 13a-d. Median stream concentrations for October 2011 through September 2012 (water year 2012) in the North Tributary of Buck Creek (a), the South Tributary of Buck Creek (b), Buck Creek (c) and Bald Mountain Brook (d), for fall (October-November), winter (December-March), snowmelt (April), spring/summer (May-July) and late summer (August-September). All concentrations are expressed as $\mu\text{mol L}^{-1}$ except ANC and BCS ($\mu\text{eq L}^{-1}$), and pH (pH units)

Table 13a. Median Stream Concentrations North Tributary of Buck Creek (Acid Buck) October 2011 - September 2012

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	5	9	4	9	7
SO_4^{2-}	26.6	34.5	26.8	28.2	18.5
NO_3^-	2.4	22.5	19.5	10.5	10.4
Cl ⁻	13.1	9.5	6.6	12.8	12.1
ANC	-36.6	-39.9	-34.5	-38.1	-23.9
DOC	1518.8	1255.8	1365.2	1531.5	1480.3
Si	101.2	130.8	75.2	80.3	92.9
Ca^{2+}	19.5	20.4	20.8	23.6	21.7
Mg^{2+}	8.4	9.4	8.3	8.6	8.7
Na^+	25.6	26.8	22.5	23.9	21.4

Table 13a. continued

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	5	9	4	9	7
K ⁺	3.4	4.9	6.8	5.3	10.7
NH ₄ ⁺	0.6	0.7	1.1	1.8	1.5
Total Al	30.6	28.0	28.8	29.3	23.7
Total Monomeric Al	16.0	17.0	16.8	16.7	15.5
Organic Monomeric Al	13.1	12.0	11.7	11.2	8.3
Inorganic Monomeric Al	4.1	5.4	5.6	5.5	6.1
pH	4.4	4.3	4.4	4.4	4.5
BCS	-91.3	-97.9	-85.4	-85.3	-65.7

Table 13b. Median Stream Concentrations South Tributary of Buck Creek (Basic Buck) October 2011 - September 2012

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	5	9	3	10	4
SO ₄ ²⁻	35.9	30.5	31.6	36.7	45.5
NO ₃ ⁻	41.1	92.8	84.5	32.5	21.0
Cl ⁻	8.4	7.5	8.0	10.2	9.9
ANC	6.9	-0.3	-2.1	34.3	112.6
DOC	259.3	209.6	270.5	252.6	238.4
Si	115.2	96.3	98.0	140.8	228.6
Ca ²⁺	31.5	31.5	35.1	43.6	60.0
Mg ²⁺	10.4	8.8	9.3	14.9	22.6
Na ⁺	33.3	27.4	25.7	44.4	63.9
K ⁺	4.1	4.8	6.1	7.2	8.1
NH ₄ ⁺	0.2	0.3	0.6	1.3	0.6
Total Al	8.8	19.8	19.9	7.2	4.2
Total Monomeric Al	5.1	10.3	9.6	4.2	2.1
Organic Monomeric Al	3.7	3.5	3.4	3.2	2.0
Inorganic Monomeric Al	2.0	6.3	6.2	0.7	0.3
pH	5.6	5.0	5.0	6.4	6.8
BCS	-15.5	-58.2	-43.3	23.3	99.6

Table 13c. Median Stream Concentrations Buck Creek (Main Buck October 2011 - September 2012)

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	5	9	4	12	4
SO ₄ ²⁻	43.4	37.2	33.4	43.2	49.1
NO ₃ ⁻	20.3	60.4	51.8	20.3	14.7
Cl ⁻	9.8	9.1	8.5	10.3	10.6
ANC	13.3	10.7	6.2	37.5	79.5
DOC	474.2	365.2	540.9	479.9	452.4
Si	137.8	119.8	100.2	158.1	199.6
Ca ²⁺	37.4	39.5	37.3	50.0	57.3
Mg ²⁺	13.3	12.4	11.0	16.9	20.5
Na ⁺	39.1	32.2	27.6	46.1	54.8
K ⁺	5.8	6.0	6.9	8.4	9.4
NH ₄ ⁺	0.3	0.3	1.1	1.4	0.9
Total Al	9.7	13.7	17.8	12.2	7.1
Total Monomeric Al	5.1	8.0	9.6	6.0	3.3
Organic Monomeric Al	4.9	4.9	5.1	4.4	2.6
Inorganic Monomeric Al	1.1	2.7	4.8	1.5	0.8
pH	5.7	5.3	5.1	6.0	6.5
BCS	-0.5	-26.0	-32.5	25.9	69.0

Table 13d. Median Stream Concentrations Bald Mountain Brook October 2011 - September 2012

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	4	9	2	7	4
SO ₄ ²⁻	38.4	36.8	32.8	36.5	49.6
NO ₃ ⁻	33.7	57.3	47.4	35.6	26.2
Cl ⁻	9.7	8.2	7.4	9.2	10.4
ANC	39.6	19.4	15.7	49.7	115.2
DOC	222.8	216.5	344.7	230.2	209.8
Si	182.1	140.6	114.6	175.2	211.1
Ca ²⁺	41.1	37.6	34.6	47.3	62.1
Mg ²⁺	19.5	15.3	13.5	18.6	29.0
Na ⁺	49.4	36.8	31.3	50.2	63.7
K ⁺	6.8	6.0	6.4	7.9	11.1
NH ₄ ⁺	0.1	0.5	0.7	1.1	0.6
Total Al	4.6	7.8	8.9	4.9	3.4
Total Monomeric Al	2.5	4.2	6.2	2.6	1.4
Organic Monomeric Al	2.4	3.3	4.3	2.4	1.4
Inorganic Monomeric Al	0.2	1.3	1.9	0.2	0.1
pH	6.5	5.8	5.7	6.6	7.0
BCS	39.9	-1.8	-8.9	51.9	108.6

Table 14a-d. Median stream concentrations for October 2010 through September 2011 (water year 2011) in the North Tributary of Buck Creek (a), the South Tributary of Buck Creek (b), Buck Creek (c) and Bald Mountain Brook (d), for fall (October-November), winter (December-March), snowmelt (April), spring/summer (May-July) and late summer (August-September). All concentrations are expressed as $\mu\text{mol L}^{-1}$ except ANC and BCS ($\mu\text{eq L}^{-1}$), and pH (pH units)

Table 14a. Median Stream Concentrations North Tributary of Buck Creek (Acid Buck) October 2010 - September 2011

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	8	18	6	6	8
SO ₄ ²⁻	32.82	40.12	25.04	20.36	19.00
NO ₃ ⁻	1.34	16.29	18.38	7.55	5.97
Cl ⁻	13.23	10.96	5.75	6.84	6.97
ANC	-41.19	-40.67	-40.22	-46.54	-51.19
DOC	1389.37	1233.71	1218.09	1726.26	1852.71
Si	112.74	137.44	65.90	74.09	83.95
Ca ²⁺	20.57	22.17	17.28	19.93	21.28
Mg ²⁺	8.42	9.58	7.22	7.07	6.90
Na ⁺	28.42	29.71	19.46	18.20	15.43
K ⁺	1.96	2.71	5.22	2.77	3.63
NH ₄ ⁺	0.42	0.57	0.90	1.16	0.94
Total Al	32.23	26.23	25.11	32.80	32.31
Total Monomeric Al	17.27	15.88	16.09	17.47	17.45
Organic Monomeric Al	12.34	9.64	10.48	12.67	13.82
Inorganic Monomeric Al	5.16	5.51	5.48	4.78	4.07
pH	4.31	4.38	4.33	4.33	4.27
BCS	-89.12	-91.91	-85.67	-99.33	-108.85

Table 14b. Median Stream Concentrations South Tributary of Buck Creek (Basic Buck) October 2010 - September 2011

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	12	24	6	10	10
SO ₄ ²⁻	35.61	34.89	26.63	36.90	30.62
NO ₃ ⁻	32.03	75.50	85.27	21.12	31.28
Cl ⁻	8.62	8.39	6.57	7.56	7.44
ANC	4.11	4.70	-12.25	7.96	10.02
DOC	301.99	207.60	351.21	262.34	471.45
Si	88.35	97.44	63.16	90.21	87.82
Ca ²⁺	26.59	31.96	24.12	22.55	35.31
Mg ²⁺	7.16	9.60	6.34	7.55	9.10
Na ⁺	26.82	29.56	17.77	22.57	27.15
K ⁺	3.74	4.82	6.49	5.29	4.53
NH ₄ ⁺	0.30	0.45	1.06	0.45	0.11
Total Al	12.33	16.09	20.87	13.62	10.01
Total Monomeric Al	8.07	8.28	12.44	6.15	8.15
Organic Monomeric Al	4.17	2.89	4.21	3.28	5.11
Inorganic Monomeric Al	4.12	5.51	8.59	2.11	2.87
pH	5.02	5.09	4.66	5.13	5.23
BCS	-33.69	-48.94	-74.54	-31.59	-19.06

Table 14c. Median Stream Concentrations Buck Creek (Main Buck) October 2010 - September 2011

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	16	28	19	12	10
SO ₄ ²⁻	38.73	43.28	28.89	37.10	35.31
NO ₃ ⁻	15.58	48.72	40.55	13.63	16.80
Cl ⁻	10.03	10.00	7.13	7.68	7.41
ANC	7.72	10.37	-5.86	6.27	19.06
DOC	669.42	364.45	535.60	531.11	787.87
Si	106.65	120.74	70.17	93.88	118.09
Ca ²⁺	33.75	40.71	27.53	26.19	41.39
Mg ²⁺	9.78	13.08	8.05	8.56	11.31
Na ⁺	27.39	35.21	19.51	25.98	28.35
K ⁺	4.66	6.20	5.87	5.59	5.48
NH ₄ ⁺	0.57	0.54	2.05	1.08	0.74
Total Al	16.32	11.34	18.71	13.34	14.85
Total Monomeric Al	10.39	6.26	10.71	7.67	9.30
Organic Monomeric Al	7.51	3.82	6.82	5.23	6.68
Inorganic Monomeric Al	3.23	2.61	3.81	2.83	2.34
pH	5.04	5.42	4.76	5.19	5.54
BCS	-26.43	-19.23	-46.11	-31.26	-2.60

Table 14d. Median Stream Concentrations Bald Mountain Brook October 2010 - September 2011

Season	Fall	Winter	Snowmelt	Spring/summer	Late Summer
Number of samples	8	18	2	6	5
SO ₄ ²⁻	38.28	42.86	29.72	39.20	35.28
NO ₃ ⁻	20.58	39.55	41.09	28.12	22.94
Cl ⁻	9.63	8.64	6.83	8.11	9.74
ANC	25.97	40.02	0.93	32.29	71.04
DOC	312.96	207.03	347.95	256.45	378.62
Si	150.84	161.28	75.32	160.67	167.72
Ca ²⁺	34.98	40.87	26.14	32.28	43.23
Mg ²⁺	13.88	17.59	8.72	15.87	18.92
Na ⁺	37.88	40.82	22.32	43.62	43.93
K ⁺	4.88	6.41	5.66	5.56	6.19
NH ₄ ⁺	0.38	0.39	0.43	0.59	0.08
Total Al	7.12	5.85	12.52	5.55	4.92
Total Monomeric Al	3.63	2.71	7.89	2.68	2.47
Organic Monomeric Al	3.19	2.23	4.12	2.35	2.38
Inorganic Monomeric Al	0.56	0.32	3.77	0.35	0.10
pH	6.16	6.24	4.94	6.28	6.54
BCS	12.21	14.41	-32.28	7.88	55.55

Trends in concentrations of SO_4^{2-} from water years 2006 to 2012 showed a seasonal pattern of highest concentrations in winter and lowest concentrations in summer (Figure 18). This pattern was most pronounced in the North Tributary of Buck Creek. All sites showed a general downward trend over the measurement period, which was also most pronounced in the North Tributary of Buck Creek. There were no clear trends in concentrations of NO_3^- , but concentrations during winter and snowmelt periods in 2007, 2011, and 2012 were anomalously high (Figure 19). Seasonality of NO_3^- concentrations was very consistent despite large year-to-year variations in concentrations. An increasing trend in DOC was observed in the North Tributary of Buck Creek and in Buck Creek, but no trend was apparent in the South Tributary of Buck Creek or Bald Mountain Brook (Figure 20). Values of BCS increased considerably over the measurement period from less than $-100 \mu\text{eq L}^{-1}$ to approximately -60 in the North Tributary of Buck Creek (Figure 21). There was no clear trend for BCS in the other three streams. Most median values were below zero throughout the seven years in Buck Creek and the South Tributary, whereas most values in Bald Mountain Brook were above zero. Concentrations of Ca^{2+} decreased in all four streams up through 2011, but a large increase was observed in the spring/summer and late summer values of 2012 (Figure 22). A similar increase was observed in the summer of 2007. Overall, indications of chemical recovery of these streams was minimal. Decreases in SO_4^{2-} were offset to some degree by decreases in Ca^{2+} concentrations. Elevated NO_3^- concentrations remain an acidifying factor during winter and snowmelt periods, and to a lesser extent during the spring/summer period.

Figure 18. SO_4^{2-} seasonal median concentrations for the North and South Tributaries of Buck Creek, Buck Creek, and Bald Mountain Brook for water years 2006 to 2013

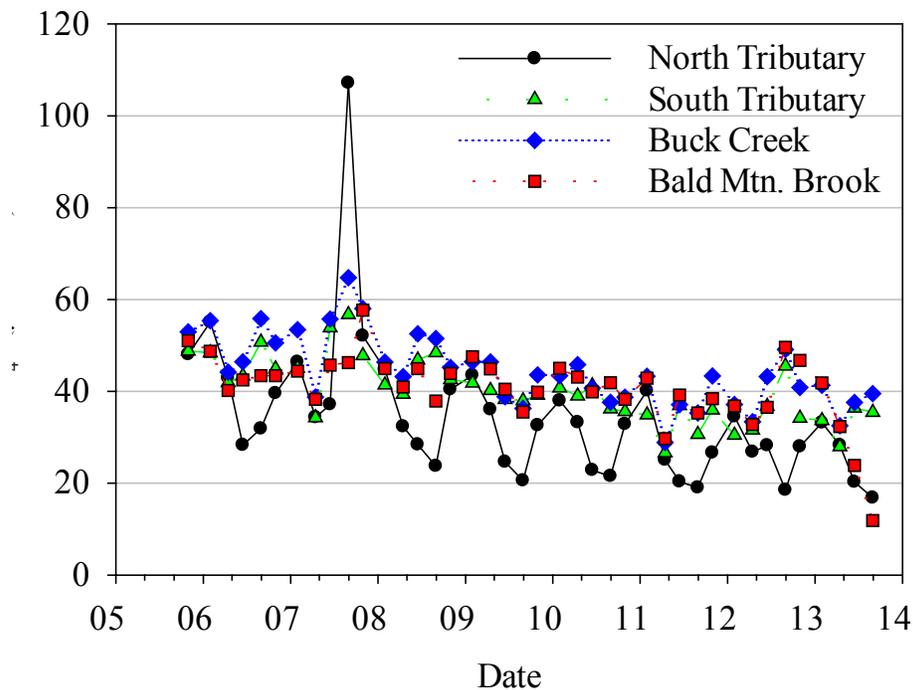


Figure 19. NO_3^- seasonal median concentrations for the North and South Tributaries of Buck Creek, Buck Creek, and Bald Mountain Brook for water years 2006 to 2013

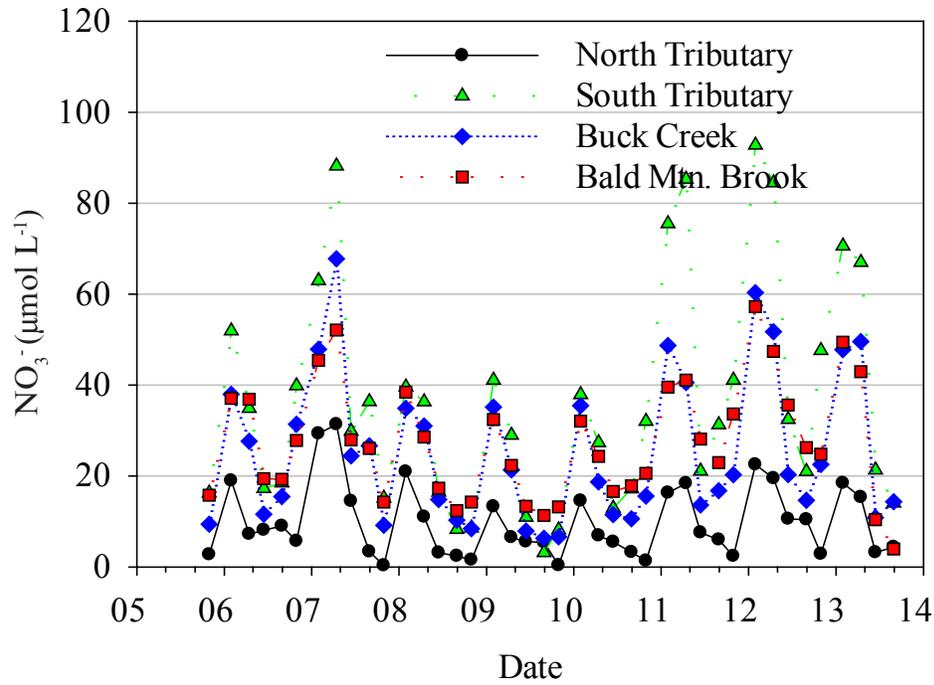


Figure 20. DOC seasonal median concentrations for the North and South Tributaries of Buck Creek, Buck Creek and Bald Mountain Brook for water years 2006 to 2013

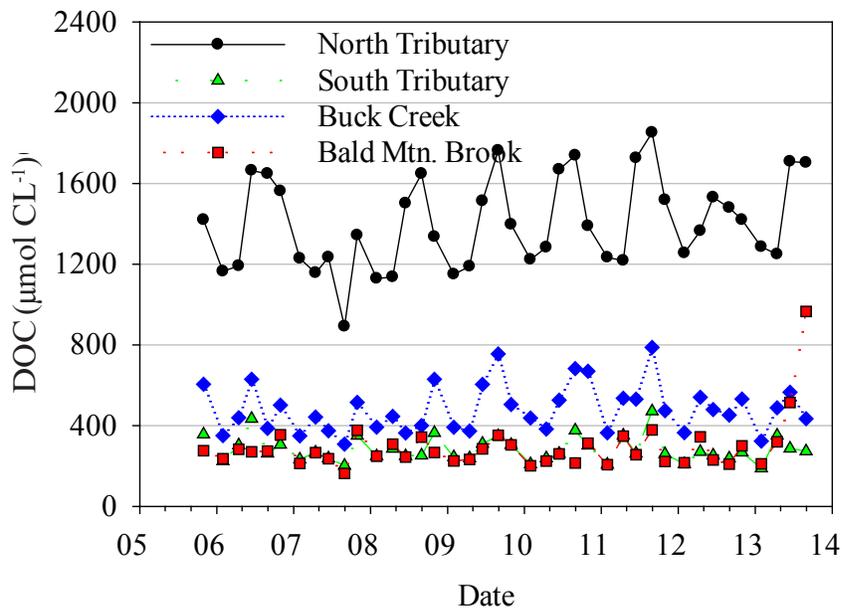


Figure 21. BCS seasonal median concentrations for the North and South Tributaries of Buck Creek, Buck Creek, and Bald Mountain Brook for water years 2006 to 2013

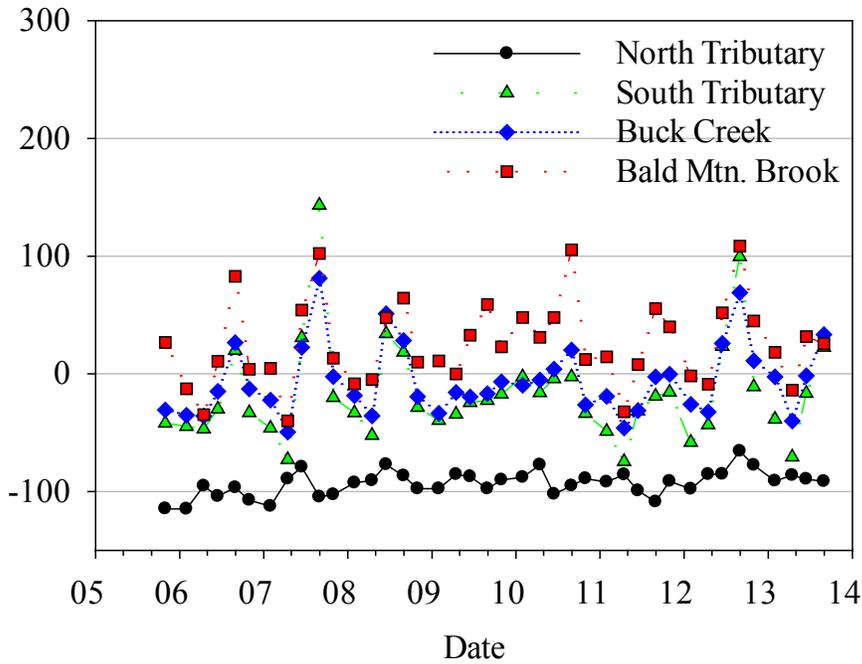
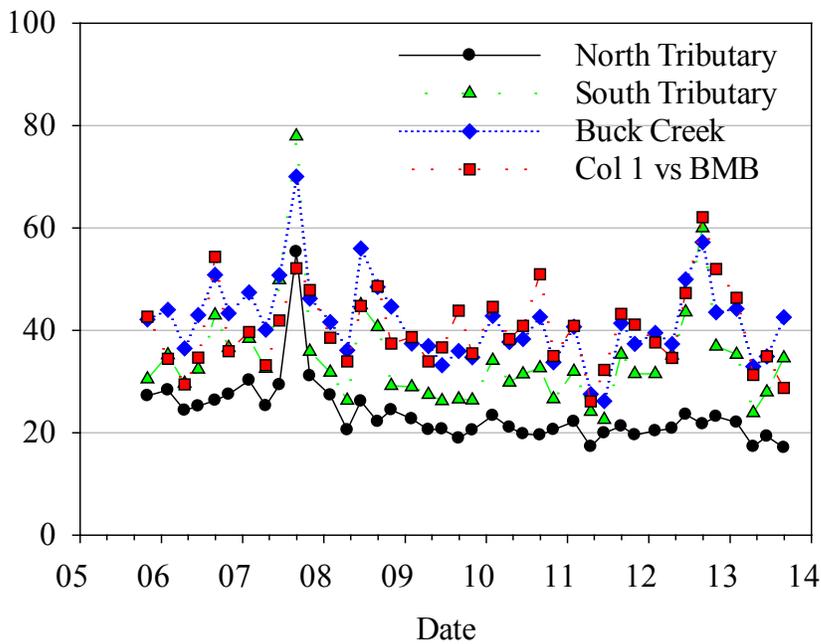
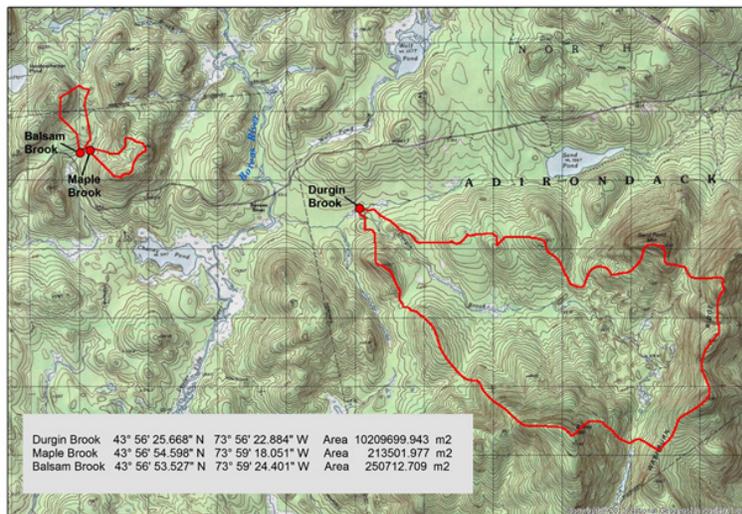


Figure 22. Ca²⁺ seasonal median concentrations for the North and South Tributaries of Buck Creek, Buck Creek, and Bald Mountain Brook for water years 2006 to 2013



Further evaluation of stream trends in 2013 resulted in a revised stream sampling strategy. This plan included developing an intensive monitoring station in a better buffered (than Buck) site which was determined to be near the Boreas River (Town of Minerva, Essex County). The intensive monitoring at Buck Creek will continue unchanged and Bald Mountain Brook and Fly Pond outlet will no longer be sampled after December 2013. The continued monitoring in Buck Creek and the new sampling in the Boreas watershed is linked to the sampling of streams in the broader Adirondack Region developed in a separate NYSERDA project. The establishment of a long-term monitoring watershed at the Boreas site is expected to fill in critical information not currently available. The watershed includes landscape features not found in existing long-term monitoring watersheds which are important components of the Adirondack Mountain ecoregion. Figure 23 shows the sampling locations and watershed extent of the three new Boreas sites. The addition of these data will broaden the environmental questions being addressed at Buck Creek (<http://ny.cf.er.usgs.gov/nyprojectsearch/projects/2457-A42-1.html>) and Archer Creek (<http://www.esf.edu/hss/em/huntington/inlet.html>). Buck Creek is representative of calcium-depleted systems that remain acidified and show minimal recovery. Archer Creek is representative of well-buffered systems where deep groundwater is integrated with surface water, and includes areas with soils highly enriched in calcium (Lawrence 2013)

Figure 23. Location of Balsam, Maple and Durgin Brooks sample sites



In 2015, a total of six bi-weekly stream sampling locations are named (informally): Buck Creek (main); North Tributary of Buck Creek; South Tributary of Buck Creek; Durgin Brook (Boreas); Maple Stream (Boreas) and Balsam Stream (Boreas).

Buck Creek – Vegetation and Soils Studies

North and South Tributary – Trees

Vegetation plots were established in the Buck Creek watershed by USGS in 2000. Fifteen vegetation plots (254 m² area each) were established in both the North Tributary and the South Tributary (Figure 24). Tree measurements are collected at five year intervals. Soil chemistry measurements were collected at 27 locations throughout the North Tributary watershed in 2009–2010.

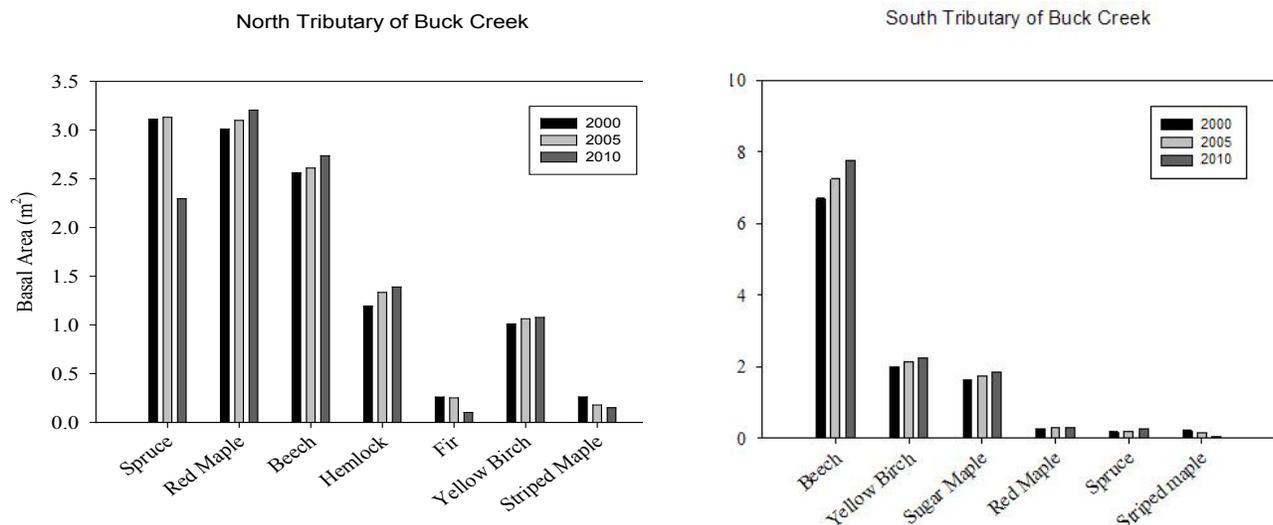
In the North Tributary watershed, the predominant tree species were red spruce, red maple, and American beech. Most tree species showed an increase in total basal area over the 10-year measurement period (2000 – 2010), with the notable exception of red spruce, which showed a pronounced decrease as a result of unusually high mortality between 2005 and 2010 of trees in all size classes (Figure 25). This decrease in red spruce resulted in an overall decrease in basal area for the watershed. The cause of the elevated mortality in red spruce is not known.

In the South Tributary watershed, American beech, the dominant tree species, showed an increase in basal area over the 10-year period (Figure 25). This occurred despite beech bark disease in virtually all beech trees in the watershed and elevated mortality of large beech trees. Increases in basal area of yellow birch, sugar maple, and red spruce also occurred during this period. Most striped maple over 5 cm diameter died over the 10 years without being replaced.

Figure 24. Watersheds of the North Tributary (navy) and the South Tributary (red) within the Buck Creek watershed



Figure 25. Basal area of major tree species (with diameter breast height (dbh) greater than 5 cm) in the North and South Tributary watershed of Buck Creek, in 2000, 2005 and 2010, based on measurements in 15 plots per watershed (each plot is 254 m² in area)



North Tributary – Soils

Soil samples were collected from the Oe horizon, Oa horizon, and upper 10 cm of the B horizon at 27 locations throughout the North Tributary watershed of Buck Creek. Soils had thick Oa horizons, which are common in forests with a large component of coniferous trees. Low pH in the Oe and Oa horizons reflect the strong influence of natural organic acidity that derives from the decomposition of organic matter (Table 15). Relatively low concentrations of exchangeable bases (Ca, Mg, K and Na) and high concentrations of exchangeable aluminum in the upper B horizon are consistent with stream chemistry data for this watershed that indicates calcium depletion by acidic deposition. Low base saturation in the Oa and upper B horizon provides minimal buffering of soil water acidity. A manuscript that includes soils data is in development.

Table 15. Mean values of soil chemistry measurements of samples collected in 2009-2010 from Oe horizon, Oa horizon and upper 10 cm of the B horizon in the North Tributary watershed of Buck Creek

Horizon	units	Oe Horizon	Oa Horizon	Upper B Horizon
thickness	cm	5.5	14.7	----
exchangeable Ca	cmolsc kg ⁻¹	16.5	8.1	0.41
exchangeable Mg	cmolsc kg ⁻¹	2.7	1.3	0.10
exchangeable K	cmolsc kg ⁻¹	1.5	0.4	0.09
exchangeable Na	cmolsc kg ⁻¹	0.06	0.04	0.023
exchangeable Al	cmolsc kg ⁻¹	0.8	7.4	8.55
exchangeable H	cmolsc kg ⁻¹	9.9	13.1	1.44
base saturation	fraction of CEC	0.65	0.32	0.06
carbon	percent	513	465	91.4
nitrogen	percent	24.6	20.1	3.61
C:N	g g ⁻¹	21	23	26
Organic matter	percent	92.7	83.2	17.9
pH (0.01 CaCl ₂)		3.16	2.74	3.53

Regional Stream Surveys

Western Adirondack Stream Survey

Despite the stream sampling efforts of the ALTM, AEAP, and other occasional Adirondack stream studies, prior to 2003 there was insufficient information to assess the current regional status of streams with regard to acidification. The Western Adirondack Stream Survey (WASS) was conducted to assess the chemical and biological conditions of streams in the region of the Adirondacks considered most impacted. Because regional stream assessments that included episodic acidification had not been previously conducted, this project was implemented as a pilot study to evaluate methods for possible future use. The effort was undertaken by program staff of the ALSC, NYSDEC (Air Resources and Fish and Wildlife), USGS.

The WASS was conducted in the 4,585 km² Oswegatchie-Black River region of the Adirondack ecological zone with the following objectives: 1) develop an improved method for distinguishing between the chemical effects of acidic deposition and those of naturally-derived acidity, 2) determine the extent of acidic deposition effects on stream chemistry and biota in this region, 3) evaluate the role of soil chemistry as a control of stream chemistry, and 4) determine to the extent possible, changes in stream chemistry over the past two decades.

Five seasonal surveys were conducted between summer 2003 and spring 2005. There were several major findings. Of the 565 streams assessed, 66% (718 km of stream reaches) were identified as prone to acidification, i.e., likely to be acidified to levels harmful to biota. Of these streams, approximately half were likely to be episodically acidified and half were likely to be chronically acidified. The percentage of streams determined to be moderately to severely impacted by acidic deposition on the basis of the diatom data ranged from 66% to 89% over four surveys. Macroinvertebrate communities were moderately to severely impacted in 52% of assessed streams. The approach of the seasonal sampling survey conducted within three-day periods throughout the study region was successful for capturing the episodic and seasonal variability of stream chemistry. When indexed to a site with both episodic and long-term monitoring data (i.e. Buck Creek), this approach was an effective method for the regional assessment of episodic acidification. More information is available in other reports (Lawrence et al. 2008a and Baldigo et al. 2009). In 2012, data from the WASS and Buck Creek were included in several articles and presentations including a synthesis paper on the ecological effects of air pollution from nitrogen and sulfur (Greaver et al. 2012), a soil calcium gradient analysis in northern hardwoods (Beier et al. 2012), and a regional forest soil nitrogen analysis (Ross et al. 2012).

East-Central Adirondack Stream Survey

Following the completion of the WASS, a second survey was conducted for the remaining portion of the Adirondack region. The East-Central Adirondack Stream Survey (ECASS) was designed as a similar flow-synchronized sampling of 200 first-order streams over a 3-day period. Three sampling seasons were proposed to take place during 2010-2012. The first round of sampling was conducted on August 9-11, 2010 at 208 stream sites. Additionally, 10 high-elevation streams were sampled during September.

The second and third (final) rounds of sampling were successfully completed in 2011. Spring sampling included: 269 sites during April 18-20; 10 high elevation sites during April 25-May 5; and five historic sites sampled weekly during April 4-May 2. The fall sampling included 230 sites during October 31-November 2. Additional collections included periphytic diatoms at each site to be analyzed by S.Passy (University of Texas Arlington) and macroinvertebrates at 40 stream sites. Preliminary chemistry assessments based on April 2011 results indicate that over one-third of streams are prone to acidification. The ECASS study region encompasses nearly 20,000 km² (approximately 80%) of the Adirondack region.

Together the WASS and ECASS stream projects have covered essentially the entire Adirondack region. This total of eight seasonal surveys collected between summer 2003 and fall 2011 now stands as the largest survey in North America to evaluate stream chemistry over varying stream flows, which is essential for evaluating acidification. The work provides important data on the current conditions that will be available to more thoroughly assess ecosystem recovery.

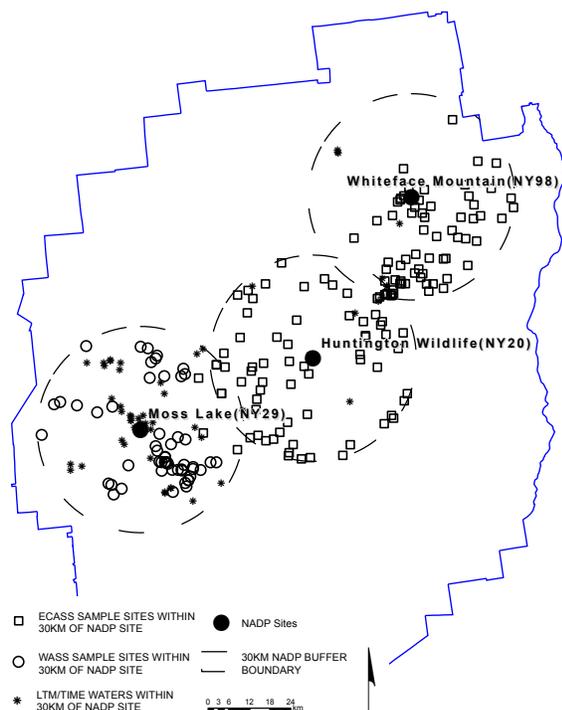
Resampling of WASS and ECASS - 2014 to 2018

To expand the information on the response of streams to decreases in wet deposition of sulfate that has been occurring in the region (30% decrease from 2003 to 2011) a resampling of a subsample of the WASS (approximately 64 streams) and ECASS will be conducted during 2014-18. This effort will continue to be led by G. Lawrence at USGS in collaboration with the overall ALTM/ALSC work identified in a separate NYSERDA project.

Relevance of Stream and Lake Data to Air Quality Policies

This proposed work is highly relevant to the development of air quality policies currently underway. The most recent review of secondary National Ambient Air Quality Standards (NAAQS) for oxides of sulfur and nitrogen (http://www.epa.gov/ttnnaaqs/standards/no2so2sec/cr_fr.html that lead the USEPA) proposed a 5-year pilot monitoring program to provide data to reduce uncertainties linking air indicators to ANC. This proposal included discussion of an aquatic acidification index (AAI), but the use of this index was tabled until further field studies in sensitive areas such as this could be completed. Much of the stream monitoring re-sampling sites discussed above occur within 30 km of the acid deposition monitoring at Moss Lake, Huntington Wildlife Forest, and Whiteface Mountain (Figure 26). This increase in available stream chemistry data along with the long and continuing record of lake chemistry will substantially support this policy effort as well as other policy questions that will develop as air quality protection moves forward.

Figure 26. Map showing locations of stream and lake survey sites occurring within 30 km of Moss Lake, Huntington Wildlife Forest, and Whiteface Mountain within the Adirondack ecoregion. Moss Lake (WASS=54; ECASS=5; LTM=22; TIME=13) of Huntington Wildlife Forest (WASS=0; ECASS=68; LTM=6; TIME=1) and of Whiteface Mountain (WASS=0; ECASS=66; LTM=5; TIME=1)



Data Reported to Date

The available data from this collective stream monitoring work under the auspices of the ALTM effort is particularly dynamic. Data available at www.adirondacklakessurvey.org include complete chemistry from three sites at Buck Creek and Bald Mountain Brook. Some data records begin as early as April 1999. All data records are current through September 2013. Seasonal medians for the three sites at Buck Creek and Bald Mountain Brook are provided in Appendix B of this report. The data have shown meaningful patterns in describing five "seasonal" periods within the annual water year. These are: winter (December through March); snowmelt (April); spring/summer (May through July); late summer (August through September) and fall (October and November). Additional data may be available by contacting the NYSDEC DAR research manager (K.Roy) or USGS (G.Lawrence).

Whiteface Mountain Cloud Monitoring

Title IV of the federal 1990 Clean Air Act Amendments (CAAA) required a two-phase nationwide reduction in sulfur dioxide (SO₂) emissions by approximately 10 million tons. The first phase was implemented in 1995 when large electric generating facilities reduced emissions. The second phase began in 2000 by targeting other power plants. Title IX of the CAAA mandated the deployment of a comprehensive research and monitoring program, which would evaluate emission reduction program effects on deposition, air quality, and changes in affected ecosystems. In response to this mandate, the USEPA implemented the Clean Air Status and Trends Network (CASTNet) in 1991.

The Mountain Cloud Acid Deposition Program (MADPro) was initiated in 1993 as part of the research necessary to support CASTNet objectives. The two main objectives of MADPro were to develop cloud water measurement systems useful in a network-monitoring environment and to update the Appalachian Mountain cloud water concentration and deposition data collected by the National Acid Precipitation Assessment Program (NAPAP) during the 1980s. MADPro measurements were conducted between May and October of 1994 – 1999 at three permanent mountaintop sampling stations. These sampling stations were located at Whiteface Mountain, New York; Clingmans Dome, Tennessee/North Carolina; and Whitetop Mountain, Virginia. A mobile manual sampling station was also operated at two locations in the Catskill Mountains of New York during 1995, 1997, and 1998.

Ecosystem acidification researchers have long recognized the critical value of total atmospheric deposition measurements and estimates, from high elevation mountain regions, and including significant contributions from cloud water (Weathers 2006). Beginning in June 2001, the ALSC commenced field operations and provided laboratory analyses of cloud water from the Whiteface site. Operation included, all quality assurance/quality control activities, data processing and review, analytical chemistry, and data delivery. The ALSC objective has been to continue the cloud-monitoring program as run under the CASTNet program. The mountaintop site at Whiteface has changed little since the cloud collection system was installed in 1994. The system has proven to be quite durable, having survived several lightning strikes and harsh weather conditions.

Site Description

Located in the northeastern part of the New York State Adirondack Park, Whiteface Mountain has an elevation of 4,867 feet and is the fifth highest peak in the Adirondacks. The site is the only high peak within the Adirondack Park with a summit that is road accessible and has AC power. The cloud collection system is installed on the roof of the summit observatory building operated and maintained by the University at Albany Atmospheric Sciences Research Center. In addition to the cloud monitor, the summit building also houses several gas monitors, meteorological sensors, and a high volume air sampler. The summit is reached in warm weather months, from late May to early October, via the Veterans Memorial Highway.

Sampling Design

The collector is an omni-directional passive collector that is also known as an Atmospheric Sciences Research Center (ASRC) or Mohnen collector (Falconer and Falconer 1980; Mohnen 1989). The collector consists of two disks separated by vertical bars with a nonstick filament strung between the disks. The principle of operation for collecting cloud water samples is relatively simple. As winds blow clouds through the collector, cloud water condenses on the filaments and gravity draws the cloud water down to a funnel. Tubing attached to the bottom of the funnel runs into the observatory and delivers cloud water to an accumulator. The accumulator collects cloud water until it is full, the site clears, or the top of the hour is reached. At the top of each hour, a distributor arm dispenses the accumulated sample into one of 24 refrigerated indexed carousel bottles (Baumgardner et al. 1997).

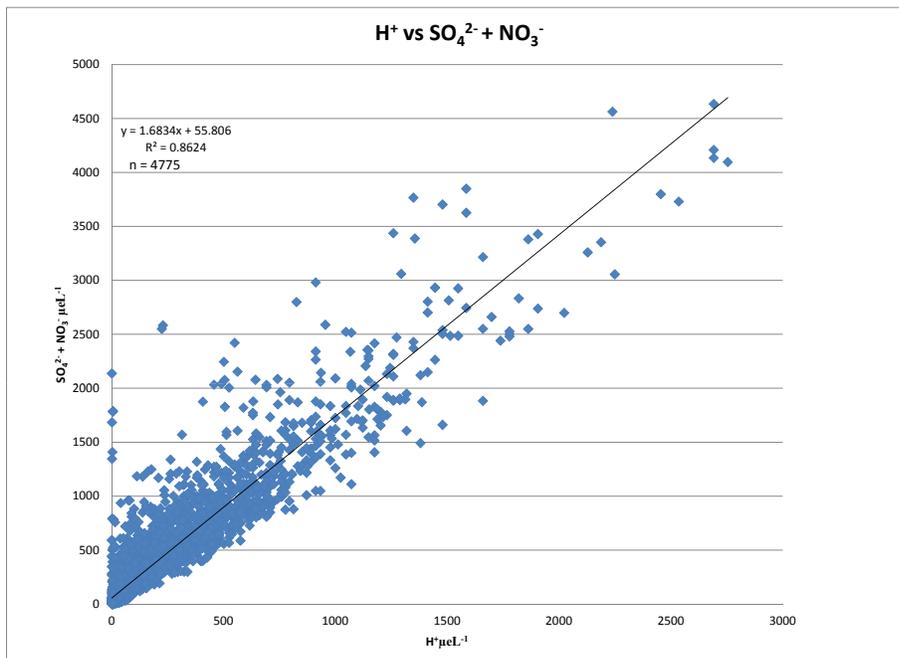
The cloud water collector is deployed from its protective housing only after the following conditions are met: the air liquid water content reaches 0.05 grams per cubic meter or greater indicating the presence of cloud; the temperature is two degrees Celsius or greater to prevent freezing; the wind speed is two meters per second or greater to assure the movement of clouds through the collector; and a heated grid rain sensor indicates no rain is present to limit sampling from precipitating clouds.

Samples are analyzed for the following parameters: Lab pH, specific conductance, nitrate, sulfate, chloride, calcium, magnesium, potassium, sodium, ammonium and total organic carbon. The primary meteorological parameters collected are: liquid water content (LWC), wind direction, wind speed, and temperature.

Fossil fuel combustion, which is the oxidation of sulfur and nitrogen oxides in the atmosphere to sulfuric acid (H_2SO_4) and nitric acid (HNO_3), are the primary source of anthropogenic acidity in cloudwater.

The major ions found in clouds at Whiteface Mountain are sulfate, hydrogen, nitrate, and ammonia. There is a strong coefficient of determination ($R^2 = 0.87$) between hydrogen and sulfate + nitrate (Figure 27).

Figure 27. Hydrogen ion versus sulfate + nitrate

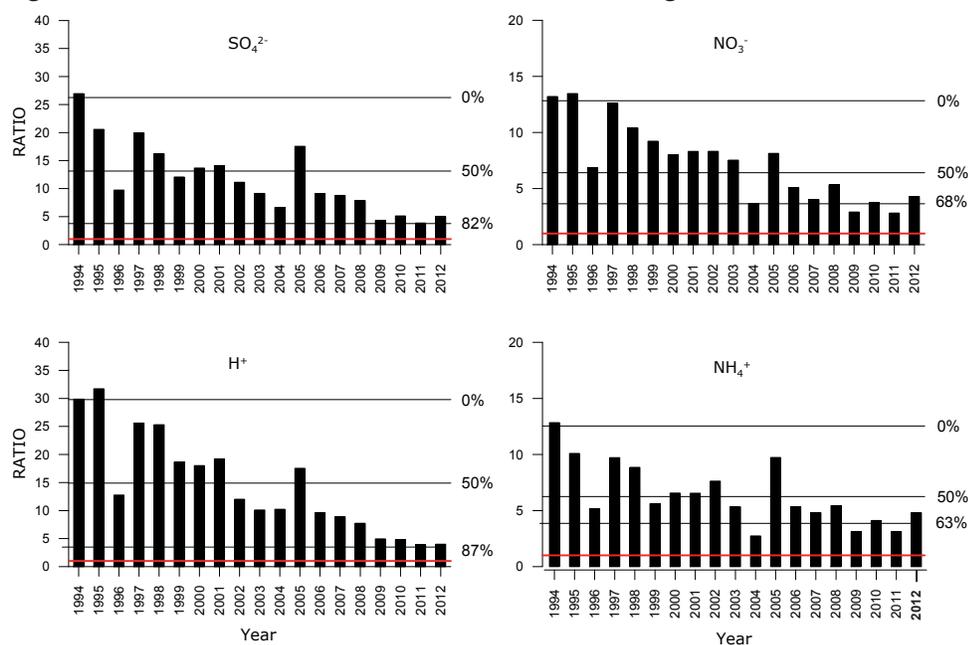


Results

Compared with precipitation, cloud water exhibits significantly higher concentrations of major ions (Khwaja et al. 1995). Cloud water depositions have been reported at 14 to 28 times rainwater depositions during the summer season (Aleksic et al. 2009). The pH of cloud water below approximately 5.0 is assumed to be influenced by anthropogenic pollution (Li and Aneja 1992; Dukett et al. 2011). For samples collected 1994–2011, approximately 86% of the cloud water samples analyzed are below pH 5.0 or $H^+ > 10.00 \mu\text{eq L}^{-1}$. For samples collected 2010–2012, approximately 74% are below pH 5.0 or $H^+ > 10.00 \mu\text{eq L}^{-1}$.

In 2009, clean air target values were established based on 4,185 cloud water samples collected for the period 1994–2009, and 263 of those values were used to identify a clean air target pH range (Dukett et al. 2011). For this report, additional data collected through 2012 has been incorporated into the analysis, which is based on 4,775 cloud water samples, with 322 of those values identifying the clean air target pH range. Additionally, for each major ion (SO_4^{2-} , NO_3^- , H^+ , and NH_4^+), results were compared against the reference clean air value by calculating simple ratios of all annual data versus the reference clean air value. Figure 28 shows these ratios, as well as, a relative comparison since the first year (1994) of the record to the last year (2012). As illustrated in Figure 28, the red horizontal line at ratio 1 indicates the best case clean air level. Ratios above 1 are influenced by anthropogenic pollution. In 1994, ratios were 26.9, 13.2, 29.9, and 12.8 times above the clean air concentration threshold for SO_4^{2-} , NO_3^- , H^+ , and NH_4^+ respectively. For 2012, SO_4^{2-} , NO_3^- , H^+ , and NH_4^+ ratios were respectively 5.0, 4.3, 4.0, and 7.8 times above 1 (Figure 28). In other words, a comparison of results from 2011 and 1994 as well as all samples that meet criteria outlined in Dukett et al. (2011) suggest the following anthropogenic reductions of 82%, 68%, 87%, and 63% for SO_4^{2-} , NO_3^- , H^+ , and NH_4^+ , respectively. Details may be found in Dukett et al. 2011.

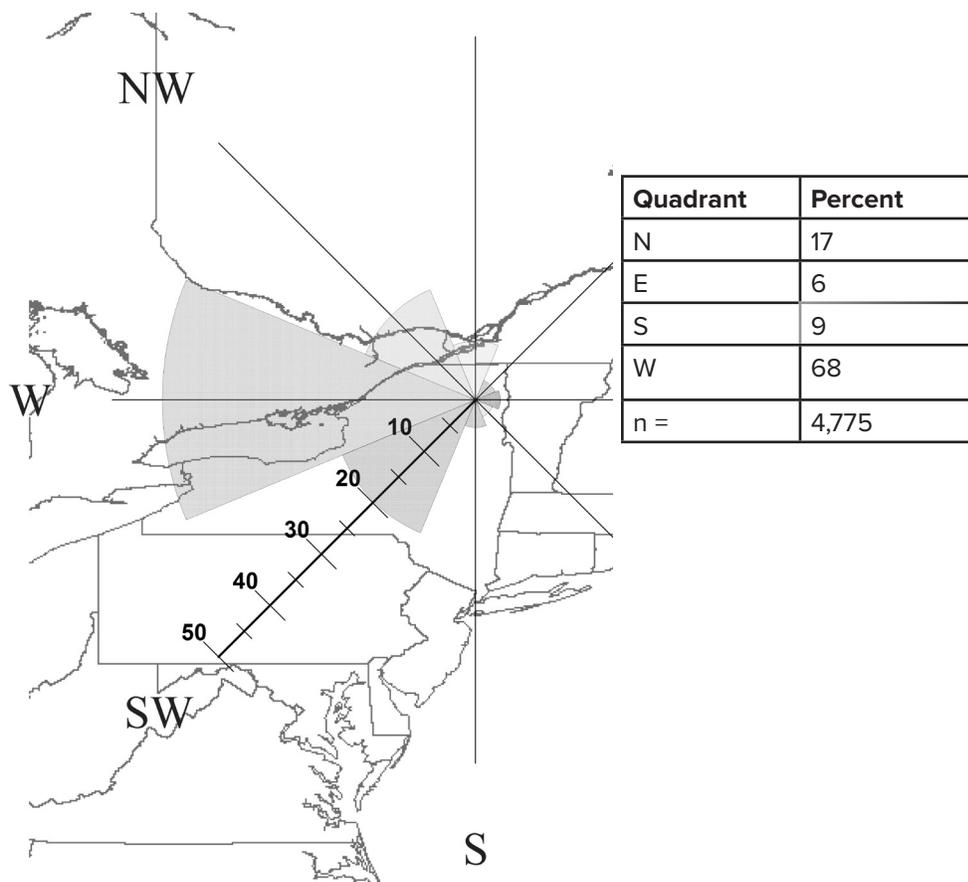
Figure 28. Ratios of all annual data versus clean air target values 1994-2012



Distribution

The origin of cloud water acidity is assumed to be based on both local and regional emission sources. Given the frequency distribution (Figure 28), it is suggested that clouds at Whiteface may pass over the Ohio Valley and Canadian Provinces. Factors such as wind speed and orographic effects help shape the movement and ion content of clouds (Baumgardner et al. 2003). ALTM lakes at higher elevations (>600 m) may have higher nitrate concentrations and acidity than lower elevation lakes (Aleksic et al. 2009). The majority of the cloud water samples collected at Whiteface Mountain arrive from a westerly (68%) direction (Figure 29).

Figure 29. 1994-2012 wind distribution by quadrant



Data Reported to Date

Data currently available from this mountain cloud study include hourly and 3-hr composites of the chemical parameters in cloud water and the meteorological data associated with those samples. As of June 2013, chemistry and meteorological data collected during the 2001–2011 sampling seasons are posted to the ALSC website at <http://www.adirondacklakessurvey.org>. Additional data may be available by contacting the NYSDEC Research Manager.

Data Summary Statistics

Summary statistics for the 2012 cloud sampling season can be found in Appendix E. These statistics are based on 'Valid' sample data criteria. The criteria for valid samples are:

- Passes MADPro Ion balance test.
- Must be analyzed for all four major ions (H^+ , SO_4^{2-} , NO_3^- , NH_4^+).
- Is a valid composite sample.
- Sample does not contain rain.

Additional information can be found in the 2012 WFC MetaData worksheet located at the Whiteface links at www.adirondacklakessurvey.org

2009 Pilot Studies

In 2009, the ALSC participated in two pilot studies to look at mercury and carbon in clouds. A mercury pilot project began on 7/7/09 and ended on 9/23/09. A second cloud collector was installed to allow for the collection in mercury specific sample bottles. A total of 21 samples were collected and shipped to Syracuse University for total mercury analysis. Bradley Blackwell, Syracuse University, used the data in his 2011 NYSEDA EMEP presentation (Blackwell et al. 2011). A carbon species pilot project collected 11 samples on 9/23/09 and 9/24/09. Samples were shipped to Rutgers University for analysis of highly polar organic compounds (HPOC). The ALSC also analyzed total organic carbon (TOC) on these samples. Carbon analysis, both at the species (HPOC) and fraction (TOC) level, provides a deeper understanding of the organic acids in cloud water; and may help increase the level of scientific understanding that clouds serve as a climate driver (National Academies 2008).

2011 Pilot Study

The carbon species pilot project started in 2009 and concluded in 2011. In 2011, a total of 54 samples were shipped to Rutgers University for highly polar organic complex analysis. The ALSC also analyzed 278 TOC samples in 2011. Jessica Sagona (Rutgers University) required TOC concentrations as a necessary preliminary step to guide HPOC analysis. Dr. Sagona's analysis of TOC and HPOC data was accepted in her 2013 dissertation (Sagona 2013).

2013 Cloud Monitoring Activities

Cloud water collections and laboratory analysis continued in 2013. For the 2013 collection season, 418 three-hour bulk samples, 12 Blank/Rinse samples, 5 AMEC split samples, and 20 University of Michigan split samples were collected. A decision was made in the fourth quarter of 2013 to integrate 2014 cloud water collections to represent day and night periods resulting in a maximum of two samples per 24-hour period.

Also, in 2013, letters of support were received from Plattsburgh State University, University of Michigan, and Indiana University expressing the value these universities find with the Whiteface Mountain Cloud project. Finally, 2013 Whiteface Cloud and Meteorological data were posted to the ALSC website on December 18, 2014.

Wet Deposition Monitoring

Site Description

The ALSC collects weekly precipitation and meteorological data from the NYSDEC wet deposition monitoring station located in St. Lawrence County at the Wanakena Ranger School in Fine, New York. The station, Wanakena Ranger School (Air Monitoring Location 4458-05), is located at an elevation of 458 m.

Sampling Design

The station was established as part of the NYSDEC Acid Deposition Monitoring Network in January 1987. The network consists of 20 monitoring sites located throughout New York State. Wanakena is a rural site that supports Type 3 instrumentation, which included a tipping bucket rain/snow gage to measure the amount of precipitation, and a Viking Hyetometer, which is a bucket type collector designed to collect samples under wet or dry conditions (<http://www.dec.ny.gov/chemical/8409.html>).

Data Reported to Date

The analyzed chemistry and meteorological data are posted on the NYSDEC Division of Air Resources Air Quality Surveillance website (www.dec.ny.gov).

Regional Fisheries Chemistry

Since 1992, the ALSC has provided laboratory services to fisheries staff in NYSDEC Regions 5 and 6 (Adirondack Region) for lake chemistry analyses. A large number of these waters are included in the NYSDEC Lake Liming Program where annual data are needed to assess the acid-base condition of lakes. These samples are collected by regional fisheries staff. The results provide a snapshot of lake chemistry relative to the viability of fisheries in areas beyond the ALTM and TIME lakes. The average number of lake water samples analyzed each year is 130.

Data Reported to Date

The lake chemistry data from this section are provided annually to NYSDEC Region 5 and 6 fisheries staff. Additional information may be available by contacting the NYSDEC Research Manager.

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Appendix A1: EPA Ammendment

Amendment to EPA Federal Assistance Number 66.042 (IGMS Award # 83482801) Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring (LTM) for Fourth Funding Period (2014)

Prepared July, 2013

PROJECT OVERVIEW

The Adirondack Lakes Survey Corporation (ALSC) and the New York State Department of Environmental Conservation (NYSDEC) have been monitoring lake chemistry in the Adirondack Region since the mid-1980s. The core elements of this monitoring are, and will continue to be, 43 lakes collected annually as part of EPA's Temporally Integrated Monitoring of Ecosystems (TIME) project, and 52 lake and stream outlets (59 total sites) collected and analyzed monthly as part of the Adirondack Long Term Monitoring (ALTM) waters as a part of EPA's Long Term Monitoring (LTM) program. The work is conducted with support from the US Environmental Protection Agency (EPA) and the New York State Energy Research and Development Authority (NYSERDA) for the purposes of evaluating the response of Adirondack surface water chemistry to changes in atmospheric deposition of acid rain precursors. EPA funds are leveraged with NYSERDA to fund ALSC personnel.

Purpose for decrease to Adirondack LTM lakes sampling:

Budget reduction necessities have required NYSERDA, NYSDEC and EPA to re-evaluate the level of support to the ALSC for the Adirondack lakes monitoring effort beginning in January 2014. The reduced sampling design is based on a recent NYSERDA report, Assessment of Long-Term Monitoring of Nitrogen, Sulfur, and Mercury Deposition and Environmental Effects in New York State (Levine and Yanai, 2012), and subsequent evaluation and discussion with EPA, NYSERDA, and NYSDEC regarding the relative value of data types, frequencies, and locations. With a nearly 20-year record, it was determined that sampling frequency may be reduced at some locations and the integrity and value of the data record and monitoring program will remain intact.

Of the four objectives (deliverables) described in the original proposal, referred to as the "statement of work", objectives one, two and four will remain the same. Objective three "To perform monthly chemistry monitoring of the 52 ALTM lakes" will be reduced in scope for the remaining two years of the current 5-year cooperative agreement. Sampling frequency in some waters will be reduced from monthly to a combination of monthly, seasonal, and annual sampling efforts, per the frequency described in Table 1. This will also reflect a reduction in the budget.

The ALSC operates with leveraged funding from all three agencies and, given the funding reduction, will see a reduction in staff from 2012 levels. The efforts of all organizations have also focused on improved efficiencies for the ALTM. Further evaluations for improving efficiencies to all aspects of the ALTM efforts are ongoing.

Changes to the Statement of Work are as follows:

- 1) Sampling efforts at 25 lake and stream sites will continue to be sampled on a monthly basis (Table 1). This list was based on a number of criteria, including a) capturing a range of DOC, ANC (pH surrogate), and NO₃; b) strongly increasing DOC sites; and c) involvement in ongoing intensive research projects.
- 2) Monthly sampling at 19 seasonal lakes/streams will be reduced seasonal (Feb, Apr, May, Jul,

Sep, Nov). These lakes and streams include: Avalanche, Black Pond, Bubb and Bubb Stream, Cascade and Cascade Stream, Clear Pond, Lake Colden, Dart, East Copperas, G Lake, Limekiln, Loon Hollow, Marcy Dam, Middle Branch, Middle Settlement, Otter and Otter Stream, and Queer.

- 3) Monthly sampling at 15 lakes will be reduced to annual sampling. These lakes will be sampled annually during the summer (July or August). These lakes and streams include: Barnes, Carry, Grass (03), Little Hope, Long, Middle, Nate, Owen, Sochia, Sunday, Willis, Windfall and Windfall Stream.

All sampling will be done in accordance with ALTM protocols and QAPP. ALSA will continue to provide project deliverables in the form of 1) annual submission of program data; 2) quarterly reports detailing sampling activity and laboratory operations, and 3) annual Program Summary report, including quality assurance activities

References:

Levine, Carrie R., R. D. Yanai. 2012. Assessment of Long-Term Monitoring of Nitrogen, Sulfur, and Mercury Deposition and Environmental Effects in New York State. New York State Energy Research and Development Authority Final Report 12-21.

Appendix A2: ALTM Trend Results; Seasonal Kendall Test

Site	Site No.	Type	Seasonal Kendall Test										ALTM Trend Results																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
			2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
Lim Site	02058	NS	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	1.21	1.52	1.83	2.14	2.45	2.76	3.07	3.38	3.69	4.00	4.31	4.62	4.93	5.24	5.55	5.86	6.17	6.48	6.79	7.10	7.41	7.72	8.03	8.34	8.65	8.96	9.27	9.58	9.89	10.20	10.51	10.82	11.13	11.44	11.75	12.06	12.37	12.68	12.99	13.30	13.61	13.92	14.23	14.54	14.85	15.16	15.47	15.78	16.09	16.40	16.71	17.02	17.33	17.64	17.95	18.26	18.57	18.88	19.19	19.50	19.81	20.12	20.43	20.74	21.05	21.36	21.67	21.98	22.29	22.60	22.91	23.22	23.53	23.84	24.15	24.46	24.77	25.08	25.39	25.70	26.01	26.32	26.63	26.94	27.25	27.56	27.87	28.18	28.49	28.80	29.11	29.42	29.73	30.04	30.35	30.66	30.97	31.28	31.59	31.90	32.21	32.52	32.83	33.14	33.45	33.76	34.07	34.38	34.69	35.00	35.31	35.62	35.93	36.24	36.55	36.86	37.17	37.48	37.79	38.10	38.41	38.72	39.03	39.34	39.65	39.96	40.27	40.58	40.89	41.20	41.51	41.82	42.13	42.44	42.75	43.06	43.37	43.68	43.99	44.30	44.61	44.92	45.23	45.54	45.85	46.16	46.47	46.78	47.09	47.40	47.71	48.02	48.33	48.64	48.95	49.26	49.57	49.88	50.19	50.50	50.81	51.12	51.43	51.74	52.05	52.36	52.67	52.98	53.29	53.60	53.91	54.22	54.53	54.84	55.15	55.46	55.77	56.08	56.39	56.70	57.01	57.32	57.63	57.94	58.25	58.56	58.87	59.18	59.49	59.80	60.11	60.42	60.73	61.04	61.35	61.66	61.97	62.28	62.59	62.90	63.21	63.52	63.83	64.14	64.45	64.76	65.07	65.38	65.69	66.00	66.31	66.62	66.93	67.24	67.55	67.86	68.17	68.48	68.79	69.10	69.41	69.72	70.03	70.34	70.65	70.96	71.27	71.58	71.89	72.20	72.51	72.82	73.13	73.44	73.75	74.06	74.37	74.68	74.99	75.30	75.61	75.92	76.23	76.54	76.85	77.16	77.47	77.78	78.09	78.40	78.71	79.02	79.33	79.64	79.95	80.26	80.57	80.88	81.19	81.50	81.81	82.12	82.43	82.74	83.05	83.36	83.67	83.98	84.29	84.60	84.91	85.22	85.53	85.84	86.15	86.46	86.77	87.08	87.39	87.70	88.01	88.32	88.63	88.94	89.25	89.56	89.87	90.18	90.49	90.80	91.11	91.42	91.73	92.04	92.35	92.66	92.97	93.28	93.59	93.90	94.21	94.52	94.83	95.14	95.45	95.76	96.07	96.38	96.69	97.00	97.31	97.62	97.93	98.24	98.55	98.86	99.17	99.48	99.79	100.10	100.41	100.72	101.03	101.34	101.65	101.96	102.27	102.58	102.89	103.20	103.51	103.82	104.13	104.44	104.75	105.06	105.37	105.68	105.99	106.30	106.61	106.92	107.23	107.54	107.85	108.16	108.47	108.78	109.09	109.40	109.71	110.02	110.33	110.64	110.95	111.26	111.57	111.88	112.19	112.50	112.81	113.12	113.43	113.74	114.05	114.36	114.67	114.98	115.29	115.60	115.91	116.22	116.53	116.84	117.15	117.46	117.77	118.08	118.39	118.70	119.01	119.32	119.63	119.94	120.25	120.56	120.87	121.18	121.49	121.80	122.11	122.42	122.73	123.04	123.35	123.66	123.97	124.28	124.59	124.90	125.21	125.52	125.83	126.14	126.45	126.76	127.07	127.38	127.69	128.00	128.31	128.62	128.93	129.24	129.55	129.86	130.17	130.48	130.79	131.10	131.41	131.72	132.03	132.34	132.65	132.96	133.27	133.58	133.89	134.20	134.51	134.82	135.13	135.44	135.75	136.06	136.37	136.68	136.99	137.30	137.61	137.92	138.23	138.54	138.85	139.16	139.47	139.78	140.09	140.40	140.71	141.02	141.33	141.64	141.95	142.26	142.57	142.88	143.19	143.50	143.81	144.12	144.43	144.74	145.05	145.36	145.67	145.98	146.29	146.60	146.91	147.22	147.53	147.84	148.15	148.46	148.77	149.08	149.39	149.70	150.01	150.32	150.63	150.94	151.25	151.56	151.87	152.18	152.49	152.80	153.11	153.42	153.73	154.04	154.35	154.66	154.97	155.28	155.59	155.90	156.21	156.52	156.83	157.14	157.45	157.76	158.07	158.38	158.69	159.00	159.31	159.62	159.93	160.24	160.55	160.86	161.17	161.48	161.79	162.10	162.41	162.72	163.03	163.34	163.65	163.96	164.27	164.58	164.89	165.20	165.51	165.82	166.13	166.44	166.75	167.06	167.37	167.68	167.99	168.30	168.61	168.92	169.23	169.54	169.85	170.16	170.47	170.78	171.09	171.40	171.71	172.02	172.33	172.64	172.95	173.26	173.57	173.88	174.19	174.50	174.81	175.12	175.43	175.74	176.05	176.36	176.67	176.98	177.29	177.60	177.91	178.22	178.53	178.84	179.15	179.46	179.77	180.08	180.39	180.70	181.01	181.32	181.63	181.94	182.25	182.56	182.87	183.18	183.49	183.80	184.11	184.42	184.73	185.04	185.35	185.66	185.97	186.28	186.59	186.90	187.21	187.52	187.83	188.14	188.45	188.76	189.07	189.38	189.69	190.00	190.31	190.62	190.93	191.24	191.55	191.86	192.17	192.48	192.79	193.10	193.41	193.72	194.03	194.34	194.65	194.96	195.27	195.58	195.89	196.20	196.51	196.82	197.13	197.44	197.75	198.06	198.37	198.68	198.99	199.30	199.61	199.92	200.23	200.54	200.85	201.16	201.47	201.78	202.09	202.40	202.71	203.02	203.33	203.64	203.95	204.26	204.57	204.88	205.19	205.50	205.81	206.12	206.43	206.74	207.05	207.36	207.67	207.98	208.29	208.60	208.91	209.22	209.53	209.84	210.15	210.46	210.77	211.08	211.39	211.70	212.01	212.32	212.63	212.94	213.25	213.56	213.87	214.18	214.49	214.80	215.11	215.42	215.73	216.04	216.35	216.66	216.97	217.28	217.59	217.90	218.21	218.52	218.83	219.14	219.45	219.76	220.07	220.38	220.69	221.00	221.31	221.62	221.93	222.24	222.55	222.86	223.17	223.48	223.79	224.10	224.41	224.72	225.03	225.34	225.65	225.96	226.27	226.58	226.89	227.20	227.51	227.82	228.13	228.44	228.75	229.06	229.37	229.68	229.99	230.30	230.61	230.92	231.23	231.54	231.85	232.16	232.47	232.78	233.09	233.40	233.71	234.02	234.33	234.64	234.95	235.26	235.57	235.88	236.19	236.50	236.81	237.12	237.43	237.74	238.05	238.36	238.67	238.98	239.29	239.60	239.91	240.22	240.53	240.84	241.15	241.46	241.77	242.08	242.39	242.70	243.01	243.32	243.63	243.94	244.25	244.56	244.87	245.18	245.49	245.80	246.11	246.42	246.73	247.04	247.35	247.66	247.97	248.28	248.59	248.90	249.21	249.52	249.83	250.14	250.45	250.76	251.07	251.38	251.69	252.00	252.31	252.62	252.93	253.24	253.55	253.86	254.17	254.48	254.79	255.10	255.41	255.72	256.03	256.34	256.65	256.96	257.27	257.58	257.89	258.20	258.51	258.82	259.13	259.44	259.75	260.06	260.37	260.68	260.99	261.30	261.61	261.92	262.23	262.54	262.85	263.16	263.47	263.78	264.09	264.40	264.71	265.02	265.33	265.64	265.95	266.26	266.57	266.88	267.19	267.50	267.81	268.12	268.43	268.74	269.05	269.36	269.67	269.98	270.29	270.60	270.91	271.22	271.53	271.84	272.15	272.46	272.77	273.08	273.39	273.70	274.01	274.32	274.63	274.94	275.25	275.56	275.87	276.18	276.49	276.80	277.11	277.42	277.73	278.04	278.35	278.66	278.97	279.28	279.59	279.90	280.21	280.52	280.83	281.14	281.45	281.76	282.07	282.38	282.69	283.00	283.31	283.62	283.93	284.24	284.55	284.86	285.17	285.48	285.79	286.10	286.41	286.72	287.03	287.34	287.65	287.96	288.27	288.58	288.89	289.20	289.51	289.82	290.13	290.44	290.75	291.06	291.37	291.68	291.99	292.30	292.61	292.92	293.23	293.54	293.85	294.16	294.47	294.78	295.09	295.40	295.71	296.02	296.33	296.64	296.95	297.26	297.57	297.88	298.19	298.50	298.81	299.12	299.43	299.74	300.05	300.36	300.67	300.98	301.29	301.60	301.91	302.22	302.53	302.84	303.15	303.46	303.77	304.08	304.39	304.70	305.01	305.32	305.63	305.94	306.25	306.56	306.87	307.18	307.49	307.80	308.11	308.42	308.73	309.04	309.35	309.66	309.97	310.28	310.59	310.90	311.21	311.52	311.83	312.14	312.45	312.76	313.07	313.38	313.69	314.00	314.31	314.62	314.93	315.24	315.55	315.86	316.17	316.48	316.79	317.10	317.41	317.72	318.03	318.34	318.65	318.96	319.27	319.58	319.89	320.20	320.51	320.82	321.13	321.44	321.75	322.06	322.37	322.68	322.99	323.30	323.61	323.92	324.23	324.54	324.85	325.16	325.47	325.78	326.09	326.40	326.71	327.02	327.33	327.64	327.95	328.26	328.57	328.88	329.19	329.50	329.81	330.12	330.43	330.74	331.05	331.36	331.67	331.98	332.29	332.60	332.91	333.22	333.53	333.84	334.15	334.46	334.77	335.08	335.39	335.70	336.01	336.32	336.63	336.94	337.25	337.56	337.87	338.18	338.49	338.80	339.11	339.42	339.73	340.04	340.35	340.66	340.97	341.28	341.59	341.90	342.21	342.52	342.83	343.14	343.45	343.76	344.07

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Appendix BL Seasonal Medians; ALTM Streams 2005-2013

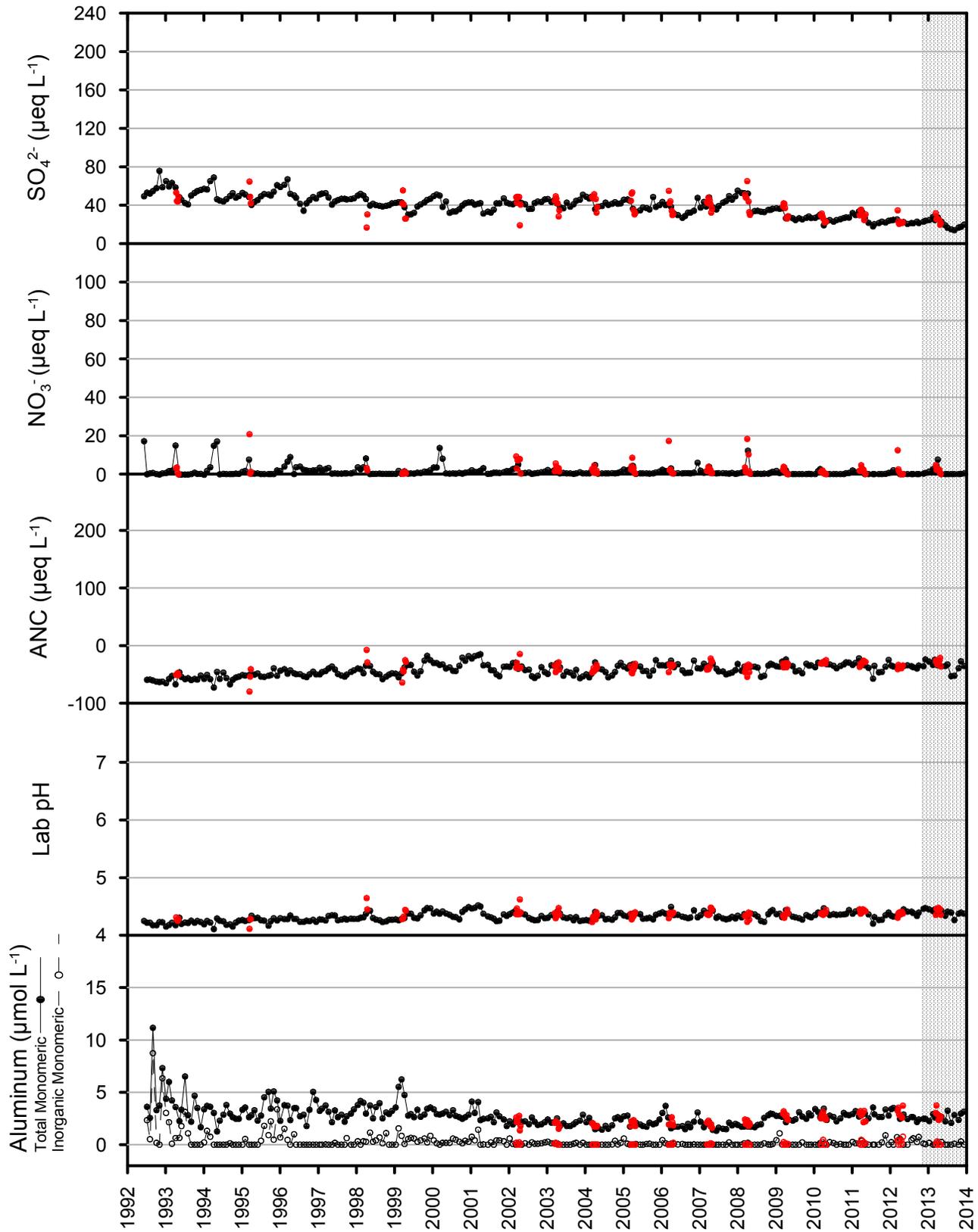
All units in µmoles unless otherwise indicated.

STREAM	WYEAR	SEASON	FREQ	middate	SO4	NO3	Cl	ANC	DOC	Si	Ca	Mg	Na	K	NH4	AL_T	AL_M	AL_O	AL_I	LabpH	BCS µeq L ⁻¹
AB07	2006	fall	17	10/30/2005	48.03	2.71	19.12	-48.47	1419.56	101.00	27.23	9.58	26.55	4.21	1.35	30.74	17.36	11.11	5.79	4.28	-114.73
AB07	2006	winter	8	1/30/2006	55.11	18.99	15.31	-41.58	1165.26	101.70	28.33	10.30	26.91	4.66	1.75	29.55	18.88	11.42	7.29	4.34	-115.02
AB07	2006	snowmelt	6	4/15/2006	42.91	7.23	11.69	-41.43	1192.33	61.75	24.36	8.60	23.61	7.17	1.76	25.54	16.96	11.61	5.35	4.35	-95.24
AB07	2006	springsummer	24	6/15/2006	28.29	8.11	10.27	-47.01	1664.46	68.64	25.19	8.13	20.86	7.42	5.36	33.73	16.33	11.84	4.37	4.33	-104.19
AB07	2006	latesummer	4	8/30/2006	31.88	8.99	14.51	-21.47	1648.37	127.02	26.30	9.01	27.79	7.53	3.06	31.98	16.48	10.88	5.58	4.51	-96.70
AB07	2007	fall	5	10/30/2006	39.54	5.70	12.52	-30.87	1562.23	90.28	27.47	9.76	24.50	3.76	2.12	29.86	17.77	10.68	6.71	4.43	-107.39
AB07	2007	winter	8	1/30/2007	46.36	29.34	11.77	-40.17	1228.90	104.84	30.20	10.85	25.36	5.86	0.88	29.43	16.85	9.99	6.92	4.40	-112.51
AB07	2007	snowmelt	2	4/15/2007	34.34	31.36	8.28	-49.29	1157.06	74.02	25.24	9.24	21.18	8.85	0.91	27.90	15.76	8.85	6.91	4.36	-89.39
AB07	2007	springsummer	7	6/15/2007	37.10	14.50	11.72	-5.63	1234.92	76.03	29.32	9.93	25.74	6.24	0.85	26.12	14.38	8.18	5.80	4.70	-79.23
AB07	2007	latesummer	1	8/30/2007	107.16	3.37	20.29	-15.11	891.39	113.48	55.37	22.37	31.81	7.37	1.30	25.87	17.08	7.70	9.38	4.63	-104.52
AB07	2008	fall	5	10/30/2007	52.10	0.31	21.26	-34.16	1343.39	104.16	31.07	11.69	26.06	5.29	1.24	29.58	16.74	10.57	6.06	4.39	-102.81
AB07	2008	winter	8	1/30/2008	44.76	20.94	11.23	-40.54	1129.87	101.06	27.32	10.13	24.26	6.06	1.56	30.12	16.84	10.62	6.52	4.37	-92.64
AB07	2008	snowmelt	3	4/15/2008	32.33	11.02	7.11	-24.29	1136.29	54.71	20.54	7.12	18.21	6.71	1.42	28.34	14.93	9.80	5.51	4.49	-90.66
AB07	2008	springsummer	6	6/15/2008	28.42	3.15	7.88	-10.83	1502.05	73.41	26.16	7.89	21.86	4.79	1.21	28.43	14.15	10.02	4.63	4.61	-77.17
AB07	2008	latesummer	4	8/30/2008	23.70	2.42	11.54	-33.05	1647.87	95.21	22.17	6.85	19.42	2.69	1.34	32.44	17.04	11.89	5.28	4.39	-86.73
AB07	2009	fall	5	10/30/2008	40.42	1.55	14.89	-50.28	1336.11	112.99	24.45	9.05	22.61	2.05	0.22	29.79	19.57	14.43	4.29	4.40	-97.65
AB07	2009	winter	11	1/30/2009	43.48	13.30	11.33	-45.90	1150.54	111.65	22.70	9.05	23.48	5.63	0.00	28.86	18.35	11.19	6.90	4.33	-97.62
AB07	2009	snowmelt	2	4/15/2009	36.05	6.49	8.02	-39.45	1189.45	64.40	20.58	7.82	21.52	5.12	0.00	33.45	16.26	10.73	5.53	4.34	-85.52
AB07	2009	springsummer	15	6/15/2009	24.63	5.57	7.20	-37.80	1512.77	72.22	20.71	7.41	17.39	3.58	1.06	30.93	18.20	12.62	4.40	4.33	-87.38
AB07	2009	latesummer	11	8/30/2009	20.56	5.45	5.77	-39.84	1763.44	70.12	18.94	6.32	14.15	3.90	2.00	30.70	18.26	12.59	4.58	4.33	-97.69
AB07	2010	fall	4	10/30/2009	32.60	0.37	14.21	-47.34	1397.24	107.78	20.49	9.13	24.32	2.58	0.00	28.20	18.97	11.58	6.71	4.30	-90.13
AB07	2010	winter	10	1/30/2010	37.96	14.55	11.28	-36.61	1223.66	138.09	23.33	9.79	26.97	4.54	0.53	26.43	17.50	10.75	5.84	4.36	-87.98
AB07	2010	snowmelt	2	4/15/2010	33.23	6.91	6.78	-41.12	1283.96	71.69	21.05	8.65	27.47	4.96	0.14	28.57	16.19	11.30	4.88	4.38	-77.38
AB07	2010	springsummer	9	6/15/2010	22.83	5.50	8.04	-41.09	1669.15	76.40	19.77	7.63	22.26	3.97	2.08	34.52	18.57	12.09	6.20	4.34	-102.25
AB07	2010	latesummer	8	8/30/2010	21.51	3.25	11.27	-36.41	1739.41	106.07	19.52	7.66	20.78	5.61	2.06	30.67	17.11	12.47	4.73	4.35	-95.13
AB07	2011	fall	8	10/30/2010	32.82	1.34	13.23	-41.19	1389.37	112.74	20.57	8.42	28.42	1.96	0.42	32.23	17.27	12.34	5.16	4.31	-89.12
AB07	2011	winter	18	1/30/2011	40.12	16.29	10.96	-40.67	1233.71	137.44	22.17	9.58	29.71	2.71	0.57	26.23	15.88	9.64	5.51	4.38	-91.91
AB07	2011	snowmelt	6	4/15/2011	25.04	18.38	5.75	-40.22	1218.09	65.90	17.28	7.22	19.46	5.22	0.90	25.11	16.09	10.48	5.48	4.33	-85.67
AB07	2011	springsummer	6	6/15/2011	20.36	7.55	6.84	-46.54	1726.26	74.09	19.93	7.07	18.20	2.77	1.16	32.80	17.47	12.67	4.78	4.33	-99.33
AB07	2011	latesummer	8	8/30/2011	19.00	5.97	6.97	-51.19	1852.71	83.95	21.28	6.90	15.43	3.63	0.94	32.31	17.45	13.82	4.07	4.27	-108.85
AB07	2012	fall	5	10/30/2011	26.63	2.40	13.08	-36.56	1518.83	101.22	19.55	8.42	25.57	3.43	0.58	30.59	15.95	13.11	4.09	4.37	-91.30
AB07	2012	winter	9	1/30/2012	34.53	2.52	9.46	-39.88	1255.84	130.82	20.35	9.35	26.83	4.87	0.73	28.03	16.97	11.99	5.42	4.34	-97.92
AB07	2012	snowmelt	4	4/15/2012	26.78	19.49	6.59	-34.51	1365.17	75.17	20.82	8.30	22.51	6.85	1.08	28.85	16.85	11.67	5.65	4.38	-85.42
AB07	2012	springsummer	9	6/15/2012	28.21	10.54	12.76	-38.06	1531.52	80.27	23.56	8.61	23.94	5.34	1.77	29.33	16.69	11.22	5.46	4.36	-85.29
AB07	2012	latesummer	7	8/30/2012	18.50	10.42	12.06	-22.88	1480.32	92.94	21.70	8.73	21.42	10.71	1.54	23.75	15.50	8.29	6.10	4.49	-65.71
BB07	2006	fall	8	10/30/2005	48.76	16.25	11.00	-7.61	356.73	74.03	30.46	6.75	22.84	5.11	0.90	17.99	8.78	2.98	5.55	4.77	-41.89
BB07	2006	winter	8	1/30/2006	48.41	51.95	11.11	-8.72	224.51	88.32	35.19	9.67	28.62	5.39	0.97	15.00	7.87	2.17	5.69	4.85	-44.77
BB07	2006	snowmelt	6	4/15/2006	41.93	34.90	10.79	-18.44	303.60	72.62	29.62	7.00	21.88	6.22	1.61	19.01	11.90	3.38	7.95	4.66	-46.90
BB07	2006	springsummer	24	6/15/2006	43.37	17.25	11.70	-5.41	434.55	84.43	32.39	8.46	26.04	6.76	2.52	20.65	7.16	3.47	4.46	4.90	-29.96
BB07	2006	latesummer	4	8/30/2006	50.72	18.50	10.82	18.98	262.07	147.97	42.97	14.19	46.46	5.24	1.72	7.84	1.76	0.83	0.92	5.93	19.96
BB07	2007	fall	5	10/30/2006	44.90	39.85	8.58	-10.38	306.08	79.11	36.59	7.73	25.19	5.14	1.50	15.49	6.90	2.39	4.85	4.84	-33.08
BB07	2007	winter	8	1/30/2007	45.08	63.01	8.40	-6.97	232.76	91.50	38.40	10.45	29.35	6.73	0.12	15.89	6.40	1.39	5.01	4.78	-46.16
BB07	2007	snowmelt	2	4/15/2007	34.26	88.18	8.68	-24.33	267.40	68.79	32.53	7.97	21.19	7.10	0.14	24.82	15.88	2.24	13.64	4.58	-72.97
BB07	2007	springsummer	7	6/15/2007	53.87	29.86	12.05	23.77	238.36	172.93	49.88	18.59	54.39	6.93	0.10	8.97	2.45	0.74	1.36	5.77	30.77
BB07	2007	latesummer	4	8/30/2007	56.75	36.35	12.42	143.76	201.95	258.93	77.95	32.14	89.66	10.39	0.25	5.22	0.70	0.32	0.37	6.84	143.39
BB07	2008	fall	5	10/30/2007	47.79	15.12	11.48	-9.12	350.44	95.34	35.88	9.63	26.55	5.01	0.89	13.88	6.53	2.54	3.99	4.89	-20.25
BB07	2008	winter	8	1/30/2008	41.41	39.58	8.84	-12.03	248.38	84.94	31.77	8.28	25.08	5.49	0.98	18.22	9.97	2.30	7.68	4.72	-33.19
BB07	2008	snowmelt	3	4/15/2008	39.39	36.34	7.98	-9.84	286.23	64.72	26.31	7.07	19.49	6.43	0.94	18.74	10.73	2.37	8.37	4.74	-52.33
BB07	2008	springsummer	6	6/15/2008	46.86	16.46	9.28	11.62	249.26	123.53	44.99	12.85	38.16	5.33	0.83	9.95	2.87	1.43	1.44	5.34	34.00
BB07	2008	latesummer	5	8/30/2008	48.44	8.27	10.28	35.23	252.49	152.09	40.67	13.17	38.26	3.58	0.84	7.01	1.81	2.04	0.83	6.30	18.38
BB07	2009	fall	10	10/30/2008	42.55	8.57	10.64	11.53	364.78	80.20	29.19	7.61	20.65	5.63	0.00	16.37	8.10	4.75	3.20	5.27	-28.50
BB07	2009	winter	11	1/30/2009	41.81	41.08	8.38	-1.92	244.57	87.19	28.94	8.23	23.48	3.58	0.00	14.47	7.77	3.26	5.07	5.12	-39.68
BB07	2009	snowmelt	2	4/15/2009	40.19	29.00	7.47	3.38	238.99	85.61	27.45	7.82	23.04	3.84	0.00	13.28	7.20	3.15	4.05	5.05	-34.31
BB07	2009	springsummer	14	6/15/2009	38.25	10.94	8.77	6.92	311.08	83.12	26.20	6.83	20.96	3.58	0.11	16.20	7.59	3.92	3.15	5.13	-24.43
BB07	2009	latesummer	5	8/30/2009	37.98	13.18	7.88	8.78	348.39	72.17	26.57	6.45	18.13	2.81	0.00	13.53	7.29	4.19	2.76	5.03	-22.65
BB07	2010	fall	4	10/30/2009	39.19	8.16	6.57	8.10	304.56	87.77	26.37	8.14	23.07	3.72	0.00	12.13	6.92	3.60	3.13	5.22	-17.19
BB07	2010	winter	9	1/																	

STREAM	WYEAR	SEASON	FREQ	middate	SO4	NO3	Cl	ANC	DOC	Si	Ca	Mg	Na	K	NH4	AL_T	AL_M	AL_O	AL_I	LabpH	BCS µeq L ⁻¹
BC01	2008	snowmelt	3	4/15/2008	43.23	31.01	10.54	14.36	445.72	83.38	36.09	10.63	24.56	7.18	0.88	17.06	9.19	3.59	5.59	5.34	-35.76
BC01	2008	springsummer	6	6/15/2008	52.59	14.81	10.73	21.64	363.61	133.02	56.01	15.97	42.33	7.43	1.02	8.60	2.96	1.87	1.05	5.56	51.16
BC01	2008	latesummer	5	8/30/2008	51.56	10.29	11.70	37.81	399.90	172.06	48.49	16.46	43.39	6.14	0.78	8.44	2.96	2.59	0.82	6.20	28.26
BC01	2009	fall	11	10/30/2008	45.21	8.40	12.76	13.60	630.14	99.01	44.66	12.35	24.78	9.21	0.17	19.28	10.03	7.07	3.48	5.39	-19.50
BC01	2009	winter	13	1/30/2009	46.44	35.15	10.34	7.56	392.15	103.67	37.43	11.93	28.26	5.37	0.06	18.28	8.51	4.48	4.26	5.22	-33.55
BC01	2009	snowmelt	2	4/15/2009	46.40	21.34	9.03	10.50	373.11	107.58	36.93	11.52	29.35	5.50	0.06	12.69	6.64	4.11	2.53	5.33	-15.80
BC01	2009	springsummer	19	6/15/2009	38.83	7.90	9.28	11.49	604.56	97.51	33.18	9.88	23.91	4.86	1.33	20.28	8.51	6.80	2.63	5.19	-19.71
BC01	2009	latesummer	16	8/30/2009	36.27	6.32	7.30	17.15	755.22	88.44	35.96	9.88	21.53	4.66	1.59	17.95	10.72	8.14	2.77	5.16	-16.93
BC01	2010	fall	4	10/30/2009	43.61	6.62	8.85	15.19	504.83	118.25	34.73	12.00	30.29	4.91	0.00	13.74	7.80	4.91	2.77	5.36	-6.78
BC01	2010	winter	15	1/30/2010	43.41	35.45	8.89	18.95	438.14	124.13	42.81	13.19	28.64	5.77	0.44	12.76	7.00	4.08	2.84	5.46	-9.85
BC01	2010	snowmelt	2	4/15/2010	45.83	18.70	9.27	12.39	383.10	122.18	37.72	12.35	33.84	5.51	0.19	11.15	5.98	3.95	2.03	5.53	-5.24
BC01	2010	springsummer	16	6/15/2010	40.72	11.50	10.00	21.49	526.56	120.62	38.30	12.94	34.74	4.97	0.80	14.57	6.14	4.34	1.99	5.60	3.97
BC01	2010	latesummer	14	8/30/2010	37.61	10.61	10.66	31.73	682.77	133.90	42.61	14.32	34.43	7.50	0.61	8.40	6.31	4.86	1.45	5.88	20.22
BC01	2011	fall	16	10/30/2010	38.73	15.58	10.03	7.72	669.42	106.65	33.75	9.78	27.39	4.66	0.57	16.32	10.39	7.51	3.23	5.04	-26.43
BC01	2011	winter	28	1/30/2011	43.28	48.72	10.00	10.37	364.45	120.74	40.71	13.08	35.21	6.20	0.54	11.34	6.26	3.82	2.61	5.42	-19.23
BC01	2011	snowmelt	19	4/15/2011	28.89	40.55	7.13	-5.86	535.60	70.17	27.53	8.05	19.51	5.87	2.05	18.71	10.71	6.82	3.81	4.76	-46.11
BC01	2011	springsummer	12	6/15/2011	37.10	13.63	7.68	6.27	531.11	93.88	26.19	8.56	25.98	5.59	1.08	13.34	7.67	5.23	2.83	5.19	-31.26
BC01	2011	latesummer	10	8/30/2011	35.31	16.80	7.41	19.06	787.87	118.09	41.39	11.31	28.35	5.48	0.74	14.85	9.30	6.68	2.34	5.54	-2.60
BC01	2012	fall	5	10/30/2011	43.35	20.26	9.82	13.35	474.20	137.77	37.35	13.30	39.11	5.76	0.33	9.67	5.12	4.85	1.08	5.72	-0.46
BC01	2012	winter	9	1/30/2012	37.16	60.37	9.14	10.67	365.24	119.83	39.50	12.38	32.22	6.02	0.35	13.72	8.01	4.86	2.72	5.27	-26.03
BC01	2012	snowmelt	4	4/15/2012	33.39	51.77	8.46	6.22	540.93	100.22	37.34	10.95	27.57	6.87	1.08	17.84	9.64	5.09	4.75	5.07	-32.46
BC01	2012	springsummer	12	6/15/2012	43.21	20.32	10.34	37.51	479.91	158.13	49.97	16.87	46.13	8.44	1.40	12.16	6.01	4.37	1.50	6.05	25.86
BC01	2012	latesummer	4	8/30/2012	49.12	14.66	10.64	79.54	452.42	199.58	57.26	20.50	54.83	9.39	0.87	7.13	3.25	2.62	0.76	6.55	68.98
BMB	2006	fall	9	10/30/2005	51.04	15.79	12.94	21.29	276.03	172.89	42.66	19.34	43.70	7.16	0.00	6.35	3.15	2.37	0.78	5.76	26.56
BMB	2006	winter	17	1/30/2006	48.75	37.08	9.75	13.18	236.45	147.01	34.43	14.61	37.39	5.50	0.00	8.08	4.72	2.90	1.81	5.77	-12.79
BMB	2006	snowmelt	4	4/15/2006	40.21	36.87	9.93	8.19	282.74	90.52	29.44	10.29	24.35	6.65	0.11	13.43	8.77	3.37	5.40	5.32	-34.73
BMB	2006	springsummer	13	6/15/2006	42.50	19.44	9.93	34.59	270.74	152.26	34.68	16.05	42.18	5.63	0.00	5.66	2.92	2.11	0.67	6.37	10.68
BMB	2006	latesummer	7	8/30/2006	43.44	19.27	10.64	91.88	274.07	195.19	54.39	25.51	53.48	8.95	0.00	3.92	1.44	1.37	0.11	6.83	82.88
BMB	2007	fall	5	10/30/2006	43.44	27.82	10.64	21.51	354.82	143.10	35.93	15.23	36.09	6.40	0.06	7.33	3.48	2.66	0.93	5.92	3.82
BMB	2007	winter	8	1/30/2007	44.43	45.44	8.86	20.22	212.99	153.67	39.67	17.49	40.00	7.55	0.08	6.22	3.90	2.52	1.37	5.92	4.58
BMB	2007	snowmelt	2	4/15/2007	38.28	52.13	20.03	5.93	266.16	100.26	33.18	12.14	27.39	7.42	0.25	14.08	8.27	3.59	4.68	5.25	-40.06
BMB	2007	springsummer	7	6/15/2007	45.73	27.95	9.93	64.88	236.24	191.69	41.92	21.81	59.13	9.46	0.22	4.92	2.02	1.70	0.37	6.59	54.22
BMB	2007	latesummer	4	8/30/2007	46.25	26.08	10.81	102.89	163.58	207.33	52.15	29.01	69.79	10.74	0.00	2.63	1.26	1.04	0.22	6.84	102.26
BMB	2008	fall	5	10/30/2007	57.71	14.27	13.83	32.76	377.07	158.91	47.90	21.81	43.48	7.67	0.00	6.33	3.22	2.48	0.74	6.24	13.24
BMB	2008	winter	8	1/30/2008	44.95	38.46	10.10	14.46	248.28	130.71	38.55	15.64	35.00	6.27	0.08	11.32	4.11	2.66	1.44	5.68	-8.53
BMB	2008	snowmelt	3	4/15/2008	40.94	28.56	7.80	13.77	308.40	99.17	33.93	11.52	26.96	6.40	0.06	10.18	6.07	3.92	2.41	5.60	-4.97
BMB	2008	springsummer	6	6/15/2008	44.95	17.35	9.93	56.17	244.37	169.89	44.79	18.31	45.44	6.65	0.11	5.11	1.74	1.85	0.15	6.61	47.72
BMB	2008	latesummer	5	8/30/2008	37.92	12.40	10.64	74.78	343.32	185.37	48.65	20.16	41.74	5.37	0.28	5.55	2.18	2.15	0.30	6.66	64.40
BMB	2009	fall	4	10/30/2008	43.91	14.27	11.17	31.07	267.36	145.93	37.43	15.23	35.44	5.76	0.00	7.09	3.72	3.53	0.24	6.17	9.86
BMB	2009	winter	9	1/30/2009	47.55	32.42	9.13	25.69	225.41	143.77	38.67	16.46	36.96	5.63	0.00	7.66	3.55	2.48	1.07	6.16	10.96
BMB	2009	snowmelt	2	4/15/2009	44.89	22.34	8.56	16.63	232.87	129.21	33.93	13.58	34.35	6.33	0.08	6.79	3.74	2.63	1.11	5.88	-0.11
BMB	2009	springsummer	6	6/15/2009	40.49	13.36	8.05	40.00	285.11	153.17	36.68	16.67	42.61	4.99	0.11	6.16	2.74	2.50	0.35	6.44	32.78
BMB	2009	latesummer	5	8/30/2009	35.50	11.32	10.08	66.15	352.21	162.96	43.86	18.48	40.05	5.94	0.00	6.31	2.86	2.89	0.00	6.69	58.95
BMB	2010	fall	4	10/30/2009	39.82	13.22	8.78	33.45	304.87	146.41	35.51	15.77	35.79	5.87	0.00	6.97	3.46	2.88	0.46	6.25	22.85
BMB	2010	winter	9	1/30/2010	45.03	32.06	7.77	52.40	200.97	174.82	44.61	20.89	45.45	6.07	0.33	4.64	2.32	2.21	0.11	6.44	47.98
BMB	2010	snowmelt	2	4/15/2010	43.11	24.32	7.73	32.98	224.35	151.36	38.29	16.71	46.29	6.70	0.04	5.51	2.55	2.38	0.23	6.32	30.90
BMB	2010	springsummer	6	6/15/2010	39.91	16.63	8.52	54.04	260.22	174.75	40.87	18.08	50.33	6.37	0.16	4.82	2.18	1.99	0.09	6.64	47.89
BMB	2010	latesummer	5	8/30/2010	41.89	17.86	9.20	108.98	214.99	211.63	50.98	25.74	57.39	7.89	0.00	3.45	1.75	1.90	0.00	6.89	105.39
BMB	2011	fall	8	10/30/2010	38.28	20.58	9.63	25.97	312.96	150.84	34.98	13.88	37.88	4.88	0.38	7.12	3.63	3.19	0.56	6.16	12.21
BMB	2011	winter	18	1/30/2011	42.86	39.55	8.64	40.02	207.03	161.28	40.87	17.59	40.82	6.41	0.39	5.85	2.71	2.23	0.32	6.24	14.41
BMB	2011	snowmelt	2	4/15/2011	29.72	41.09	6.83	0.93	347.95	75.32	26.14	8.72	22.32	5.66	0.43	12.52	7.89	4.12	3.77	4.94	-32.28
BMB	2011	springsummer	6	6/15/2011	39.20	28.12	8.11	32.29	256.45	160.67	32.28	15.87	43.62	5.56	0.59	5.55	2.68	2.35	0.35	6.28	7.88
BMB	2011	latesummer	5	8/30/2011	35.28	22.94	9.74	71.04	378.62	167.72	43.23	18.92	43.93	6.19	0.08	4.92	2.47	2.38	0.10	6.54	55.55
BMB	2012	fall	4	10/30/2011	38.40	33.67	9.70	39.62	222.75	182.13	41.13	19.54	49.40	6.81	0.08	4.62	2.53	2.39	0.21	6.53	39.90
BMB	2012	winter	9	1/30/2012	36.81	57.26	8.21	19.36	216.49	140.58	37.64	15.30	36.76	5.97	0.47	7.82	4.20	3.25	1.27	5.81	-1.83
BMB	2012	snowmelt	2	4/15/2012	32.81	47.39	7.39	15.72	344.69	114.63	34.61	13.46	31.35	6.41	0.67	8.93	6.20	4.27	1.93	5.68	-8.87
BMB	2012	springsummer	7	6/15/2012	36.53	35.59	9.16	49.73	230.16	175.21	47.33	18.57	50.16	7.86	1.14	4.88	2.59	2.38	0.21	6.60	51.87
BMB	2012	latesummer	4	8/30/2012</																	

Appendix C: ALTM Time Series 1992–2013

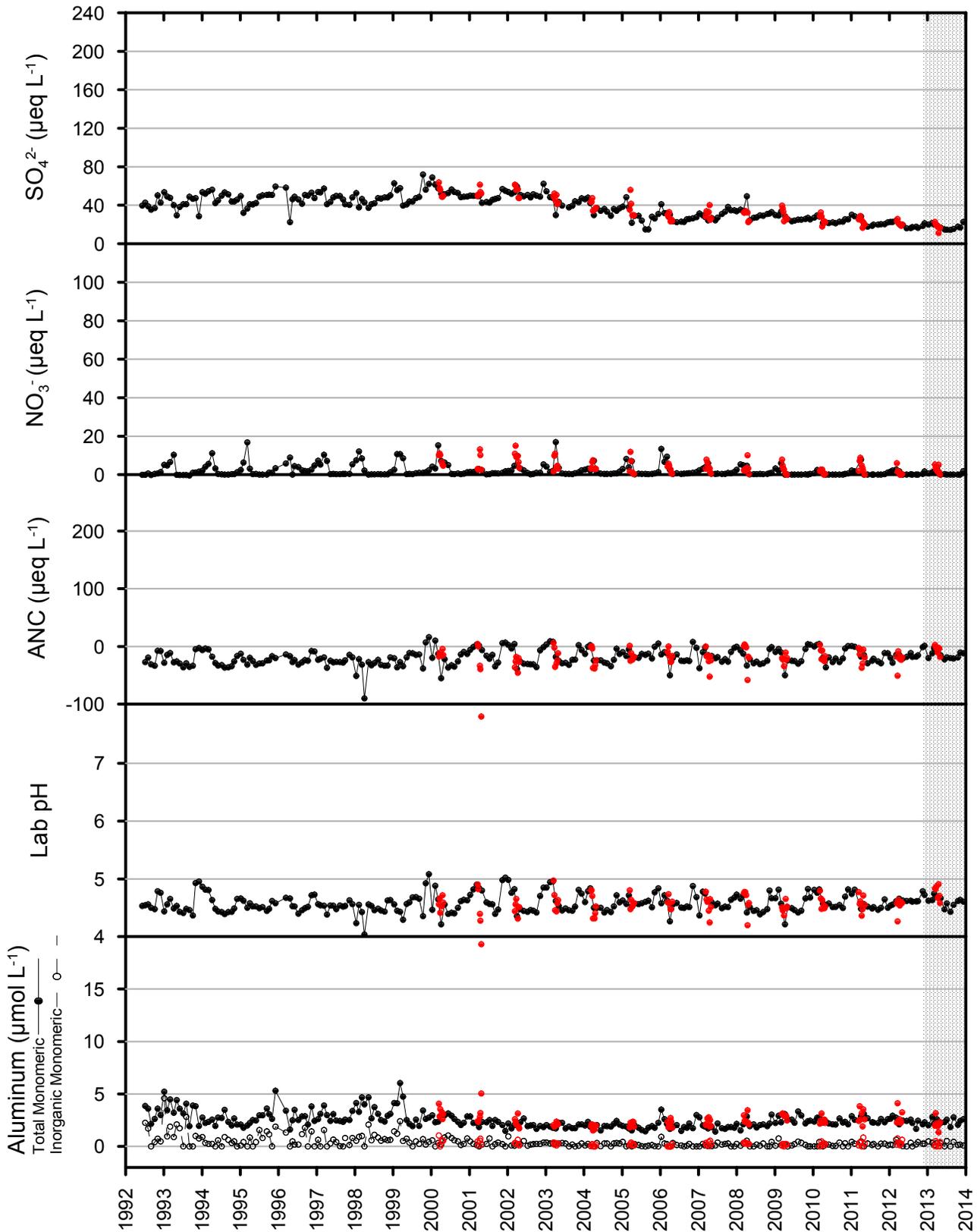
LITTLE ECHO POND (020126) Mounded seepage
High DOC



spring melt data in red

EAST COPPERAS POND (020138)

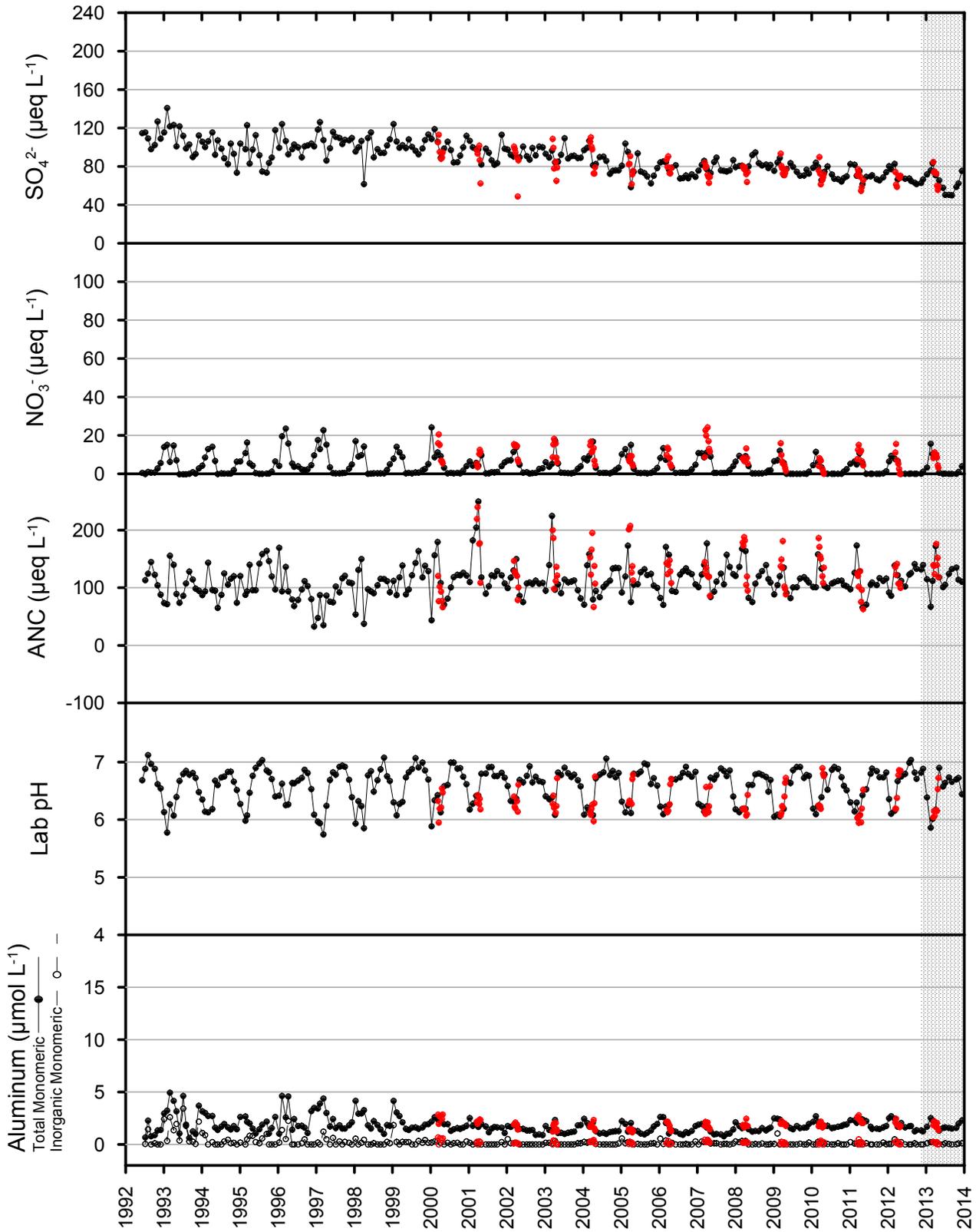
Thin till drainage
High DOC



spring melt data in red

MIDDLE POND (020143)

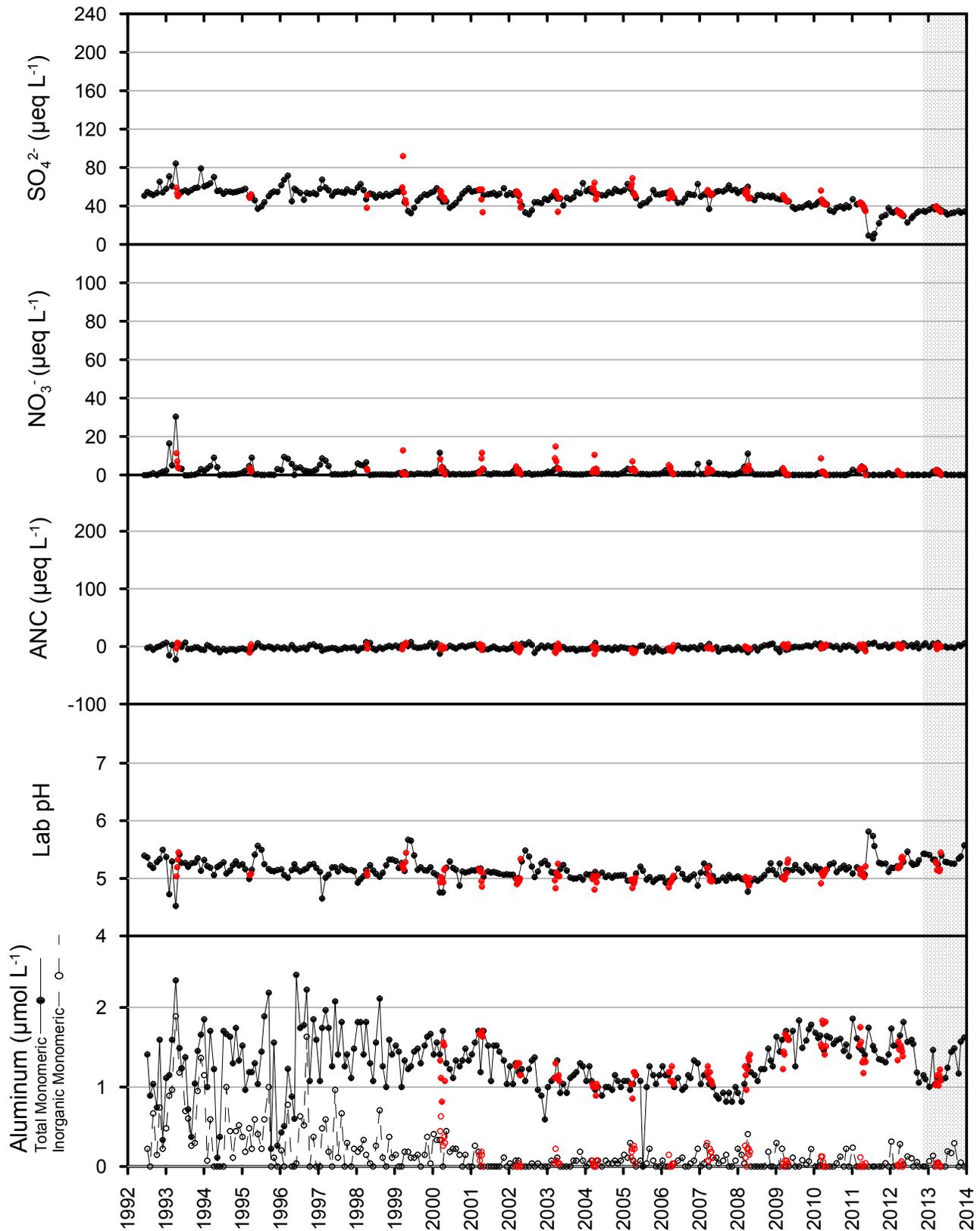
Carbonate influenced



spring melt data in red

SUNDAY POND (020188)

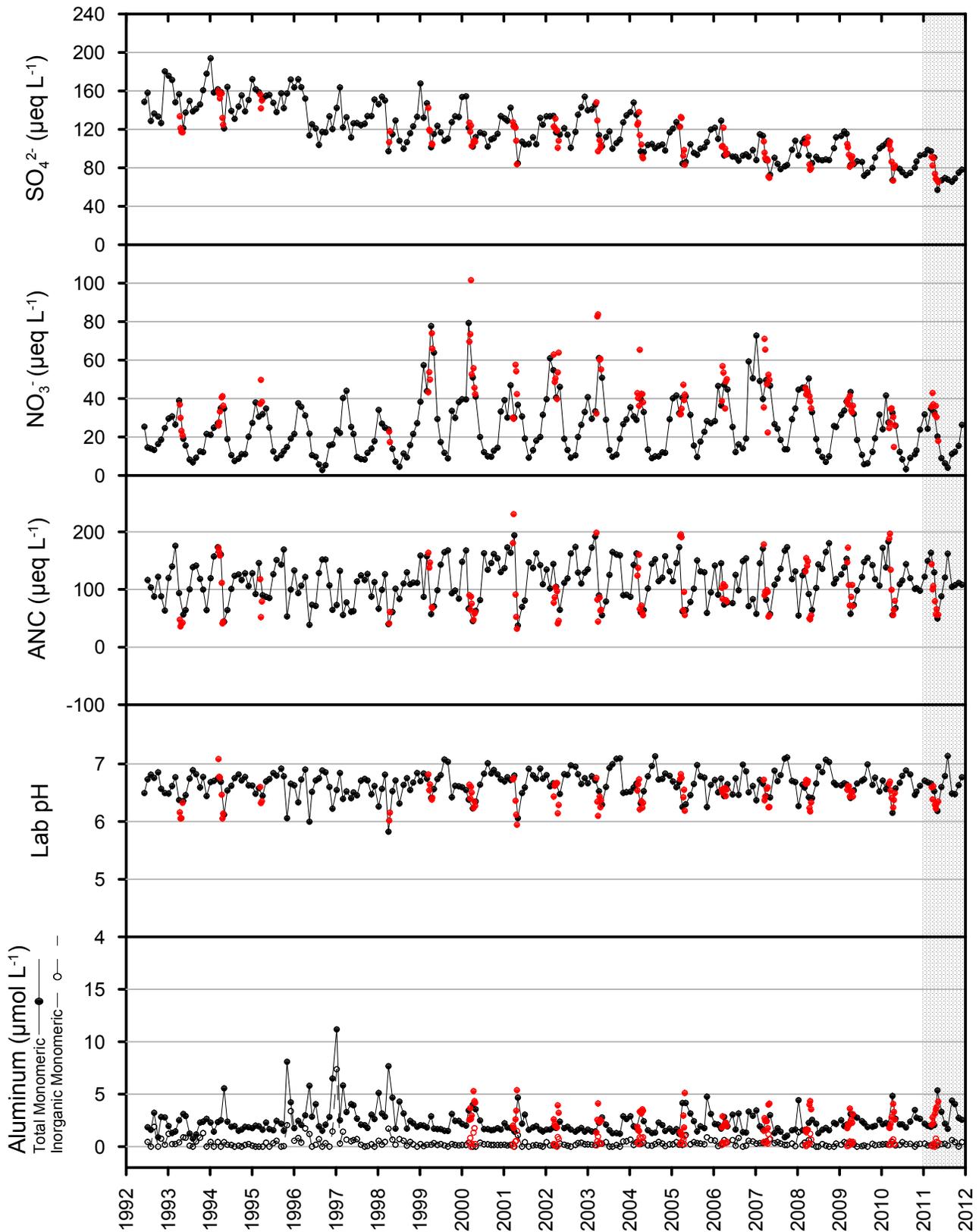
Mounded seepage
Low DOC



spring melt data in red

OWEN POND (020233)

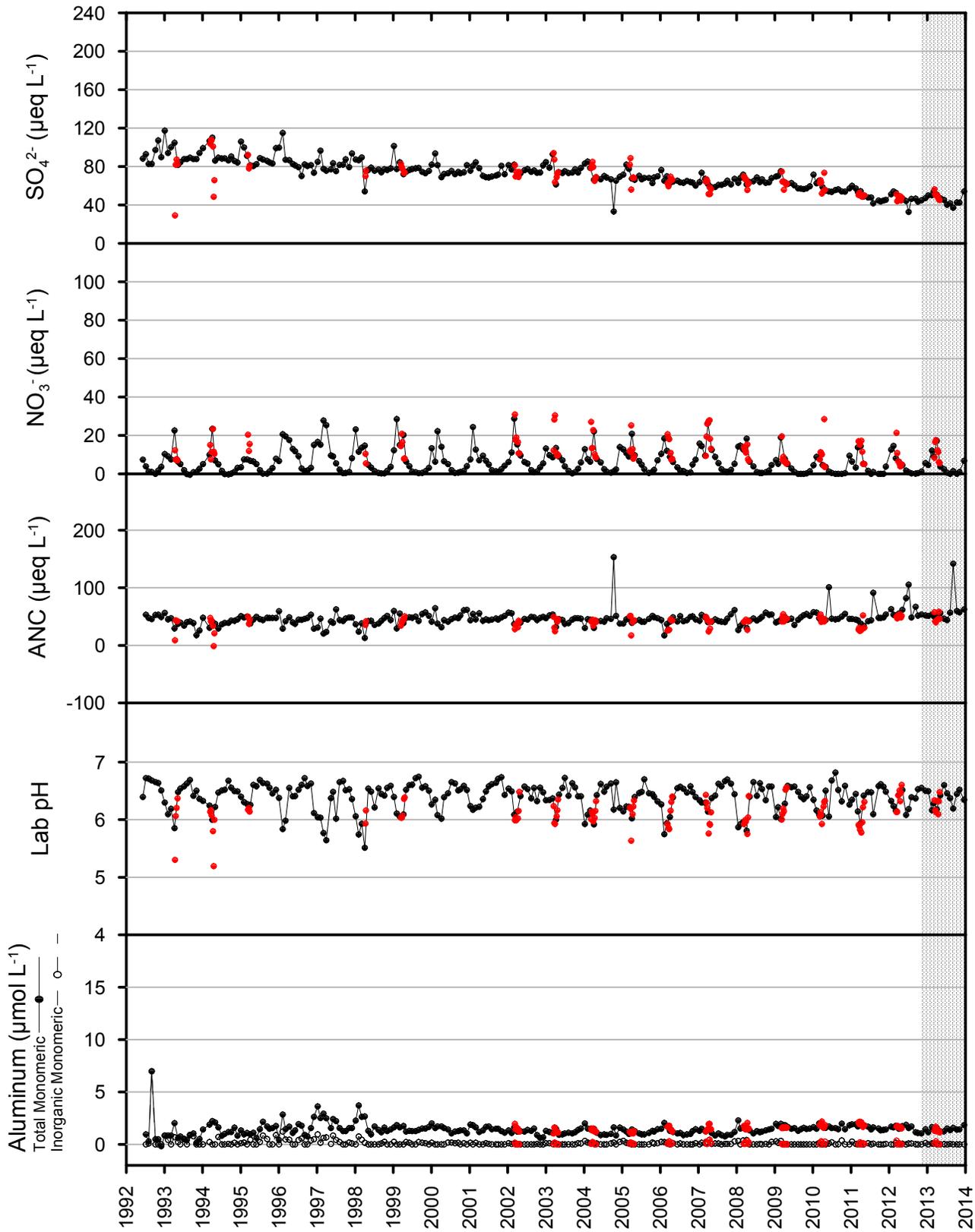
Thick till drainage
Low DOC



spring melt data in red

HEART LAKE (020264)

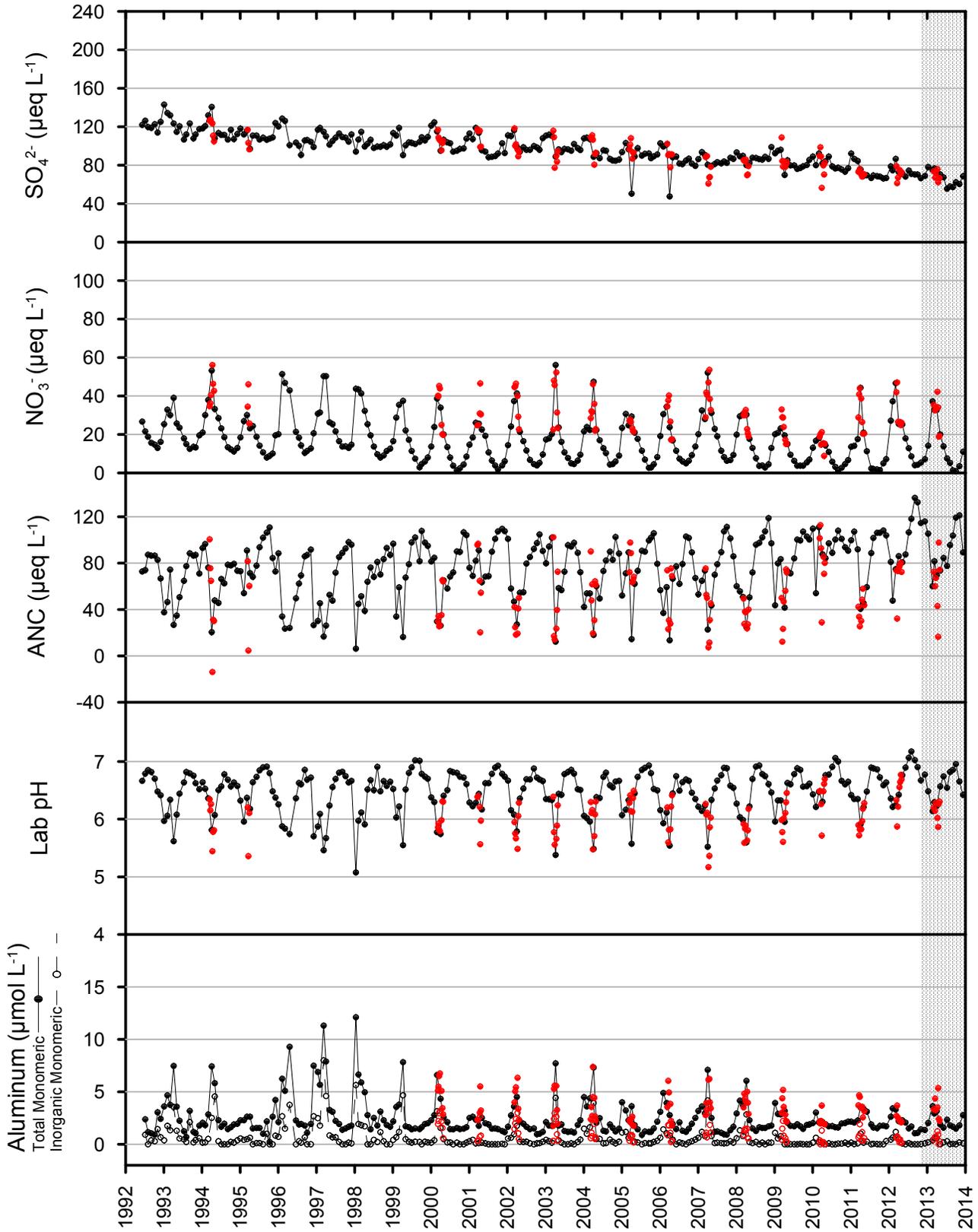
Medium till drainage
Low DOC



spring melt data in red

MOSS LAKE (040746)

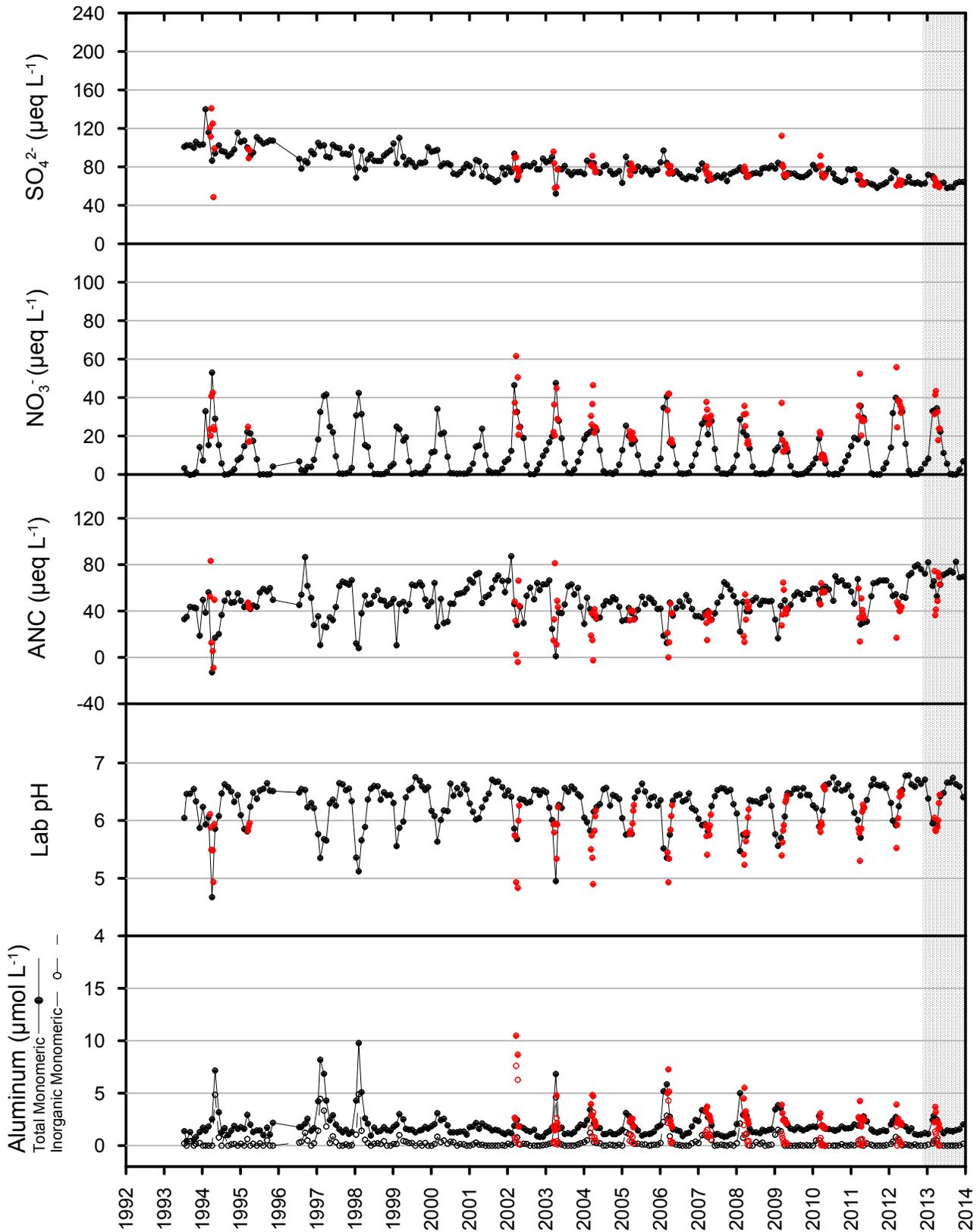
Medium till drainage
Low DOC



spring melt data in red

BUBB LAKE (040748)

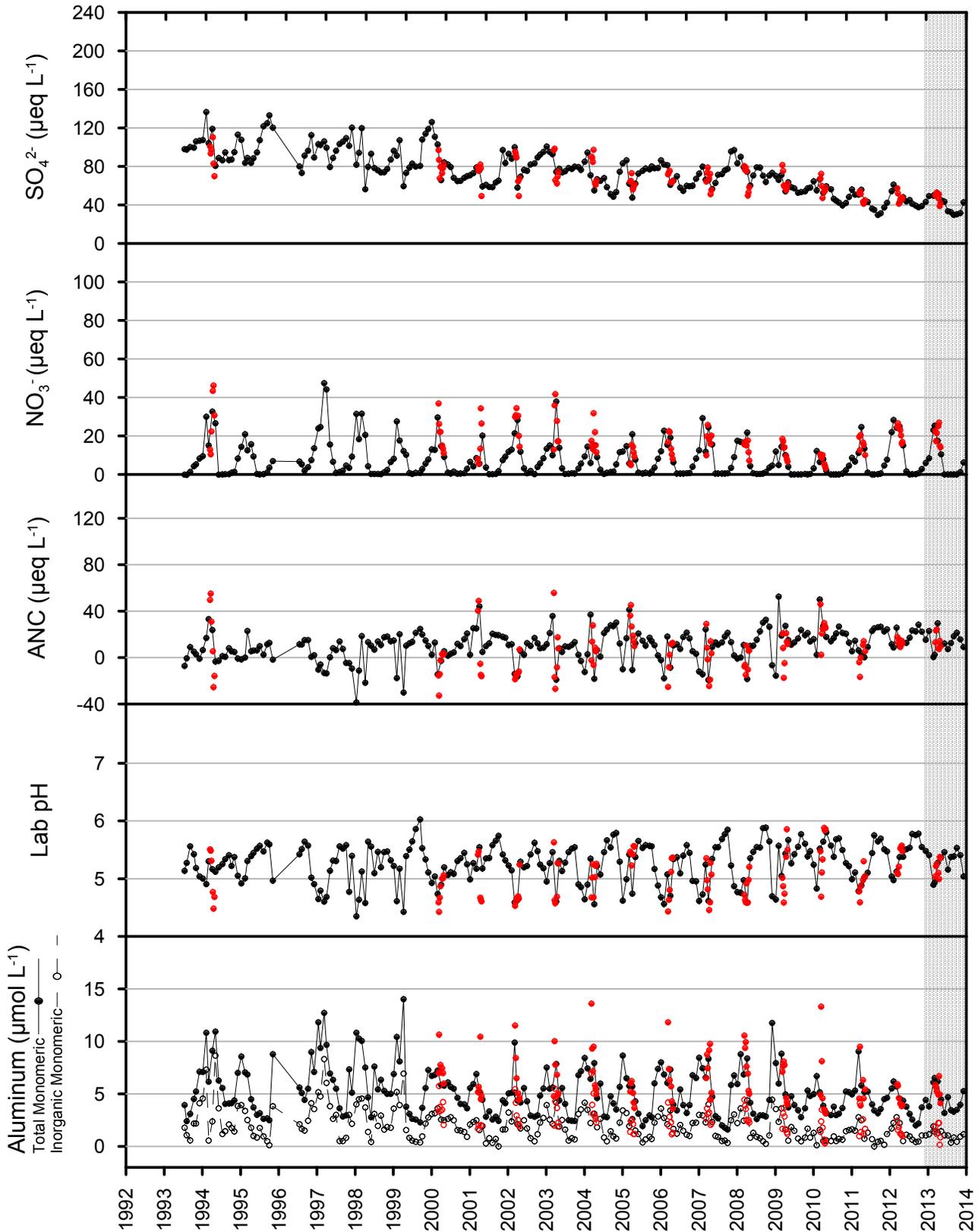
Thin till drainage
Low DOC



spring melt data in red

WEST POND (040753)

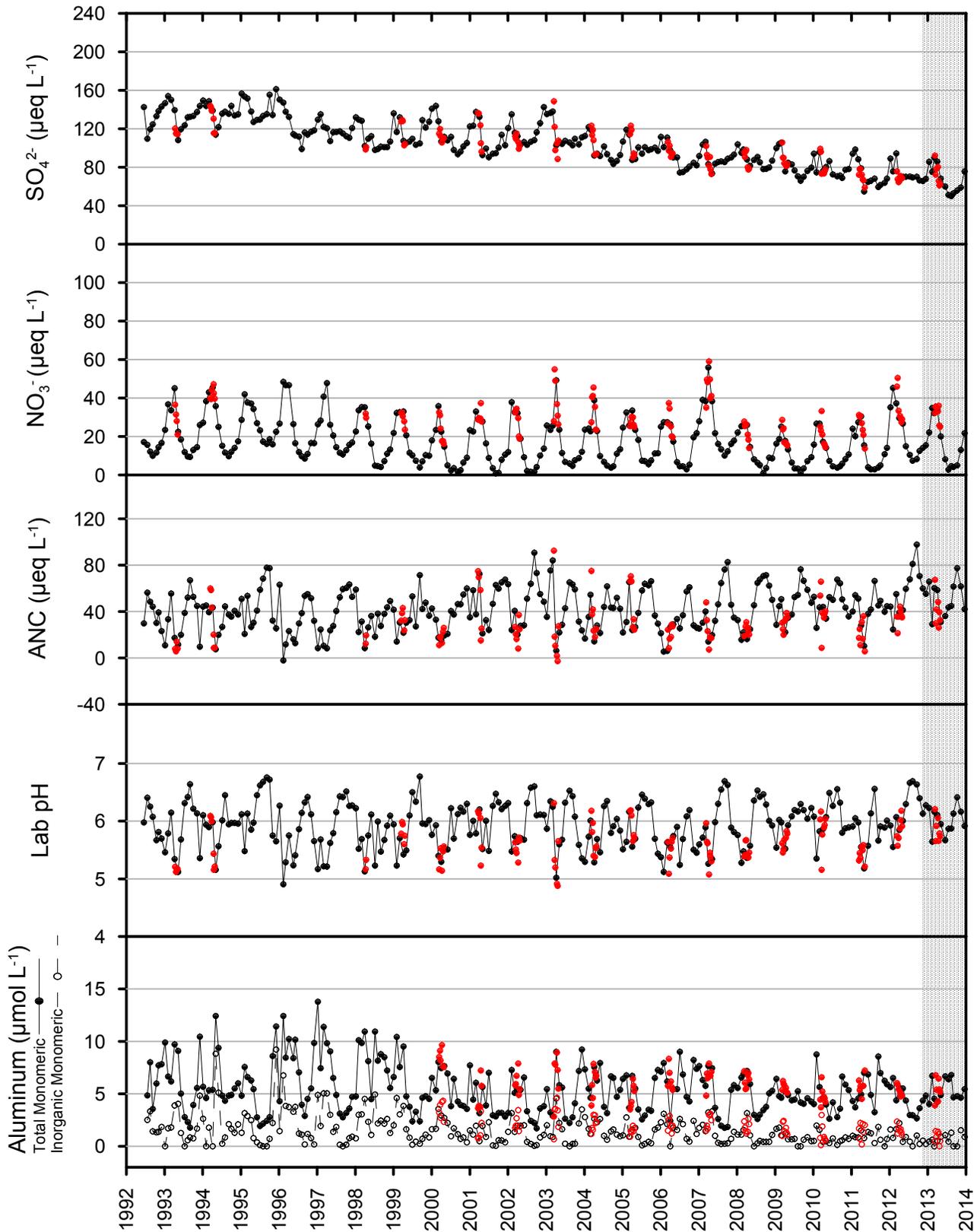
Thin till drainage
Low DOC



spring melt data in red

SAGAMORE LAKE (060313)

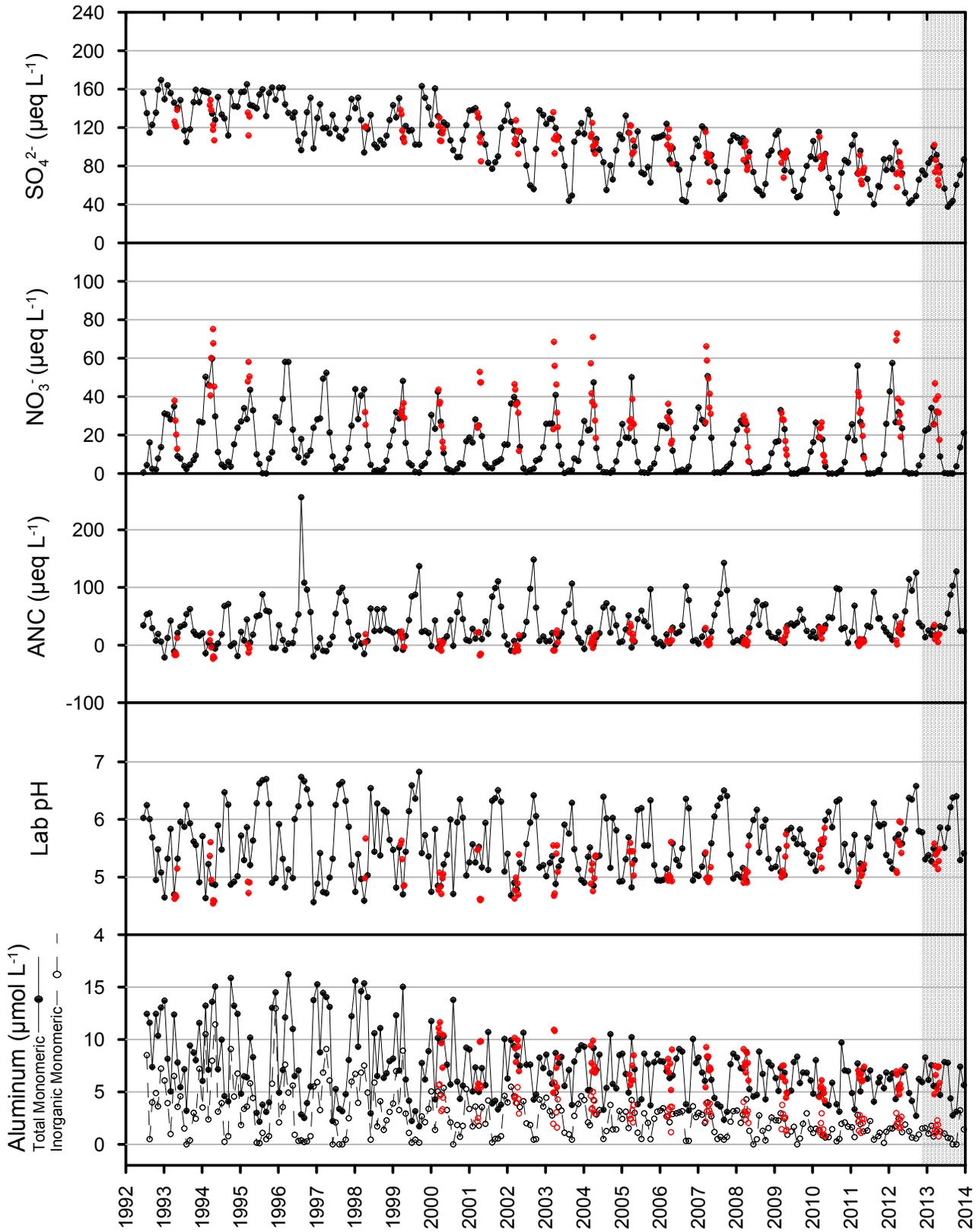
Medium till drainage
High DOC



spring melt data in red

RAQUETTE LAKE RESERVOIR (060315A)

Medium till drainage
High DOC



spring melt data in red

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Appendix D: Presentations, Reports, and Papers 2007–2012

PRESENTATIONS

Date/Location	Location	Presented at	Title	Prepared by	Presented by
November 6-7, 2013	Albany, NY	NYSERDA Environmental, Monitoring, Evaluation and Protection Program Linking Science and Policy conference	“Refinements to the Adirondack Long Term Monitoring (ALTM) lakes sampling program”	K.Roy, L.Sedefian, K.Civerolo, J.Dukett, N.Houck, M.Cantwell, G.Lampman and C.Funk	K.Roy (poster)
November 6-7, 2013	Albany, NY	NYSERDA Environmental, Monitoring, Evaluation and Protection Program Linking Science and Policy conference	“ASRC Whiteface Mountain Field Station”	P.Casson, R.Brandt, J.Schwab and J.Dukett	Poster
November 6-7, 2013	Albany, NY	NYSERDA Environmental, Monitoring, Evaluation and Protection Program Linking Science and Policy conference	“An Examination of Fish Presence using the Relationship between Base Cations (BC) and Strong Organic Anions (RCOO-) in Water Collected by Adirondack Lakes Survey Corporation”	J.E.Dukett, N.Houck, P.Snyder and S.Capone	J.Dukett (poster)
August 20, 2013	Wilmington, NY	Atmospheric Science Research Center Falconer Science/Natural History Lecture Series	“Enhancement to acid deposition monitoring in NYS and other things”	K.Roy	K.Roy
July 16, 2013	Edinburgh, Scotland	11th International Conference on Mercury as a Global Pollutant	Validating landscape models for mercury in northeastern US lakes using dragonfly larvae as mercury bio-sentinels. [included data from 43 Adirondack TIME lakes]	S.J.Nelson, C.Chen, .P.Krabbvenholf, J.S.Kahn and B.Zoellick	S.J.Nelson (poster)
June 2013	Troy, NY	EPA Clean Air Markets Division LTM/TIME Cooperator’s Meeting	Revised sampling strategy for ALTM lakes	K.Roy	K.Roy
May 15-16, 2013	Lake Placid, NY	Adirondack Research Consortium 20th Annual Conference on the Adirondacks	“Enhancements to acid deposition monitoring in New York State”	K.L.Civerolo, H.D.Felton, K.M.Roy, G.G.Lampman	K.Roy (poster)
May 17, 2013	Albany, NY	Technical Memorandum to Mark Watson and Greg Lampman (NYSERDA), Clara Funk and Jason Lynch (USEPA)	“Final Revised ALTM Program - Supplemental Technical Assessment”	L.Sedefian	Technical report
March 2013	Lake Placid, NY	New England Association of Environmental Biologists Conference	“Increases in Dissolved Organic Carbon Accelerate Loss of Toxic Al in Adirondack Lakes Recovering from Acidification”	G.B.Lawrence, J.Dukett, N.Houck, P.Snyder and S.Capone	P.Snyder
March 2013	Saratoga, NY	Northeastern Ecosystem Research Cooperative’s Conference	“Increases in Dissolved Organic Carbon Accelerate Loss of Toxic Al in Adirondack Lakes Recovering from Acidification”	G.B.Lawrence, J.Dukett, N.Houck, P.Snyder and S.Capone	J.Dukett
March 2013	Saratoga, NY	Northeastern Ecosystem Research Cooperative’s Conference	“Enhancements to acid deposition monitoring in New York State”	K.L.Civerolo, H.D.Felton, K.M.Roy and G.G.Lampman	K.Roy (poster)
March 2013	Inlet, NY	Adirondack Research Forum	“Increases in Dissolved Organic Carbon Accelerate Loss of Toxic Al in Adirondack Lakes Recovering from Acidification”	G.B.Lawrence, J.Dukett, N.Houck, P.Snyder and S.Capone	J.Dukett
March 2013	Ray Brook, NY	NYSDEC Region 5 Accomplishments 2012 Regional Director	ALTM Program highlights for 2012	K.M.Roy	R.Stegemann
March 2013	Northville, NY	NYSDEC Region 5 Accomplishments 2012 Regional Director	ALTM Program highlights for 2012	K.M.Roy	R.Stegemann
March 2013	Warrensburg, NY	NYSDEC Region 5 Accomplishments 2012 Regional Director	ALTM Program highlights for 2012	K.M.Roy	R.Stegemann
January 2013	Plattsburgh, NY	Adirondack Research Symposium	ALTM Program	K.M.Roy & J.Dukett	K.M.Roy and J.Dukett
September 14, 2012	Willsboro, NY	Garden Club of America, Adirondack Conservation Field Program since the 1980s.	Adirondack Park acid rain science and advocacy	K.Roy	K.Roy

August, 2012	Saranac Lake, NY	Saranac Lake Rotary Club	About the Adirondack Lakes Survey Corporation	J.Dukett	J.Dukett
August, 2012	Lake Placid & Wilmington, NY	PBS Mountain Lake Journal	What's falling from the sky	J.LaDuke, J.Dukett and M.Kelting	Television
July 10, 2012	Wilmington, NY	Atmospheric Sciences Research Center Summer Lecture Series	About the Adirondack Lakes Survey Corporation and the Whiteface Mountain Cloud project	J.Dukett	J.Dukett
May 21-25, 2012	Potsdam, Germany	North-Watch Workshop	Regulation of sulfur budgets of forested lake/watersheds in the Adirondack Mountains of New York State: Shift from atmospheric regulation to climate control	M.Mitchell, C.T.Driscoll, P.McHale, K.M.Roy, Z.Dong	Paper (M.Mitchell)
May 16-17, 2012	Lake Placid, NY	Adirondack Research Consortium Annual Meeting	Recent fish community changes and mercury in Adirondack long-term monitoring lakes	K.Roy,	K.Roy
May 16-17, 2012	Lake Placid, NY	Adirondack Research Consortium Annual Meeting	The Adirondack Lakes Survey Corporation: Where timely environmental monitoring data reaches the public	J.Dukett, N.Houck, P.Snyder and S.Capone	Poster (Dukett)
April 19, 2012	Ray Brook, NY	Earth Week Adirondack Park Agency Board Meeting	The Adirondack Long Term Monitoring Program: Recent trends and the latest data	K.Roy, J.Dukett, N.Houck, P.Snyder and S.Capone	K.Roy, J.Dukett, N.Houck, P.Snyder and S.Capone
March 7-8, 2012	Old Forge, NY	Ninth Annual Adirondack Research Forum	Program updates, deliverables, news and recent analysis associated with the Adirondack Lakes Survey Corporation	J.Dukett, and N.Houck	J.Dukett, and N.Houck
December 7, 2011	Albany, NY	New York State Department of Environmental Conservation (NYSDEC) PE Continuing Education Seminar	Adirondack acid rain update - acid deposition impacts, monitoring and trends in Adirondack lakes and streams	K.Roy	K.Roy
November 15-16, 2011	Albany, NY	New York State Energy Research and Development Authority (NYSERDA) Environmental Monitoring, Evaluation, and Protection (EMEP) Program Linking Science and Policy Conference	A comparison of the Temporally Integrated Monitoring of Ecosystems and Adirondack long-term monitoring programs in the Adirondack mountain region of New York	K.Civerolo, and K.Roy	Poster (Civerolo)
November 15-16, 2011	Albany, NY	NYSERDA EMEP Conference	Adirondack long term monitoring lakes: A compendium of site descriptions, recent chemistry, and selected research information	K.Roy, N.Houck, P.Hyde, M.Cantwell, and J.Brown	Poster (Roy)
November 15-16, 2011	Albany, NY	NYSERDA EMEP Conference	Carbon observations from cloud water at Whiteface Mountain New York	J.Dukett, P.Snyder, S.Capone, N.Houck, N.Aleksic, M.Mazurek, and J.Sagona	Poster (Dukett)
November 15-16, 2011	Albany, NY	NYSERDA EMEP Conference	Fish community changes and mercury in Adirondack long term monitoring lakes	K.Roy and A.Bulger	Poster (Roy)
November 15-16, 2011	Albany, NY	NYSERDA EMEP Conference	Understanding the molecular composition of highly polar organic compounds in cloudwater and fine particles in the Northeastern US	J.Sagona, M. Mazurek, and J.Dukett	Poster
July 29, 2011	Lake Placid, NY	The Greater Adirondack Resource Conservation and Development Council - Adirondack Waterfest	The Adirondack Lake Survey Corporation	ALSC Staff	Poster
July 10-15, 2011	Lewiston, ME	The Gordon Conference, Bates College	The road to recovery of Adirondack lakes from acidic deposition: Are we there yet?	C.T.Driscoll	C.T.Driscoll

June 8, 2011	Croghan, NY	First Annual Black River Watershed Conference	Ongoing research in the western Adirondacks, headwaters to the Black River	G.Lawrence	G.Lawrence
June 6-7, 2011	Durham, NH	USEPA LTM/TIME Cooperators Workshop	Update Adirondack lakes LTM (monthly) trends; TIME (summer)/LTM comparison; and recent stream survey results	K.Roy	K.Roy
May 18-19, 2011	Lake Placid, NY	Adirondack Research Consortium Annual Meeting	Progress toward clean cold water at Whiteface Mountain New York	J.Dukett	J.Dukett
May 18-19, 2011	Lake Placid, NY	Adirondack Research Consortium Annual Meeting	Adirondack long term monitoring lakes: A compendium of site descriptions, recent chemistry, and selected research information	K.Roy, N.Houck, P.Hyde, M.Cantwell, and J.Brown	Poster (Houck)
May 2011	Troy, NY	Fifth USGS/NYSDEC Summit	Acidification of the Adirondack ecosystem: A park-wide assessment of aquatic and terrestrial effects	G.Lawrence	G.Lawrence
April 26 and June 17, 2011	Tupper Lake, NY	Whiteface Mountain - Olympic Region Scenic Byways Natural History Interpretation Project - Wild Center discussion group	Research at Whiteface Mountain - discussion group	J.Dukett and K.Roy	J.Dukett
April 6-9, 2011	Albany, NY	Northeast Natural History Conference. Special session: Ecological Status and Recovery of Acidified Adirondack Surface Waters	A comparison of the TIME (summer) and LTM (year-round) programs during 1992-2008	K.Civerolo and K.Roy	K.Roy
April 6-9, 2011	Albany, NY	Northeast Natural History Conference. Special session: Ecological Status and Recovery of Acidified Adirondack Surface Waters	Comparison of methods for estimating critical loads of acidic deposition in the western Adirondack region of New York	G.Lawrence	G.Lawrence
March 14, 2011	Albany, NY	Office of the Attorney General - Briefing to scientific staff	Adirondack long-term monitoring to assess acid rain and emissions policies	G.Lampman, J.Dukett and K.Roy	G.Lampman, J.Dukett and K.Roy
March 2, 2011	Old Forge, NY	Eight Annual Adirondack Research Forum	Progress toward clean cold water at Whiteface Mountain New York	J.Dukett	J.Dukett
January 14, 2011	Ray Brook / Albany teleconference	NYSDEC Bureau of Air Quality Analysis and Research (BAQAR) project overview presentations	Adirondack long term monitoring project - overview to BAQAR staff	K.Roy, J.Dukett, P.Snyder, N.Houck, and S.Capone	K.Roy, J.Dukett, P.Snyder, M.Cantwell, and S.Capone
October 2010	Arlington, VA	USEPA Workshop "Interacting Effects of Climate and Nitrogen on Ecosystem and Their Services"	Invited participant. Purpose: Review current science and inform policy-driven scientific needs. Buck Creek, Inlet, NY findings.	G.Lawrence	G.Lawrence
Fall 2010	San Francisco, CA	American Geophysical Union Meeting	Highly polar organic compounds in summer cloudwater from Whiteface Mountain, NY - Poster	J.Sagona, J.Dukett, and M.Mazurek	Poster presentation
May 19, 2010	Lake Placid, NY	17th Annual Conference of the Adirondack Research Consortium	A comparison of contemporary cloudwater pH to pre-industrial values at Whiteface Mountain	J.Dukett	J.Dukett
March 3, 2010	Old Forge, NY	Seventh Annual Adirondack Research Forum	Trends in Adirondack lake chemistry	K.Roy	K.Roy
November 16, 2009	Albany, NY	Atmospheric Sciences Research Center Student/Faculty Seminar, SUNY Albany	Impacts, monitoring and trends in Adirondack streams and lakes and cloud chemistry trends at Whiteface Mountain	K.Roy	K.Roy
October 14-15, 2009	Albany, NY	New York State Energy Research and Development Authority (NYSERDA) Environmental Monitoring, Evaluation, and Protection (EMEP) Program Linking Science and Policy Conference	Acid deposition impacts, monitoring and trends in Adirondack lakes and streams	K.Roy, G.Lawrence and C.Driscoll	K.Roy

October 14-15, 2009	Albany, NY	NYSDERDA EMEP Conference	Chlorophyll a and total phosphorus: New to the compliment of chemical parameters analyzed by the Adirondack Long-Term Monitoring Program	J.E.Dukett, P.Snyder, N.Houck, S.Capone and K.Roy	Poster presentation
October 14-15, 2009	Albany, NY	NYSDERDA EMEP Conference	A Comparison of contemporary cloud water pH to pre-industrial values at Whiteface Mountain	J.E.Dukett, N.Aleksic, N.Houck, P.Casson, and M.Cantwell	Poster presentation
October 6-8, 2009	Saratoga Springs, NY	National Atmospheric Deposition Program (NADP) Fall 2009 Annual Meeting and Science Symposium	Changes in fish communities in Adirondack lakes	K.Roy, A.Bulger and C.Driscoll	K.Roy
October 6-8, 2009	Saratoga Springs, NY	NADP Fall 2009 Annual Meeting and Science Symposium	The response of acid-impacted lake-watersheds in the Adirondack region	C.Driscoll, K.Driscoll, K.Roy, Q.Zhao, T.Sullivan and M. Mitchell	C.Driscoll
October 6-8, 2009	Saratoga Springs, NY	NADP Fall 2009 Annual Meeting and Science Symposium	Liquid water content and chemical composition in clouds at Whiteface Mountain, NY	N.Aleksic and J.Dukett	Poster presentation
June 9, 2009	Albany, NY	New York State Department of Environmental Conservation (NYSDEC) Division of Air Resources (DAR) Seminar	Analysis of cloud and precipitation chemistry at Whiteface Mountain	N.Aleksic, K.Roy, G.Sistla, J.Dukett, N.Houck and P.Casson	N.Aleksic, K.Roy
June 3-4, 2009	College Park, PA	USEPA Temporally Integrated Monitoring of Ecosystems/Long Term Monitoring Cooperator Workshop	A regional perspective for the Adirondack Mountains	K.Roy, C.Driscoll, and G.Lawrence	K.Roy
May 15, 2009	Saranac Lake, NY	Focus Earth Series by Bob Woodruff video interview for "The Future of Coal Country" to be aired Summer 2009	Sampling for acid rain effects in the Adirondacks	K.Roy, P.Casson and J.Brown	Video interview
August 26, 2008	Wilmington, NY	Whiteface Mountain Atmospheric Center Ray Falconer Summer Lecture Series	Lakes, streams and cloud monitoring in the Adirondacks		K.Roy
June 2, 2008	Lake Placid, NY	North Country Public Radio (Canton, NY) interview with Brian Mann	Subject: National air pollution cap and trade policies and the battle to stop acid rain in the Adirondacks	K.Roy	Radio interview
May 21-22, 2008	Lake Placid, NY	Adirondack Research Consortium 15th Annual Conference	Adirondack Long-Term Monitoring recent findings - lakes	K.Roy, J.Dukett, S.Capone, N.Houck and S.Capone	K.Roy
May 13, 2008	Ray Brook, NY	Cornell Water Resources Institute Reactive Nitrogen Round Table Teleconference	Presentation of Adirondack long term monitoring sites and findings	K.Roy	K.Roy
February 14, 2008	Troy, NY	Meeting of The Nature Conservancy and USGS Research Scientists on Acid Deposition Research in New York State	Adirondack Long Term Monitoring Program - study sites	K.Roy	K. Roy
November 15-16, 2007	Albany, NY	New York State Energy Research and Development Authority (NYSDERDA) Environmental Monitoring, Evaluation, and Protection (EMEP) Program Linking Science and Policy Conference	Changes in water quality of Adirondack lakes	K.Roy, J.Dukett, S.Capone, N.Houck and P. Snyder	K.Roy
September 30, 2007	Ray Brook, NY	NYSDEC Executive Staff regional visit	Adirondack Lakes Survey Corporation/Adirondack Long Term Monitoring Program overview	K.Roy	K.Roy
May 22-24, 2007	Tupper Lake, NY	Adirondack Research Consortium 14th Annual Conference on Sustainability, Climate Change, and Protected Areas - Setting a Practical Research Agenda for the North Country	Recent acidification trends in Adirondack lakes	K.Roy, C.Driscoll, K.Driscoll, J.Dukett, N.Houck, P.Snyder, and S.Capone	K.Roy
May 4-6, 2007	Hamilton, NY	New York State Federation of Lake Association 24th Annual Conference	Recent acidification trends in Adirondack lakes	K.Roy, C.Driscoll, K.Driscoll, J.Dukett, N.Houck, P.Snyder, and S.Capone	K.Roy
January 10, 2007	Albany, NY	NYSDEC Division of Air Resources, New Staff Orientation	The Adirondack Long Term Monitoring Program (surface water acidification)	K.Roy	K.Roy

PUBLISHED REPORTS AND ARTICLES

YEAR	Journal, Book or Other	Title	Authors
December 2013	Journal of Chromatography A	“Sequential Derivatization of Polar Organic Compounds in Cloud Water Using PFBHA, BSTFA and GCMS Analysis”	J.A.Sagona, J.Dukett, H.A.Hawley, M.Mazurek
June 2013	Environmental Science and Technology	“Increases in Dissolved Organic Carbon Accelerate Loss of Toxic Al in Adirondack Lakes Recovering from Acidification	G.B.Lawrence, J.Dukett, N.Houck, P.Snyder and S.Capone
March 2013	NYS Conservationist Volume 6 Number 3 Spring	“Understanding Acid Rain”	NYSDEC Div. of Public Affairs and Education, NYSDEC Division of Air Resources
March 2013	NYS Conservationist Volume 67 Number 5	“On the Road to Recovery - Acid Rain and the Adirondacks”	K.L.Civerolo and K.M.Roy
January 2013	Hydrologic Processes	“Lake/watershed sulfur budgets and their responses to decreases in atmospheric sulfur deposition: watershed and climate controls”	M.J.Mitchell, C.T.Driscoll, P.J.McHale, K.M.Roy and Z.Dong
November 2012	Hydrological Processes	Lake/watershed sulfur budgets and their response to decreases in atmospheric sulfur deposition: Watershed and climate controls	M.Mitchell, C.T.Driscoll, P.McHale, K.M.Roy, Z.Dong
June 2012	Report to NYSERDA	http://onlinelibrary.wiley.com/doi/10.1002/hyp.9670/abstract A long-term monitoring program for evaluating changes in water quality in selected Adirondack waters: Core program 2007-2011 program summary report 2011. Report 12-26 NYSERDA 4915, Albany, NY	K.Roy, J.Dukett, N.Houck, and G.Lawrence
July 2011	Environmental Pollution (2011) 159:2750-2758	www.nyserda.ny.gov/~media/Files/Publications/Research/Environmental/12-16-A-Long-Term-Monitoring-Program.pdf Changes in the chemistry of acidified Adirondack streams from the early 1980s to 2008 http://dx.doi.org/10.1016/j.envpol.2011.05.016	G.B.Lawrence, H.A.Simonin, B.P.Baldigo, K.M.Roy and S.B.Capone
August 2011	Report to NYSERDA	Adirondack long term monitoring lakes: A compendium of site descriptions, recent chemistry, and selected research information http://www.nyserda.ny.gov/~media/Files/Publications/Research/Environmental/11-12-altm-compendium.ashx?sc_database=web	K.Roy, N.Houck, P.Hyde, M.Cantwell, and J.Brown
August 2011	Atmospheric Environment 45(2011) 6669-6673	Progress toward clean cloud water at Whiteface Mountain, New York doi:10.1016/j.atmosenv.2011.08.070	J.Dukett, N.Aleksic, N.Houck, P.Snyder, P.Casson, and M.Cantwell
August 2011	Report to NYSERDA	A long-term monitoring program for evaluating changes in water quality in selected Adirondack waters: Core program 2007-2011 data summary report 2010. Report 11-20 NYSERDA 4915, Albany, NY http://www.nyserda.ny.gov/~media/Files/Publications/Research/Environmental/11-20%20Water%20Quality%20in%20Selected%20Adirondack%20Waters%202010%20Summary%20Report.ashx?sc_database=web	K.Roy, J.Dukett, N.Houck, and G.Lawrence
August 2011	Water Air and Soil Pollution (2011) 222: 285-296	A comparison of the Temporally Integrated Monitoring of Ecosystems and Adirondack Long-Term Monitoring Programs in the Adirondack Mountain Region of New York doi: 10.1007/s11270-011-0823-8	K.L.Civerolo, K.M.Roy, J.L.Stoddard, and G.Sistla
December 2011	Atmospheric Environment 46 (2012) 56-64	Long term recovery of lakes in the Adirondack region of New York to decreases in acidic deposition http://www.sciencedirect.com/science/article/pii/S1352231011011058	K.Waller, C.Driscoll, J.Lynch, D.Newcomb and K.Roy
December 2011	Office of Science and Technology Report National Science and Technology Council	National Acid Precipitation Assessment Program report to Congress 2011: An integrated assessment	D.A.Burns and others
2010	Atmospheric Research 98(2010) 2-4:400-405	Probabilistic relationship between liquid water content and ion concentrations in cloud water.	N.Aleksic, and J.Dukett
2010	Report to NYSERDA	A sampling design for the 2008-2012 fisheries resurvey of the 52 Adirondack Long-Term Monitoring (ALTM) lakes. NYS Department of Environmental Conservation and Adirondack Lakes Survey Corporation, Ray Brook, NY	K.Roy and S.Capone
2010	Report to NYSERDA	A long-term monitoring program for evaluating changes in water quality in selected Adirondack waters: Core program 2007-2011 data summary report 2009. Report 10-21 NYSERDA 4915, Albany, NY	K.Roy, J.Dukett, N.Houck, and G.Lawrence

REPORTS /POLICY DOCUMENTS UTILIZING ALTM/ALSC PROGRAM DATA

Year	Report or Other	Title	Authors
May 2013	Dissertation	“Highly Polar Organic Compounds in Atmospheric Fine Particles and Cloud Water: A Study in the Northeastern United States”	J.Sagona
2011	Technical Report to NESCAUM	Steady-state critical loads and exceedance for terrestrial and aquatic ecosystems in the Northeastern United States Http://www.nescaum.org/activities/major-reports	E.K.Miller
2011	National Acid Precipitation Assessment Program Report to Congress	National Acid Precipitation Assessment Program report to Congress 2011: An integrated assessment. Http://ny.water.usgs.gov/projects/NAPAP/	D.A.Burns et al.
2011	Comments of the New York State Department of Environmental Conservation Division of Air Resources to the EPA Proposed Rule	Secondary national ambient air quality standards for oxides of nitrogen and sulfur federal register notice http://www.epa.gov/air/nitrogenoxides/actions.html#mar12	D.Shaw (NYSDEC) to R.Wayland and R.Haeuber (US EPA) April 3, 2012
2011	EPA Policy Document	Policy assessment for the review of the secondary national ambient air quality standards for oxides of nitrogen and oxides of sulfur, U.S. Environmental Protection Agency, Washington, D.C., EPA-452/R-11-005a.	USEPA
2010	EPA Report	Acid rain and related programs: 2009 highlights 15 years of results 1995 to 2009. EPA-430-R-10-014 Washington, DC http://www.epa.gov/airmarkets/progress/ARP09_4.html	USEPA Clean Air Markets Division
2010	EPA Report	Acid Rain and related programs: 2009 environmental results, Washington, DC http://www.epa.gov/airmarkets/progress/APR09.html	USEPA Clean Air Markets Division
2010	EPA Report	Policy assessment for the review of the secondary national ambient air quality standards for NOx and SOx: Second external review draft for the Clean Air Scientific Advisory Committee, Washington, DC	USEPA
2009	EPA Report	Risk and exposure assessment for review of secondary national ambient air quality standards for oxides of nitrogen and oxides of sulfur (Final report). U.S. Environmental Protection Agency, Washington, D.C., EPA-452/R-11-005a.	USEPA
2008	EPA Report	Integrated science assessment (ISA) for oxides of nitrogen and sulfur ecological criteria (Final report). U.S.Environmental Protection Agency, Washington, D.C., EPA/600/R-08/082F.	USEPA

Appendix E: 2012 Whiteface Cloud Summary Data

Whiteface 2012 Summary Data

A complete record of Whiteface Cloud data may be obtained at www.adirondacklakessurvey.org/ by selecting the Whiteface Info & Data menu tab.

Parameter	UNITS	COUNT	Min	Max	Mean	Std. Dev.
Cloud Samples		168				
Volume	mL	168	42.00	2994.00	821.55	740.28
LWC	g m ⁻³	166	-0.02	1.65	0.55	0.31
SO4	µeq L ⁻¹	168	1.02	995.36	99.17	145.26
NO3	µeq L ⁻¹	168	0.77	1142.23	64.52	142.58
Cl	µeq L ⁻¹	168	0.21	88.05	4.48	9.04
Ca	µeq L ⁻¹	162	-0.85	1485.45	35.24	145.95
Mg	µeq L ⁻¹	162	-0.01	127.35	7.11	15.11
Na	µeq L ⁻¹	161	-0.97	105.86	4.49	12.15
K	µeq L ⁻¹	161	-0.11	43.63	2.08	4.85
NH4	µeq L ⁻¹	168	-0.85	1390.53	109.81	188.25
TOC	µMoles L ⁻¹	130	11.71	2432.74	378.41	412.09
SCONDUCT	µS cm ⁻¹	139	1.90	318.40	33.01	43.14
LABpH		168	3.63	6.49	—	—
H⁺	µeq L ⁻¹	168	0.33	234.96	41.07	45.35

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