



Water Quality Monitoring at Saratoga National Historical Park

Northeast Temperate Network 2013 Summary Report

Natural Resource Data Series NPS/NETN/NRDS—2014/658



ON THE COVER

Kroma Kill, May 2013

Photograph by: Linda White

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

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Executive Summary

This report on the water quality of Saratoga National Historical Park (SARA) includes data gathered by the Northeast Temperate Network (NETN) in the 2013 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. The data address the NETN objective to detect change in the status of physical, chemical, or biological attributes of park freshwater bodies.

The NETN Freshwater Monitoring Protocol calls for a total of four park streams to be sampled monthly from May through October at SARA. Staff measured physical and in-situ water chemistry parameters each month and periodically collected water samples for analysis at the University of Maine's Sawyer Environmental Chemistry Research Laboratory.

Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, dissolved oxygen, and turbidity), weather, stream flow (discharge), and stream stage. In May and August, water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, nutrients, dissolved organic carbon (DOC), chloride, and sulfate.

Most water quality parameters for the monitored streams were within state standards, and were generally within the ranges of the historic NETN monitoring data from SARA. The exception was pH in Kroma Kill, which exceeded the state standard in October. Kroma Kill and the Mill Creek Confluence had high values for color, turbidity, TP, TN, and NO_3 . The pattern suggests impacts on the water quality due to agricultural activity in the watershed, and TP and TN values were well above the non-regulatory EPA criteria. The TN values were well above the 2.0 mg/L standard used in some other northeastern states (New York has no numeric TP standard). Other findings of note include high chloride values in Upper Mill Creek and more moderate values in Kroma Kill and the Mill Creek Confluence. The chloride levels are likely due to runoff from road deicing. In addition, the sulfate level in American's Creek was high, possibly due to natural sources. ANC measurements showed that all streams had sufficient buffering to avoid severely depressed pH values from spring snowmelt and runoff that can contribute acidity and sediment to the stream water.

Introduction

This report on the water quality of Saratoga National Historical Park (SARA) generated by the Northeast Temperate Network (NETN) Water Quality Monitoring Program includes data gathered in the 2013 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. Appendix A contains tabular data collected in 2013.

The vital signs for freshwater bodies included in the NETN Freshwater Monitoring Protocol (Lombard et al. 2006) are water chemistry, nutrient enrichment, water quantity, and the detection of invasive plant species. These metrics were chosen to address the NPS Inventory and Monitoring Program objective to detect change in the status of physical, chemical, or biological attributes of the ecosystem.

The NETN Freshwater Monitoring Protocol calls for a total of four park streams to be sampled monthly from May through October at SARA. A NETN hydrologic technician measured physical and in-situ water chemistry parameters each month and periodically collected water samples for analysis at the University of Maine's Sawyer Environmental Chemistry Research Laboratory. All monitoring data are incorporated into a series of comprehensive databases that ultimately feed the U.S. Environmental Protection Agency's "STORET" data system, the repository for all NPS water quality and quantity data.

Sampling Sites

There are 8 miles of perennial streams divided between four watersheds in SARA that all flow into the Hudson River (Figure 1). These watersheds are the Kroma Kill, Mill Creek, American's Creek and Great Falls Creek. In addition, the historic ruins of the old Champlain Canal cut across the downstream end of the major drainages of park, and water from the Hudson River can back up into the park. Since there are no major ponds or impoundments in Saratoga, NETN monitoring is designed to characterize only the streams in the park (Lombard et al 2006).

One monitoring site has been identified in each major watershed in the park where water quality samples can be taken and streamflow measured (Table 1). In addition, there are major tributaries in the Mill Creek watershed within park boundaries, and thus an additional site has been identified on the North Fork of Mill Creek. The three park streams monitored by NETN are considered warm water fisheries, capable of supporting bass, perch, sunfish, and similar species (Vana-Miller et al 2001). Kroma Kill (SARASA) is a third order stream in the park and is monitored upstream of the first bridge crossing along the Park Entrance Road from Route 4. The bridge provides an adequate staff gage site, a constricted area for hydraulic control, and a platform for sampling during high flows.

The sample site established for American's Creek (SARASB) is below Bemis Point at the end of the American River Fortifications. Here the stream flows through a narrow channel incised into bedrock. Flow proves difficult to measure in very dry years.

Mill Creek enters the Hudson River as a second order stream. The Upper Mill Creek site (SARASC) is located near where the stream enters the park, just downstream of the park tour road. The stream is very small at this location but appears to be perennial and the box culvert can be used for accurate discharge measurements when flows are elevated.

The Lower Mill Creek site (SARASD) is approximately 200 m downstream of the confluence of the North and South Forks (historic site SARA0053). This site provides an integrated sample for the watersheds of the North and South Forks. The South Fork can have low flow and would not be a reliable year-round sampling site that meets sampling site criteria.

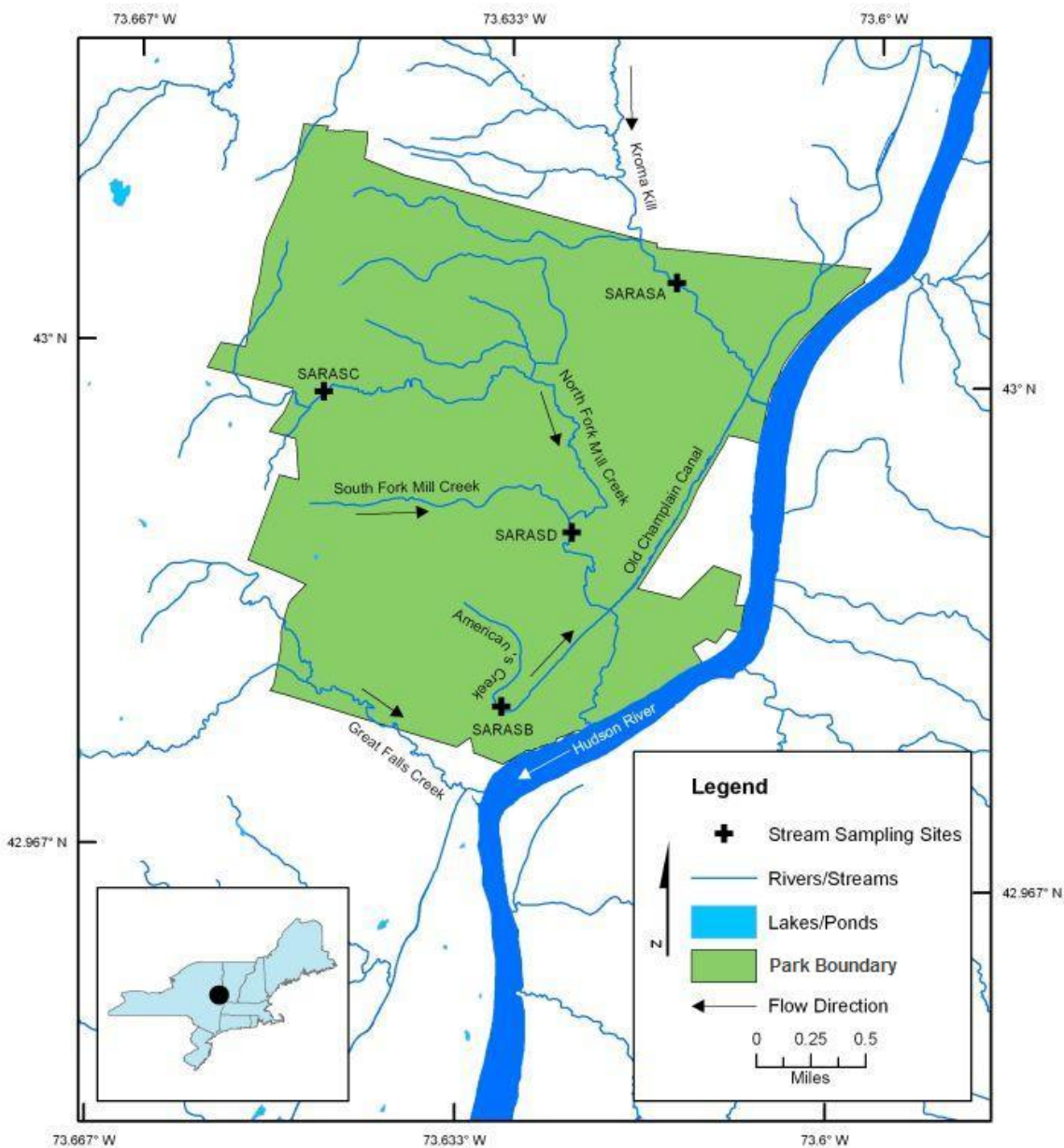


Figure 1. NETN water monitoring sites at Saratoga NHP.

Table 1. Water quality monitoring sites at Saratoga NHP.

Water Body	NETN Site Code	Latitude	Longitude
Kroma Kill (Stream A)	SARASA	43.0058333	-73.61730
American's Creek (Stream B)	SARASB	42.9771667	-73.63100
Upper Mill Creek (Stream C)	SARASC	42.9973833	-73.64855
Mill Creek Confluence (Stream D)	SARASD	42.9889500	-73.62555

Methods

Detailed descriptions of all monitoring methods are found in the original protocol (Lombard et al. 2006) and the most recent protocol update (Gawley et al. 2014). Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) determined with a YSI 600XL sonde, turbidity measured with a LaMotte 2020e meter, weather, stream flow (discharge), and stream stage (water level). In May and August, water samples were obtained and analyzed for acid neutralizing capacity (ANC), color, and nutrients. Beginning in 2012, fractions of these water samples were also analyzed for dissolved organic carbon (DOC), chloride, sulfate, and chlorophyll *a*. Nutrient chemistry parameters were analyzed from a grab sample obtained by submerging the sample bottle directly in the stream with a gloved hand.

Stream discharge was measured using U.S. Geological Survey protocols (Rantz et al 1982), employing a measuring tape, wading rod, and a SonTek FlowTracker current meter or a Price Pygmy current meter to measure a particular cross-sectional area of the stream and the velocity of the water at that cross section. Stream stage was measured by using a measuring tape or folding ruler to “tape down” or “tape up” from a fixed datum point to the surface of the water, or by reading the water level off of a staff gauge. Bolts were installed to permanently mark some of the datum points in July 2012. Staff gauges were installed at Upper Mill Creek in July 2013 and Kroma Kill in August 2013.

In-situ stream water chemical and physical measurements and water samples were collected within 5 meters from the location of the discharge measurement. Sonde measurements were taken in the main stream flow with care taken that the sonde was not resting directly on the stream bottom.

Water Quality Standards

New York’s Surface Water Quality Standards (New York State Department of Environmental Conservation 2008) designates Class AA as the most restrictive stream classification for water quality. The standard for color states there will be none that will “impair the waters for their best usages”. For phosphorus and nitrogen, there will be “none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.” pH “shall not be less than 6.5 nor more than 8.5,” color “shall not exceed 15 color units (platinum-cobalt method),” and turbidity “shall not exceed 5 nephelometric units” (New York State Department of Environmental Conservation 2008).

“For trout spawning waters (TS), the DO concentration shall not be less than 7.0 mg/L from other than natural conditions. For trout waters (T), the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L. For nontrout waters, the minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L” (New York State Department of Environmental Conservation 2008).

Table 2. New York stream water quality standards.

Water quality classification code	Max Temperature (°C)	Min Dissolved Oxygen (mg/L)	pH Range (standard units)	Max Total Nitrogen (µg/L)	Max Total Phosphorus (µg/L)	Color (color units, platinum-cobalt method)	Turbidity (NTU)	Sulfate (mg/L)
AA	--	4.0	6.5-8.5	No algae growth	No algae growth	--	--	--

EPA Ecoregion 7 water quality criteria (Table 2; U.S. Environmental Protection Agency 2000) are also used as a benchmark in this report. EPA water quality criteria for nutrients help translate narrative criteria within State or Tribal water quality standards by establishing values for causal variables (e.g., total nitrogen and total phosphorus) and response variables (e.g., turbidity and chlorophyll *a*). Causal variables are necessary to provide sufficient protection of designated uses before impairment occurs and to maintain downstream uses. Early response variables are necessary to provide warning signs of possible impairment and to integrate the effects of variable and potentially unmeasured nutrient loads (U.S. Environmental Protection Agency 2002).

Table 3. EPA Ecoregion 7 nutrient criteria for streams.

Nutrient Criteria	Value
Total Phosphorus	33 µg/L
Total Nitrogen	0.54 mg/L

These criteria were developed specifically for Ecoregion 7 (which includes both NETN parks in New York) and are designed to represent conditions of surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient over-enrichment from cultural eutrophication. The values are EPA's scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality. They do not have any regulatory impact or meaning.

The criteria were established based on the lower 25th percentile of streams for which the EPA found data. This percentile of all streams is expected to approximately correspond to the 75th percentile of reference (undisturbed) streams. In other words, 75% of streams in the ecoregion do not meet the criteria, nor do roughly 25% of reference streams. (U.S. Environmental Protection Agency 2000).

Results

Monitoring results for 2013 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2013 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2013 for the specified parameter and site (Appendix A contains all data in tabular form). A box plot (Figure 2) is a summary plot that graphs data as a box representing statistical values. The boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles respectively. Outliers are displayed as black filled circles. At least nine data points are required to compute the 5th, 10th, 90th and 95th percentiles. If a percentile point cannot be computed, that set of points is not drawn. If EPA or other water quality criteria exist for a particular parameter they are displayed on the graphs as specification lines.

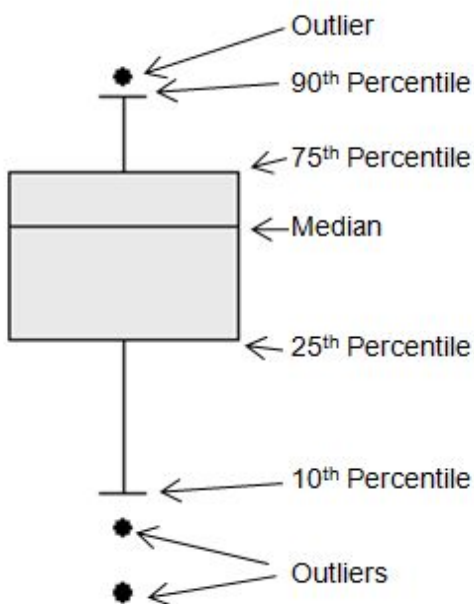


Figure 2. Explanation of box plot graph.

Water Quality

Measures of water quality include specific conductance, pH, water temperature, dissolved oxygen (DO), acid neutralizing capacity (ANC), and apparent color. Assessment of water quality data aids in the interpretation of the biotic condition and ecological processes of surface water resources.

Specific Conductance

Specific conductance (Figure 3) is a measure of the ability of water to carry an electrical current, and is directly related to the level of dissolved ions in the water. An increase in specific conductance can be an indicator of pollutants in the water. Naturally occurring values range from less than 20 to more than 1,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$). Specific conductance values from 2013 were within the appropriate range for high ionic strength waters, and were generally within the range of values shown on the box plots. The June values at American's Creek (Stream B) and Upper Mill Creek (Stream C) were the lowest values on record for each site.

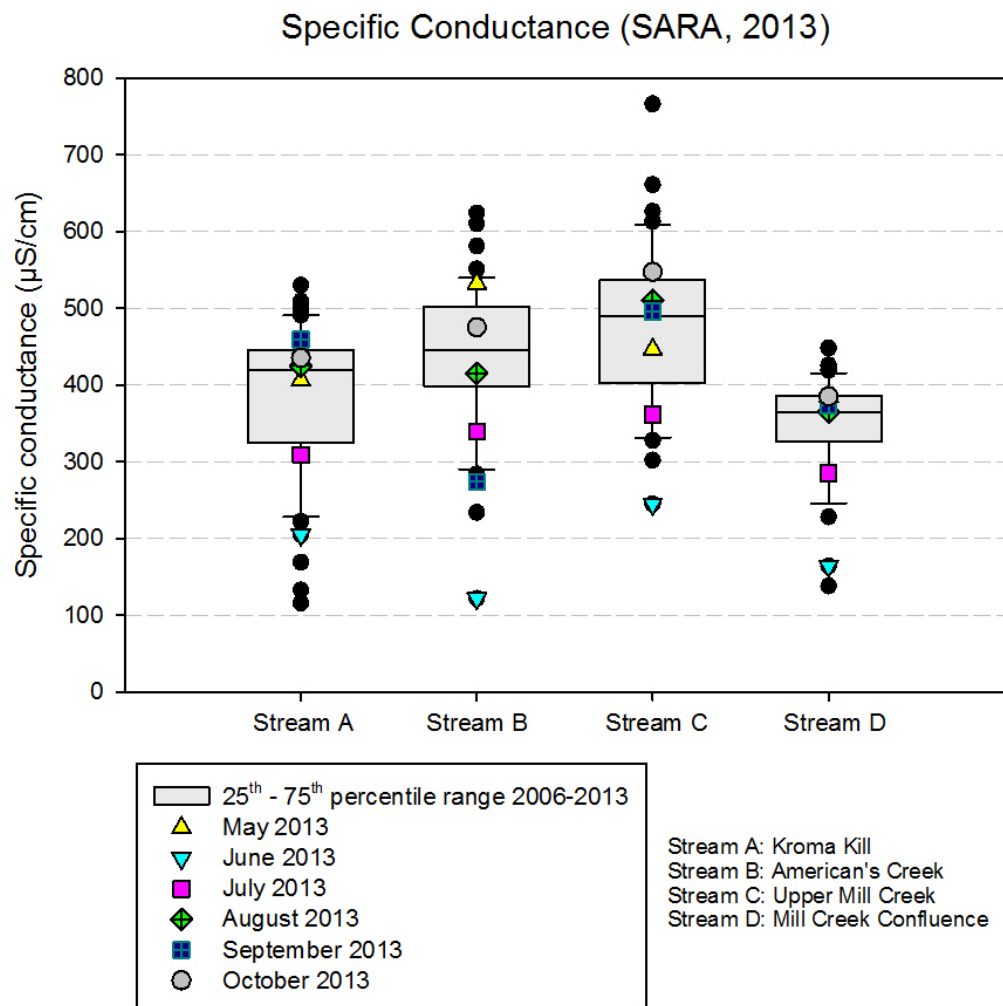


Figure 3. Specific conductance from 2013 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2013.

pH Level

The pH of a water body reflects how acidic or basic the water is, measured on a scale of 1 to 14, with 7 being neutral. Acid waters are below 7, and alkaline waters are above 7. A one unit change in pH represents a 10-fold change in acidity or alkalinity. New York standards, like those of most northeast states, indicate that a pH between 6.5 and 8.5 is within the acceptable range. pH values from the 2013 monitoring season (Figure 4) were basic, and were between the upper and lower New York water quality standards, with the exception of the October value at Kroma Kill (Stream A).

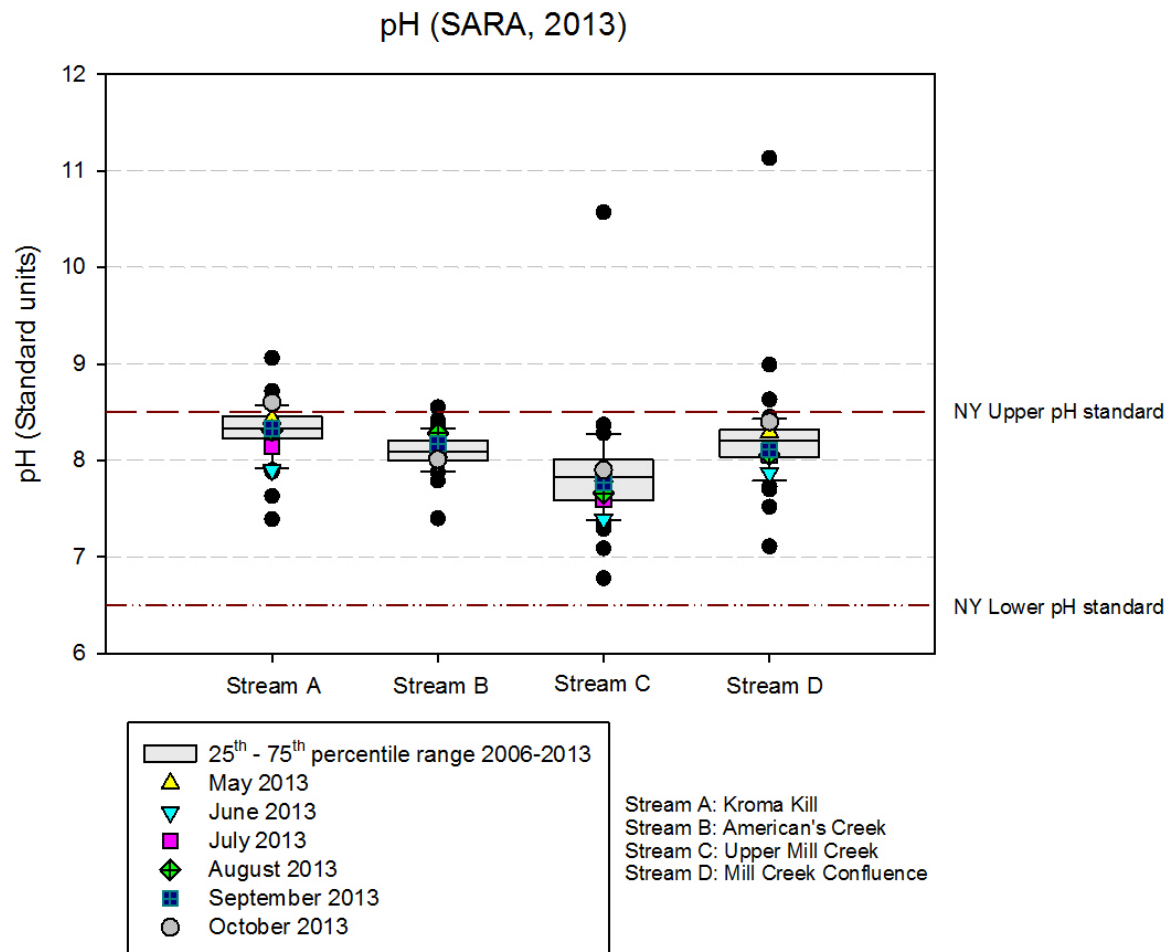


Figure 4. pH from 2013 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2013.

Temperature

Temperature can affect water chemistry and biology. For example, the amount of oxygen that water can hold is directly related to the temperature of the water. The higher the temperature, the less oxygen water can hold, which can be observed in both diel (day and night) and seasonal shifts. Oxygen will naturally decline during the summer months as water temperatures rise. Temperature can also determine the kinds of plants and animals found in the lake or pond. Certain species of fish, insects, and algae will predominate during the cooler temperatures of the spring and fall, yet be less apparent during the warmer temperatures of summer. The majority of the surface water temperatures (Figure 5) appeared to be within the normal range of variability in 2013, and as expected the coldest values were recorded in October and the warmest were recorded in July.

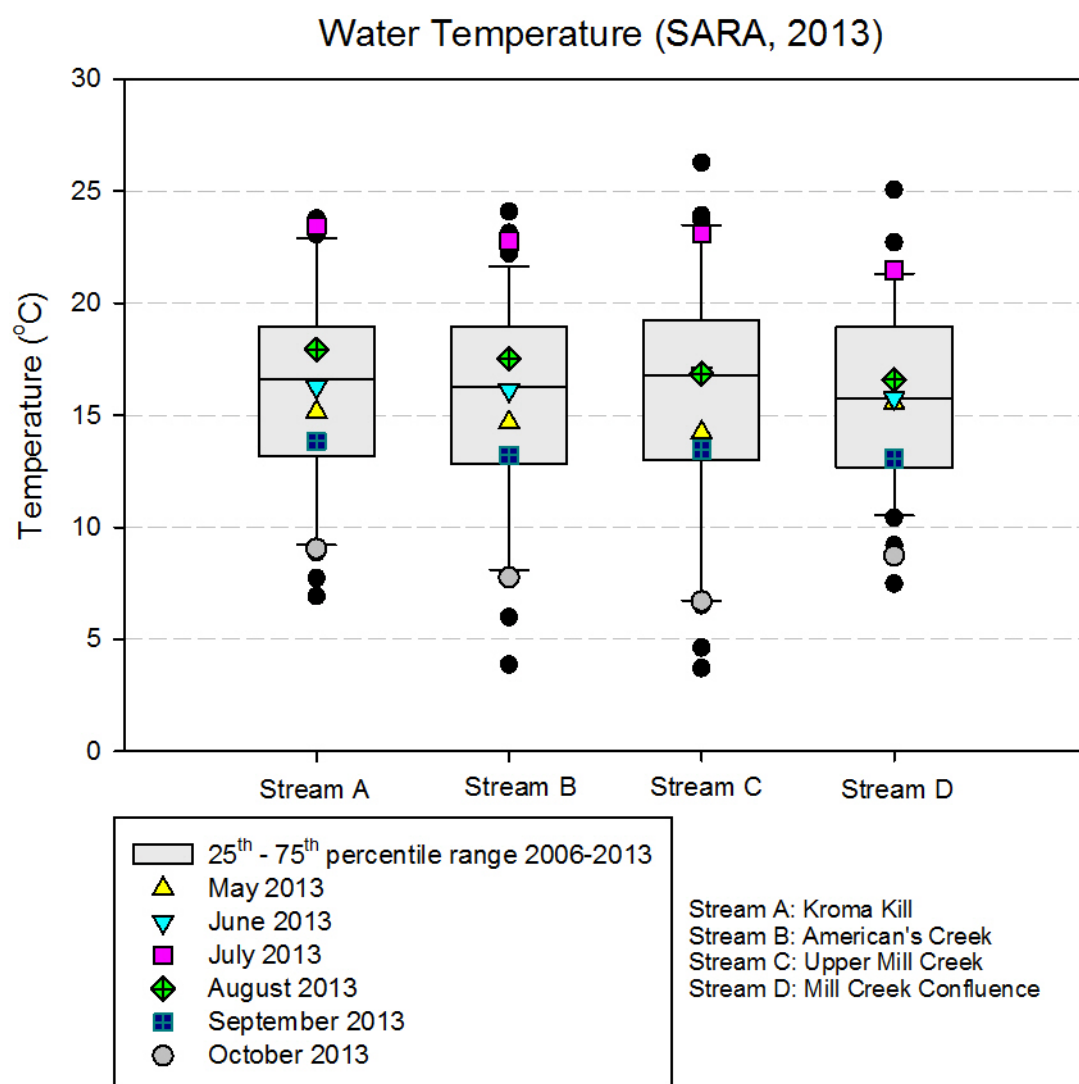


Figure 5. Water temperature (surface) from 2013 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2013.

Dissolved Oxygen

Dissolved oxygen (DO) is a critical indicator of water quality because aquatic life generally needs DO concentrations at or above 5 mg/L to thrive. Low oxygen can directly kill or stress organisms such that they will not be able to successfully reproduce or grow. Water with less than 1 part per million (ppm) of oxygen is considered anoxic (no oxygen present). All SARA sites were well oxygenated in 2013 (Figure 6), and above the 4 mg/L state DO standard.

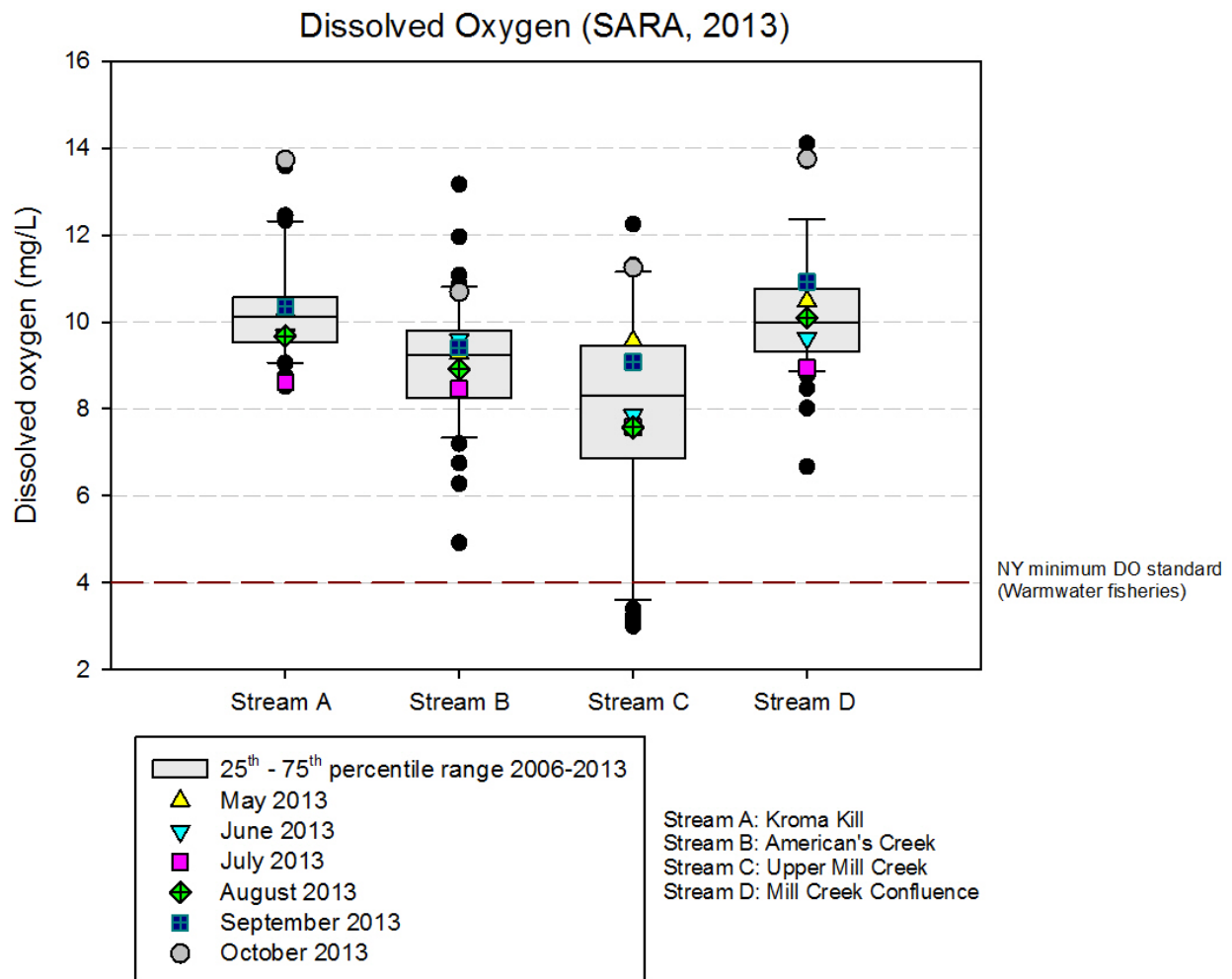


Figure 6. Dissolved oxygen (surface) from 2013 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2013.

Acid Neutralizing Capacity

Acid neutralizing capacity (ANC) is also known as alkalinity, or buffering capacity. It is due primarily to the presence of naturally available bicarbonate, carbonate, and hydroxide ions, with bicarbonate being the major form. Most states do not have numerical criteria for ANC in their water-quality standards. ANC values greater than 100 $\mu\text{eq/L}$ are considered well-buffered, while values less than zero typify acidic waters (Stoddard et al. 2003). Acid neutralizing capacity measured in the 2013 samples (Figure 7) illustrates that SARA streams were extremely well-buffered, likely due to the underlying geology. The SARA streams did not follow the typical pattern of lower May (Spring) ANC values. This pattern usually occurs due to episodic acidification from spring snowmelt and runoff.

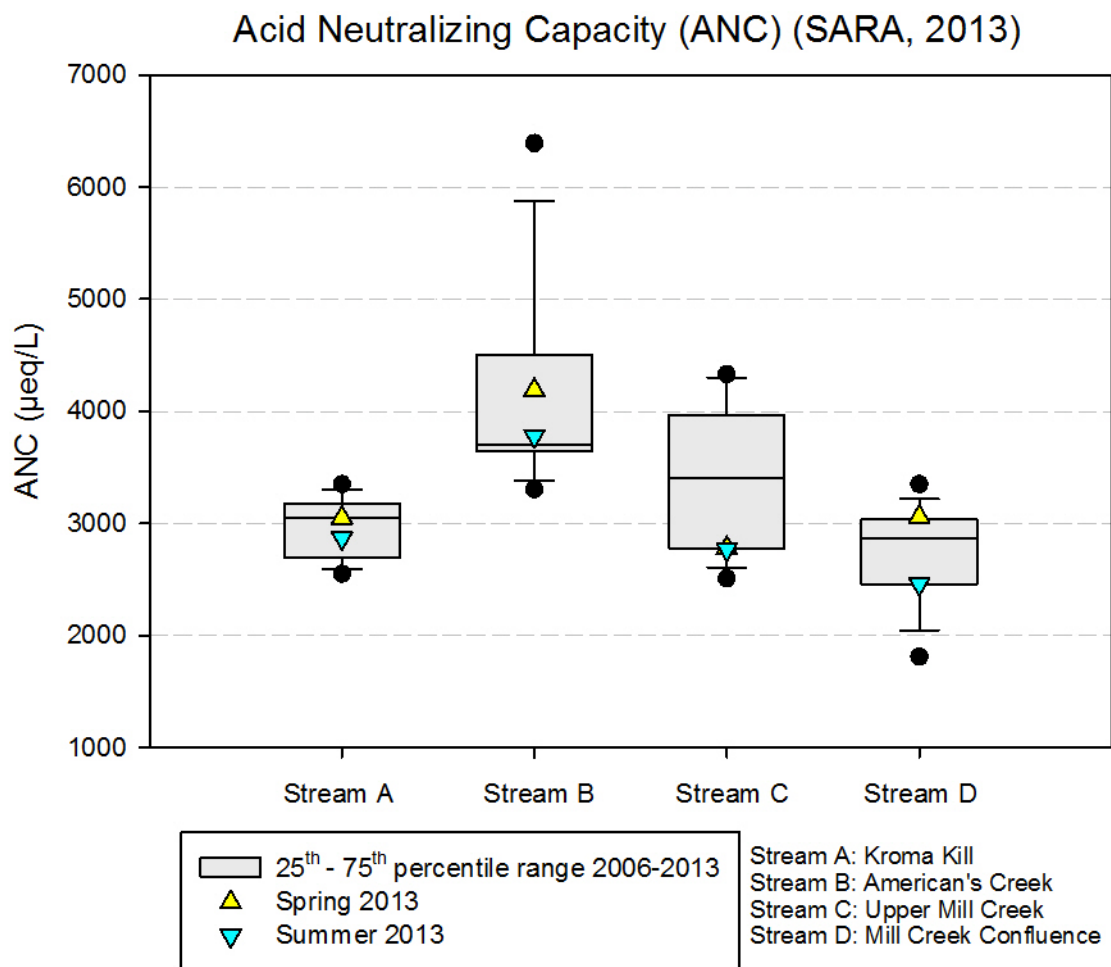


Figure 7. Acid neutralizing capacity from 2013 water samples overlaid on a box plot of measurements taken from 2006-2013.

Apparent Color

Color in pond and stream water is caused by natural metallic ions, humus and peat materials, plankton, weeds, and industrial wastes. Color is reported in Pt-Co units (PCU). True color is the color measurement of water from which suspended particles have been removed by filtration. Apparent color (the measurement method utilized by NETN) is determined on original samples without filtration. Color can be a rough indicator for organic acidity.

Water bodies with apparent color values of greater than 25 PCU are considered to be highly colored, and often exhibit reduced water clarity and high phosphorus concentrations. Values of color are usually not included in water quality standards, except to note that they should be “as naturally occurs”.

Most of the color measurements from 2013 monitoring were near or above median color values displayed on the boxplot (Figure 8), and show SARA streams to be highly colored. Summer color values for Kroma Kill and the Mill Creek Confluence were among the highest recorded for each site, and may reflect contributions from agricultural activity in the watersheds. Much of the color is likely due to runoff and sediment input to the streams, rather than dissolved constituents, since the samples were not filtered before analysis.

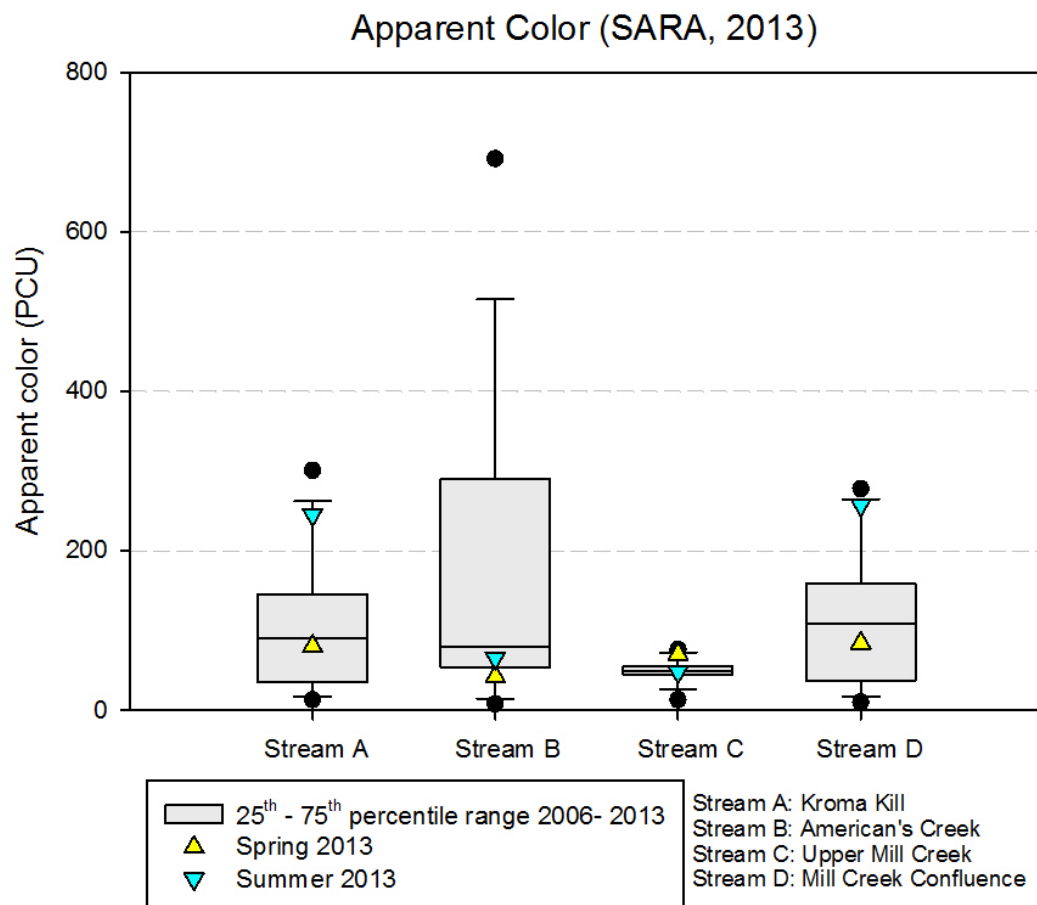


Figure 8. Apparent color from 2013 water samples overlaid on a box plot of measurements taken from 2006-2013.

Dissolved Organic Carbon

NETN began measuring dissolved organic carbon in 2012. Carbon is a nutrient required for biological processes. Sources of organic carbon in water include humic substances from plant and soil organic matter, wetland peat deposits, and atmospheric deposition. Certain forms of DOC can contribute to “tea” color in water, which can affect light attenuation. DOC is also an important part of the energy balance and acid-base chemistry in many freshwater systems. It also affects the transport (solubility and bioavailability) of metals, including mercury, in aquatic systems.

DOC concentrations in most streams in temperate zones range from 1 mg/L to 20 mg/L, with a worldwide mean of 5.75 mg/L (Meybeck 1982). SARA DOC concentrations (Figure 9) were moderate in 2013.

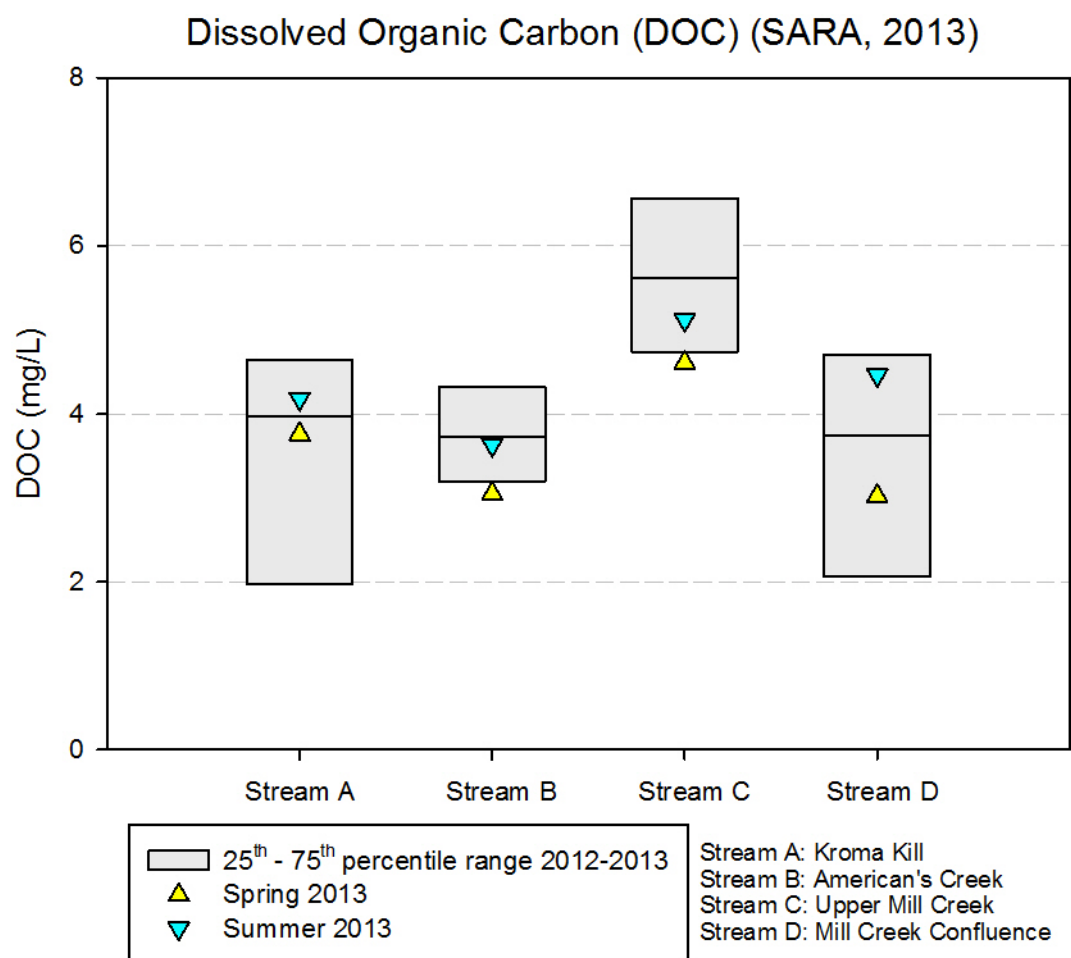


Figure 9. Dissolved organic carbon (DOC) from 2013 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2013.

Turbidity

Turbidity is the measure of the relative clarity of a liquid. It is measured by passing light through a water sample to determine how much light is scattered, and the results are reported in nephelometric turbidity units (NTU). Turbidity is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. In natural waters, turbidity is often used as an indicator of water quality and productivity. Turbidity is measured in the field using an electronic meter.

Turbidity in the water can create aesthetic, ecological, and health issues. Turbid water may indicate runoff from construction, roads, agriculture or other types of pollution. Suspended sediment can carry nutrients and pesticides throughout the water system. Suspended particles near the surface absorb additional heat from sunlight, raising the water temperature. High turbidity levels can reduce the amount of light reaching lower depths of lakes and streams, which can inhibit growth of submerged aquatic plants, and reduce dissolved oxygen levels. Suspended materials can clog fish gills, affecting fitness, growth, and reproduction (U.S. Environmental Protection Agency 1997). A number of the turbidity values measured in SARA streams during 2013 (Figure 10), the second year of NETN turbidity testing, were greater than the expected range of dry-weather turbidity of surface

waters, which normally ranges from 0 to 10 NTU (U.S. Environmental Protection Agency 1999). Occasional higher values at Kroma Kill, American's Creek, and the Mill Creek Confluence may be attributed to runoff from precipitation events prior to sampling. However, consistently high values at sites at Kroma Kill and the Mill Creek Confluence may also reflect agricultural activity in the watersheds. June values for Kroma Kill and American's Creek were eliminated due to a rain event leading to turbidity values outside of the range of the turbidity meter.

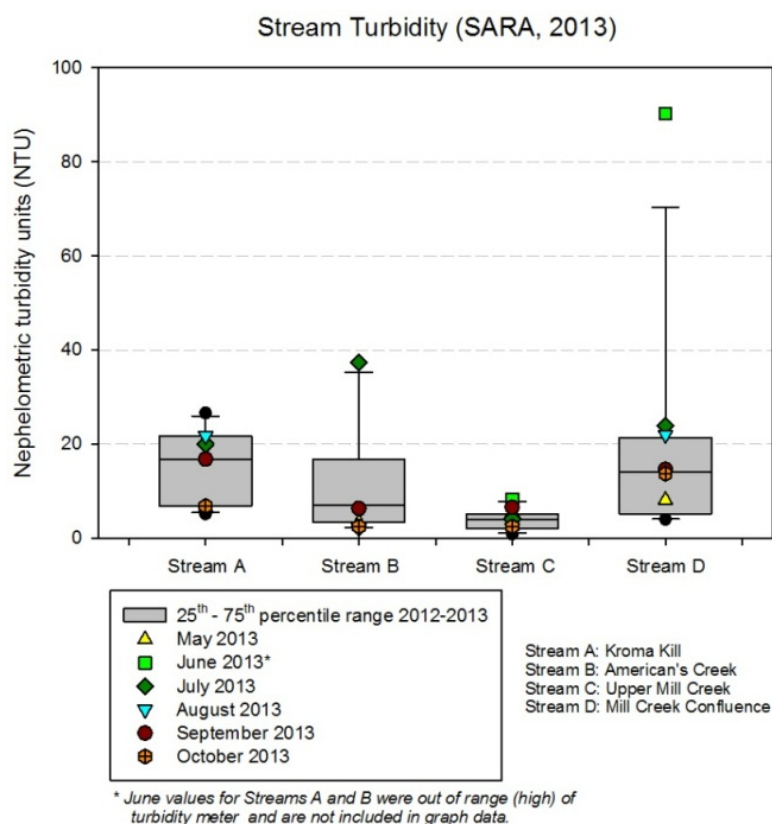


Figure 10. Stream turbidity from 2013 monthly measurements. The data are overlaid on a box plot of measurements taken in 2012-2013.

Nutrient Enrichment

Nutrient enrichment and the acceleration of eutrophication have been identified in most NETN parks as one of the stressors of greatest concern. Total phosphorus and several forms of nitrogen are measured to give managers information regarding the trophic status and productivity of freshwater systems.

Phosphorus

Phosphorus (P) is one of the major nutrients needed for plant growth. It is generally present in small amounts in natural systems and limits the plant growth in streams and ponds. Total phosphorus (TP) is a measure of both inorganic and organic forms of phosphorus, and is the common water quality standard or criteria metric. Although several forms of phosphorus were tested individually since 2006, tests for total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) were discontinued in 2012.

In 2013 all total phosphorus concentrations (Figure 11) were moderately high. Most of the measurements were below the EPA Ecoregion 7 criterion of 33 $\mu\text{g/L}$ and two measurements (one from Kroma Kill and one from Mill Creek Confluence) were above the criterion. As described above (“Water Quality Standards”), the EPA criteria do not have any regulatory meaning.

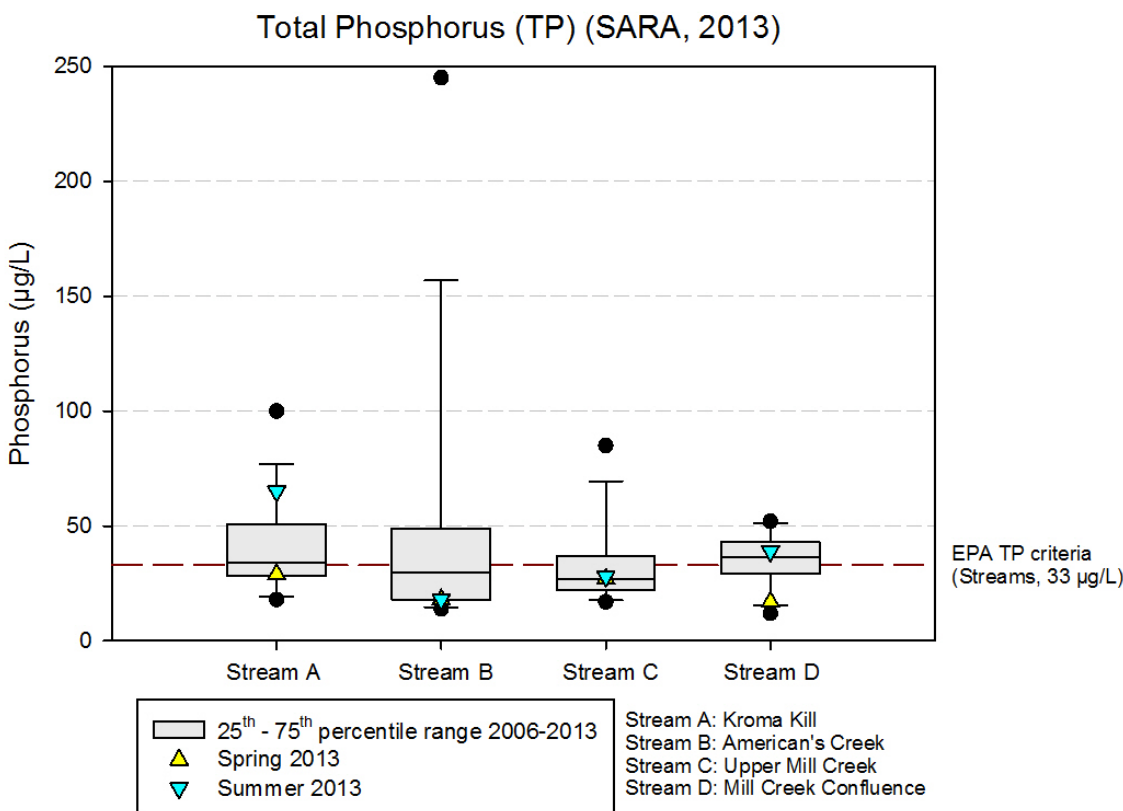


Figure 11. Total phosphorus (TP) from spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2013.

Nitrogen

Total nitrogen (TN) is a measure of all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in marine waters, and it can also limit some freshwater systems. The importance of nitrogen in the aquatic environment varies according to the relative amounts of the forms of nitrogen present, including nitrate, nitrite, and ammonia. Nitrate (NO_3) is the most oxidized and stable form of nitrogen in a water body, and is the primary form of nitrogen used by plants as a nutrient. Nitrite (NO_2) is an unstable form of nitrogen that is either rapidly oxidized to nitrate (nitrification) or reduced to nitrogen gas (de-nitrification). This form of nitrogen can also be used as a source of nutrients for plants. Ammonia (NH_3) is generated by bacteria as a decomposition product of nitrogenous organic compounds, and is also readily assimilated by plants. Results of NO_3 , NO_2 , and NH_3 tests are all reported as the concentrations of the N component of these compounds, expressed in mg/L.

Test results for several forms of nitrogen are shown in Figure 12. TN values for Kroma Kill and the Mill Creek Confluence were high and exceeded the EPA Region 7 criterion of 0.54 mg/L, although as with TP this criterion does not have regulatory meaning. NO_3 results from these sites were also extremely high, suggesting effects from agricultural activities in the watersheds. TN measurements at these sites were above 2.0 mg/L, the value used as a TN standard in several northeast states (New York has no numeric TN standard). Nitrite test results in all streams were low, and all of the 2013 ammonia test results were below the method reporting limit of 0.08 mg/L.

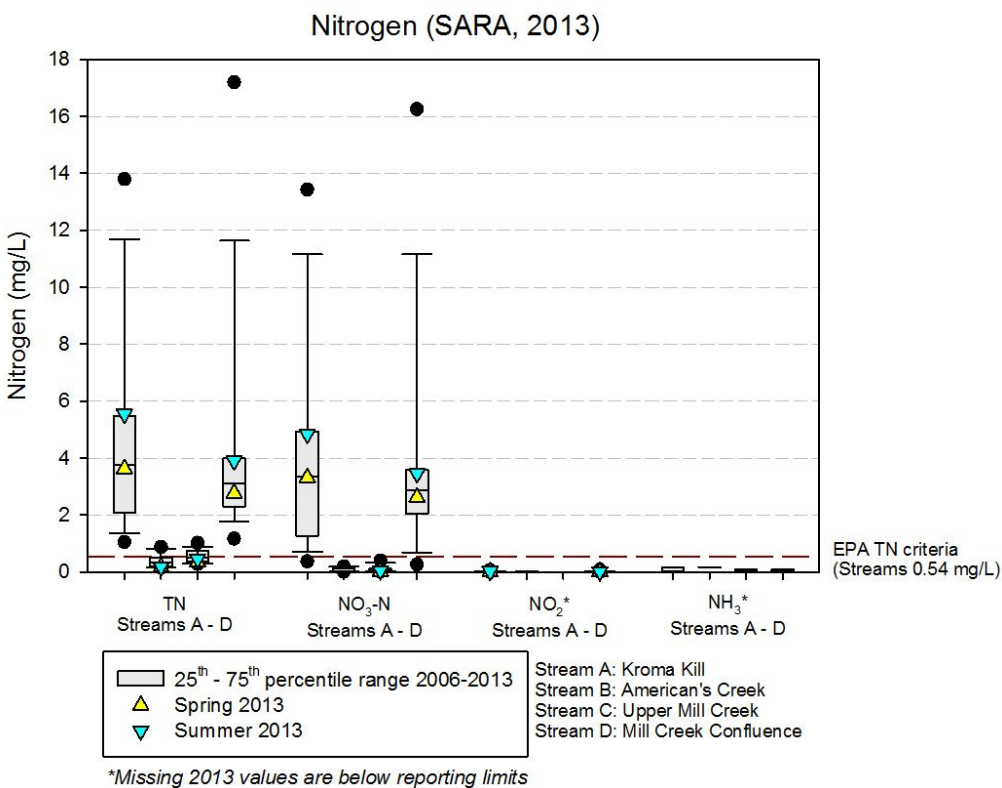


Figure 12. Total nitrogen (TN), nitrate ($\text{NO}_3\text{-N}$), nitrite (NO_2) and ammonia (NH_3) from 2013 water samples. The data are overlaid on a box plot of measurements taken from 2006-2013.

Other Analytes

Chloride

Chloride is one of the major negatively-charged ions in fresh water systems. The chloride content of natural surface waters will depend to a great extent on the geology of the area. Concentrations are generally greater in lakes that are in proximity to marine regions. Another source of chloride is road run-off from de-icing materials. Chloride is important in terms of metabolic processes, as it influences osmotic salinity balance and ion exchange.

Average chloride concentration in natural fresh water is 234.1 μ eq/L (Wetzel 1983). Chloride values in SARA samples were moderately high in 2013, with the exception of low values at American's Creek (Stream B) and high values at Upper Mill Creek (Stream C) (Figure 13).

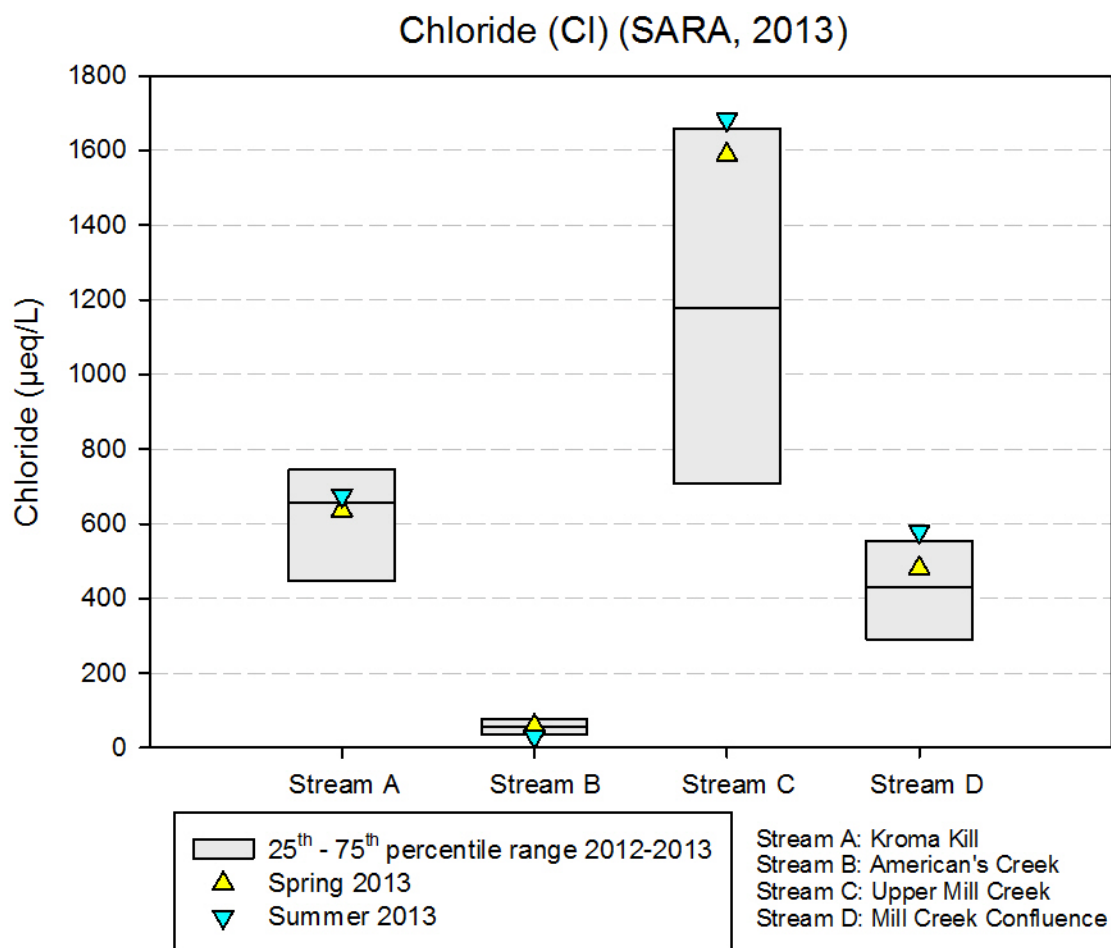


Figure 13. Chloride from 2013 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2013.

Sulfate

Sulfate is found in most natural waters, originating from watershed geology and soils, and also from atmospheric transport and deposition (in precipitation) of by-products from the combustion of fossil fuels. Sulfate can play a major role in acidification of lakes and streams. Sulfate concentrations in atmospheric deposition have declined significantly since 1982, in part due to the 1995 implementation of Phase I controls of the Clean Air Act Amendments and in part to other long-term pollution reduction efforts (Kahl 1999).

The usual range of sulfate concentration in natural water is 104 $\mu\text{eq/L}$ to 695 $\mu\text{eq/L}$ (Wetzel 1983). Sulfate concentrations at SARA were moderate in most sites and very high in American's Creek in 2013 (Figure 14).

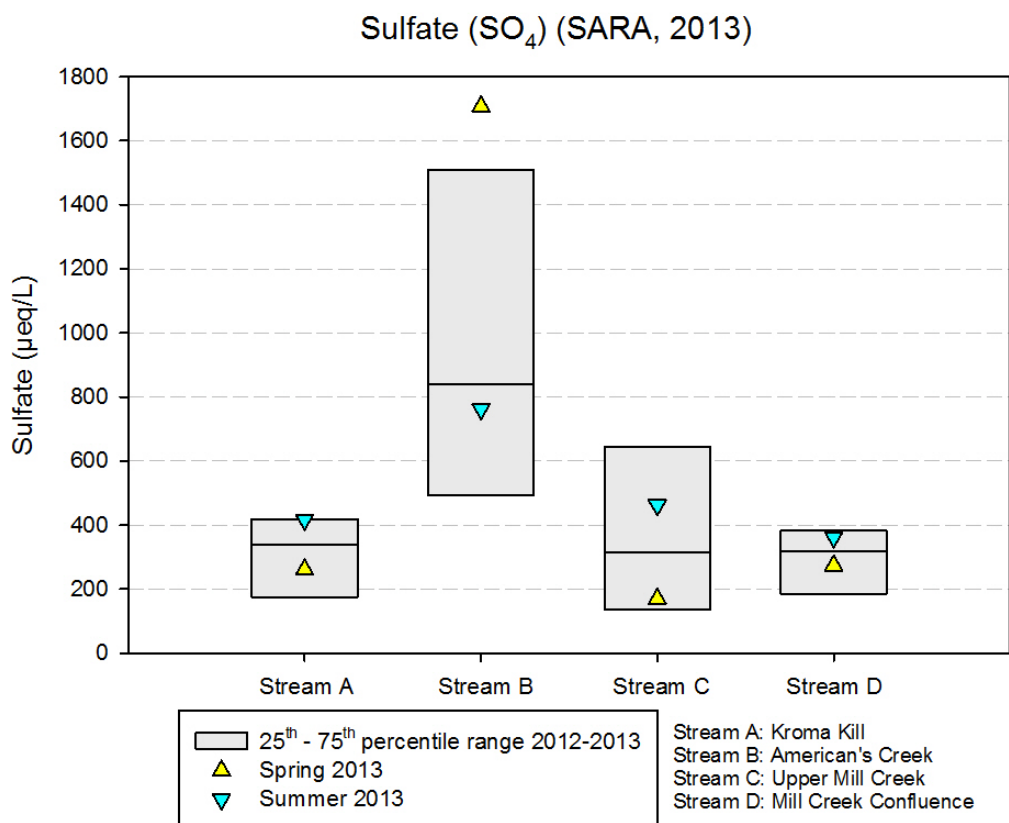


Figure 14. Sulfate from 2013 spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2012-2013.

Water Quantity

Monthly stream discharge measurements, taken with a current meter and wading rod, can be used to calculate loading of nutrient chemical constituents (flow times concentration), and also provide a record of variations in stream flow. Stream stage (height of water) measurements can be paired with discharge values and over time a stage to discharge relationship can be calculated. Once this relationship is established, investigators can interpolate the stream discharge from the stage measurement alone. Numerous discharge measurements at all ranges of streamflow are required to establish and maintain an accurate stage to discharge relationship. Stream stage measurements from 2013 are graphed in Figure 15. Discharge and stage measurements from 2013 are listed in Table A3 in Appendix A.

Stage measurements were consistent during the 2013 season. Higher stage measurements in June and July indicate rain events. NETN staff are currently reviewing discharge and stage measurement methodology and quality assurance/quality control procedures in order to enhance the quality and utility of the water quantity data. A stage to discharge relationship graph will be produced once sufficient data are collected.

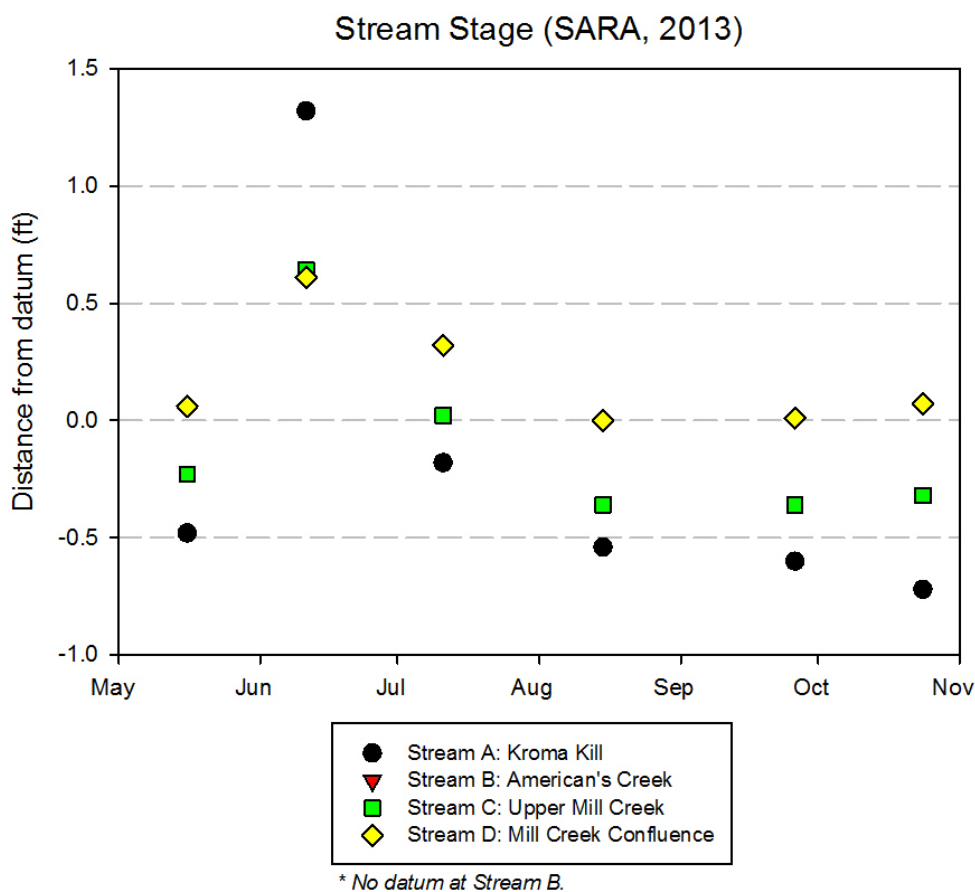


Figure 15. Stream stage obtained in 2013 by measuring from a permanent datum point to the water surface.

Invasive Aquatic Plants

Invasive aquatic plant monitoring was not conducted at SARA during the 2013 monitoring season, since the protocol specifies that targeted invasive aquatic plant monitoring is only conducted at pond and lake sites. However, during future visits to all NETN parks, monitoring crews will be increasingly attentive for the presence of Didymo (*Didymosphenia geminata*), also known as “rock snot,” a highly invasive algae species that has recently invaded the northern reaches of the Connecticut River in New Hampshire and the White River and Battenkill Rivers in Vermont. This species has a great potential to alter habitats and displace native species, and is of great concern to officials in regions where infestations have been established.

Didymo can easily be spread by waders and potentially by water monitoring equipment and other gear that touches the bottoms of streams in infested areas. Just one cell breaking off and drifting downstream can spread the algae. Enhanced equipment cleaning and decontamination procedures are being included in the latest NETN monitoring protocol revision (Gawley et al. 2014).

Since non-native, invasive plants have recently been detected with increasing frequency in Northeastern lakes and ponds, it has become crucial to closely monitor the status of park waters. The early detection of an infestation can make eradication or control more feasible, and it can lead to efforts that reduce the spread of the plant to neighboring water bodies. Designating the early detection of these plants as a NETN vital sign and the ongoing partnership with state and local monitoring and eradication efforts are highly effective prevention strategies.

Quality Assurance and Quality Control (QA/QC)

QA/QC is important to the success of a long-term data collection and trend detection program. Quality assurance (QA) is achieved through the establishment and use of the NETN Freshwater Monitoring Protocol. Specific procedures are used to control critical components of a project such as sampling at the right place with the right equipment and using the right methods. Over the years, staff will change, equipment may be updated, and methods may evolve. Although these changes will be kept to a minimum, changes are inevitable and therefore following an established and well-documented protocol will ensure that the data remain valid.

QA requirements incorporated in the protocol include consistency and low turnover in project leaders and staff, consistency in staff training and oversight, consistency in equipment used and calibration methods, the selection of a well-established chemical laboratory with a proven track record, and a robust sample design that includes an adequate number of field and laboratory quality control (QC) samples.

QC includes the assessment of bias and variability through the use of additional samples such as blank and replicate samples. QC samples are an objective assessment of whether or not QA protocols are adequate. The protocol calls for the collection of two blank and two replicate samples (one each from lakes/ponds and streams, respectively) during both the spring and summer nutrient sampling months at Acadia NP, and the same number, distribution, and schedule at the combined eight “Lower NETN” parks. Sample collection sites are selected at random from both monitoring groups.

The latest (2014) protocol revision requires in situ measurements, including Secchi transparency, sonde water quality, and stream discharge, to be periodically replicated to ensure that field equipment and observers are performing within the required precision standards. Water quality sonde temperature, pH and specific conductance measurements are to be compared monthly in the laboratory with similar measurements made with a NIST-traceable thermometer and benchtop pH and conductivity meters. Sonde dissolved oxygen measurements will be compared in the field to measurements made using a LaMotte dissolved oxygen test kit (Winkler titration method). These additional procedures will begin network-wide in the 2014 monitoring season.

Nutrient QC Sample Results

Analysis results of all 2013 blank samples collected from Lower NETN ponds and streams (Appendix B, Table B1) were below the method reporting limits, indicating little or no contamination was introduced during the sampling, handling and analysis processes. Replicate sample analysis results (Appendix B, Table B2) showed that most Lower NETN samples were in the acceptable range of precision (relative percent difference $\leq 10\%$). The replicate pair from SAIRSB (Turning Basin at Saugus Iron Works NHS) was the notable exception to this statement. There is a significant tidal influence on Turning Basin water quality, and the highly elevated chloride and sulfate concentrations in the replicate sample suggest that this sample was collected after the (flood) tide change.

Summary

Most water quality parameters for the monitored streams were within state standards, and were generally within the ranges of the historic NETN monitoring data from SARA. The exception was pH in Kroma Kill, which exceeded the state standard in October. Kroma Kill and the Mill Creek Confluence had high values for color, turbidity, TP, TN, and NO₃. The pattern suggests impacts on the water quality due to agricultural activity in the watershed, and TP and TN values were well above the non-regulatory EPA criteria. The TN values were well above the 2.0 mg/L standard used in some other northeastern states (New York has no numeric TP standard). Other findings of note include high chloride values in Upper Mill Creek and more moderate values in Kroma Kill and the Mill Creek Confluence. The chloride levels are likely due to runoff from road deicing. In addition, the sulfate level in American's Creek was high, possibly due to natural sources. ANC measurements showed that all streams had sufficient buffering to avoid severely depressed pH values from spring snowmelt and runoff that can contribute acidity and sediment to the stream water.

Monitoring under the NETN protocol builds on the historic water quality monitoring by the National Park Service and other agencies to provide critical baseline information on the chemical and physical status of the streams monitored in Saratoga National Historical Park. Several changes implemented in the 2012 monitoring season, including the addition of sulfate, chloride, and dissolved organic carbon (DOC) analyses to the spring and summer water chemistry testing, are helping to expand the scope and usefulness of the monitoring data. As more data are collected, the ability to detect changes outside this natural range of variability will increase, which in turn will more clearly indicate the status of the vital signs of water quality, nutrient enrichment, water quantity, and the detection of invasive plant species.

Literature Cited

- Gawley, W. G., B. R. Mitchell, and E. A. Arsenault. 2014. Northeast Temperate Network lakes, ponds, and streams monitoring protocol. 2014 Revision. Natural Resource Report NPS/NETN/NRR—2014/XXX. National Park Service, Fort Collins, Colorado.
- Kahl, S. 1999. Responses of Maine surface waters to the Clean Air Act Amendments of 1990. EPA CX826563-01-0. Published Report-602094.
- Lombard, P., W. Gawley, J. Caldwell. 2006. Freshwater Vital-Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN) PHASE III: Water-Quality Monitoring Protocols in Lakes, Ponds and Streams. USGS, Augusta, Maine, 222 p.
- Meybeck, M. 1982. Carbon, nitrogen, and phosphorus transport by world rivers. *American Journal of Science*, Vol. 282, April 1982, p. 401-450.
- New York State Department of Environmental Conservation. 2008. Surface water and groundwater quality standards and groundwater effluent limitations. <http://www.dec.ny.gov/regs/4590.html>, link checked on 13 December 2013.
- Rantz, S.E., et al. 1982. Measurements and computation of streamflow, volumes 1 and 2: U.S. Geological Survey Water-Supply Paper 2175: 631 p.
- Stoddard, J., J. S. Kahl, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. Murdoch, J. Webb, and K. Webster. 2003. Response of surface-water chemistry to the Clean Air Act Amendments of 1990. U.S. Environmental Protection Agency USEPA/620/R-03/001, Washington, DC, 78 p.
- Vana-Miller, D., C. Martin, L. White. 2001. Water resources management plan : Saratoga National Historical Park, New York. National Park Service, Saratoga National Historical Park. New York. Published Report-657177.
- U.S. Environmental Protection Agency. 1997. Volunteer stream monitoring: a methods manual. EPA 841-B-97-003, November 1997.
- U.S. Environmental Protection Agency. 1999. Guidance Manual for Compliance with the Interim Enhanced Surface Water Treatment Rule: Turbidity Provisions. EPA 815-R-99-010, April 1999.
- U.S. Environmental Protection Agency. 2000. Nutrient Criteria Technical Guidance Manual, Rivers and Streams. First Edition. EPA-822-B00-002, July 2000.
- U.S. Environmental Protection Agency. 2002. Ecoregional nutrient criteria. U.S. Environmental Protection Agency Fact Sheet USEPA-822-F-02-008, October 2002.
- Wetzel, R. G. 1983. *Limnology*: New York, Saunders Publishing Company.

Appendix A. Saratoga National Historical Park (SARA) Water Monitoring Data, 2013.

Table A1. YSI sonde in-situ stream water quality measurements collected at SARA.

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	Specific Conductance (μS/cm)
Kroma Kill (Stream A)	5/16/2013	0.21	15.15	10.27	8.43	406
Kroma Kill (Stream A)	6/11/2013	0.43	16.26	9.69	7.90	205
Kroma Kill (Stream A)	7/11/2013	0.42	23.44	8.61	8.14	309
Kroma Kill (Stream A)	8/15/2013	0.14	17.93	9.67	8.31	425
Kroma Kill (Stream A)	9/26/2013	0.38	13.84	10.35	8.33	459
Kroma Kill (Stream A)	10/24/2013	0.43	9.05	13.73	8.60	435
American's Creek (Stream B)	5/16/2013	0.07	14.67	9.28	8.09	532
American's Creek (Stream B)	6/11/2013	0.20	16.12	9.59	7.98	122
American's Creek (Stream B)	7/11/2013	0.35	22.77	8.46	8.06	339
American's Creek (Stream B)	8/15/2013	0.16	17.52	8.91	8.28	415
American's Creek (Stream B)	9/26/2013	0.28	13.21	9.41	8.17	274
American's Creek (Stream B)	10/24/2013	0.52	7.76	10.69	8.01	475
Upper Mill Creek (Stream C)	5/16/2013	0.08	14.22	9.56	7.84	446
Upper Mill Creek (Stream C)	6/11/2013	0.34	16.86	7.85	7.39	245
Upper Mill Creek (Stream C)	7/11/2013	0.46	23.10	7.58	7.59	361
Upper Mill Creek (Stream C)	8/15/2013	0.20	16.85	7.57	7.66	510
Upper Mill Creek (Stream C)	9/26/2013	0.20	13.45	9.08	7.77	496
Upper Mill Creek (Stream C)	10/24/2013	0.48	6.70	11.25	7.90	547
Mill Creek Confluence (Stream D)	5/16/2013	0.10	15.54	10.48	8.29	385
Mill Creek Confluence (Stream D)	6/11/2013	0.04	15.76	9.62	7.87	164
Mill Creek Confluence (Stream D)	7/11/2013	0.44	21.46	8.94	8.05	285
Mill Creek Confluence (Stream D)	8/15/2013	0.11	16.58	10.09	8.06	365
Mill Creek Confluence (Stream D)	9/26/2013	0.33	13.07	10.92	8.11	373
Mill Creek Confluence (Stream D)	10/24/2013	0.44	8.74	13.76	8.40	385

Appendix A. Saratoga National Historical Park (SARA) Water Monitoring Data, 2013 (continued).

Table A2. Laboratory nutrient chemistry data for SARA. “<MRL” indicates the result was below the method reporting limit (0.005 for NO₂, and 0.08 for NH₃). *Missing values indicate data are unavailable.*

Site	Date	ANC (µeq/L)	A Color (PCU)	DOC (mg/L)	TP (µg/L)	TN (mg/L)	NO ₃ (µeq/L)	NO ₃ -N (mg/L Calc)	NO ₂ (mg/L)	NH ₃ (mg/L)	Cl (µeq/L)	SO ₄ (µeq/L)
Kroma Kill (Stream A)	5/16/2013	3,050	80	3.76	29	3.63	235	3.314	0.0079	<MRL	636	261
Kroma Kill (Stream A)	8/15/2013	2,870	245	4.18	65	5.54	343	4.836	0.018	<MRL	676	417
American's Creek (Stream B)	5/16/2013	4,190	42	3.05	18	0.169	<MRL 1	<MRL	<MRL	<MRL	59	1,707
American's Creek (Stream B)	8/15/2013	3,780	65	3.63	18	0.185	<MRL 1	<MRL	<MRL	<MRL	30	762
Upper Mill Creek (Stream C)	5/16/2013	2,780	70	4.61	27	0.356	1.1	0.016	<MRL	<MRL	1,589	170
Upper Mill Creek (Stream C)	8/15/2013	2,770	48	5.12	28	0.458	3.3	0.047	<MRL	<MRL	1,683	462
Mill Creek Confluence (Stream D)	5/16/2013	3,060	84	3.02	17	2.77	186	2.623	0.0056	<MRL	481	274
Mill Creek Confluence (Stream D)	8/15/2013	2,460	257	4.46	39	3.9	245	3.455	0.013	<MRL	580	362

Appendix A. Saratoga National Historical Park (SARA) Water Monitoring Data, 2013 (continued).

Table A3. Stream stage and discharge data for SARA. *Missing values indicate data are unavailable.*

Site	Date	Datum name	Distance from datum (ft)	Total CS area (sqft)	Average velocity (f/s)	Discharge (cfs)
Kroma Kill (Stream A)	5/16/2013	Bolt1	-0.48	8.88	0.23	2.04
Kroma Kill (Stream A)	5/16/2013	Bolt2	-0.68	8.88	0.23	2.04
Kroma Kill (Stream A)	6/11/2013	Bolt3	-0.30			
Kroma Kill (Stream A)	6/11/2013	Bolt3	-0.30			
Kroma Kill (Stream A)	7/11/2013	Bolt1	-0.18	9.81	0.72	7.06
Kroma Kill (Stream A)	7/11/2013	Bolt2	-0.22	9.81	0.72	7.06
Kroma Kill (Stream A)	8/15/2013	Bolt1	-0.54	8.49	0.21	1.78
Kroma Kill (Stream A)	8/15/2013	Bolt2	-0.60	8.49	0.21	1.78
Kroma Kill (Stream A)	8/15/2013	SG1	0.30	8.49	0.21	1.78
Kroma Kill (Stream A)	9/26/2013	SG1	0.28	7.54	0.16	1.23
Kroma Kill (Stream A)	9/26/2013	Bolt1	-0.60	7.54	0.16	1.23
Kroma Kill (Stream A)	9/26/2013	Bolt2	-0.70	7.54	0.16	1.23
Kroma Kill (Stream A)	9/26/2013	SG1	0.28	7.54	0.16	1.23
Kroma Kill (Stream A)	10/24/2013	Bolt1	-0.72	1.87	1.11	2.08
Kroma Kill (Stream A)	10/24/2013	Bolt2	-2.22	1.87	1.11	2.08
Kroma Kill (Stream A)	10/24/2013	SG1	0.32	1.87	1.11	2.08
Upper Mill Creek (Stream C)	5/16/2013	Bolt1	-0.23	2.56	0.04	0.11
Upper Mill Creek (Stream C)	6/11/2013	Bolt1	0.64	4.56	2.69	12.25
Upper Mill Creek (Stream C)	7/11/2013	Bolt1	0.02	1.25	1.59	1.98
Upper Mill Creek (Stream C)	7/11/2013	SG1	1.00	1.25	1.59	1.98
Upper Mill Creek (Stream C)	8/15/2013	Bolt1	-0.36			
Upper Mill Creek (Stream C)	8/15/2013	SG1	0.62			
Upper Mill Creek (Stream C)	9/26/2013	SG1	0.62	1.32	0.03	0.04
Upper Mill Creek (Stream C)	10/24/2013	Bolt1	-0.32	2.02	0.05	0.10
Upper Mill Creek (Stream C)	10/24/2013	SG1	0.66	2.02	0.05	0.10
Mill Creek Confluence (Stream D)	5/16/2013	Bolt1	0.06	2.48	0.19	0.46
Mill Creek Confluence (Stream D)	6/11/2013	Bolt2	-0.18	20.71	2.62	54.20
Mill Creek Confluence (Stream D)	7/11/2013	Bolt1	0.32	7.39	0.80	5.91
Mill Creek Confluence (Stream D)	7/11/2013	Bolt1	0.30	7.39	0.80	5.91
Mill Creek Confluence (Stream D)	7/11/2013	Bolt2	-0.44	7.39	0.80	5.91
Mill Creek Confluence (Stream D)	8/15/2013	Bolt1	0.00	1.40	0.22	0.31
Mill Creek Confluence (Stream D)	9/26/2013	Bolt1	0.01	1.54	0.14	0.22
Mill Creek Confluence (Stream D)	9/26/2013	Bolt2	-0.78	1.54	0.14	0.22
Mill Creek Confluence (Stream D)	10/24/2013	Bolt2	-0.72	1.63	0.21	0.35

Appendix B. Saratoga National Historical Park (SARA) Blank and Replicate Water Samples, 2013.

Table B1. 2013 Blank sample analysis results (Lower NETN).

Site	Date	ANC ($\mu\text{eq/L}$)	A Color (PCU)	DOC (mg/L)	Chla ($\mu\text{g/L}$)	Cl ($\mu\text{eq/L}$)	SO ₄ ($\mu\text{eq/L}$)	TP ($\mu\text{g/L}$)	TN (mg/L)	NO ₂ (mg/L)	NO ₃ ($\mu\text{eq/L}$)	NH ₃ (mg/L)
MABIPA	6/4/2013	-0.1	0	<MRL 0.5	<MRL 1	<MRL 2	<MRL 2	<MRL 1	<MRL 0.1	<MRL 0.005	<MRL 1	<MRL 0.08
MABIPA	8/7/2013	-0.2	0	<MRL 0.5	<MRL 1	<MRL 2	<MRL 2	<MRL 1	<MRL 0.1	<MRL 0.005	<MRL 1	<MRL 0.08
MORRSB	5/13/2013	-0.5	0	<MRL 0.5		<MRL 2	<MRL 2	<MRL 1	<MRL 0.1	<MRL 0.005	<MRL 1	<MRL 0.08
SARASA	8/15/2013	0.3	0	<MRL 0.5		<MRL 2	<MRL 2	<MRL 1	<MRL 0.1	<MRL 0.005	<MRL 1	<MRL 0.08

Appendix B. Saratoga National Historical Park (SARA) Blank and Replicate Water Samples, 2013 (continued).

Table B2. Replicate sample analysis results and measurement quality analysis (Lower NETN).

Site	Date	Color Reg	Color Rep	Diff (PCU)	% Diff	DOC Reg	DOC Rep	Diff (mg/L)	% Diff	ANC Reg	ANC Rep	Diff (µeq/L)	% Diff	Chla Reg	Chla Rep	Diff (µg/L)	% Diff
SAIRSB	5/23/2013	94	93	1	1.1%	5.88	5.16	0.72	12.24%	1,130	1,300	-170	15.0%	n/a	n/a		
SAGAPA	6/6/2013	40	44	-4	10.0%	2.26	2.26	0.00	0.00%	715	718	-3	0.4%	< MRL	< MRL		
SAGAPA	8/8/2013	44	47	-3	6.8%	1.82	1.89	-0.07	3.85%	1,110	1,110	0	0.0%	2.4	2.4	0.0	0.0%
ROVASD	8/21/2013	26	28	-2	7.7%	2.75	2.79	-0.04	1.45%	2,290	2,290	0	0.0%	n/a	n/a		

Site	Date	TP Reg	TP Rep	Diff (µg/L)	% Diff	TN Reg	TN Rep	Diff (mg/L)	% Diff	NO ₃ Reg	NO ₃ Rep	Diff (µeq/L)	% Diff	NO ₂ Reg	NO ₂ Rep	Diff (mg/L)	% Diff
SAIRSB	5/23/2013	56	74	-18	32.1%	1.41	1.36	0.05	3.5%	44.0	44.0	0.0	0.0%	0.043	0.042	0.001	2.3%
SAGAPA	6/6/2013	21	22	-1	4.8%	0.31	0.31	-0.01	2.0%	9.8	9.8	0.0	0.0%	< MRL	< MRL		
SAGAPA	8/8/2013	15	16	-1	6.7%	0.30	0.30	0.00	0.3%	11.0	11.0	0.0	0.0%	< MRL	< MRL		
ROVASD	8/21/2013	28	29	-1	3.6%	0.75	0.76	-0.01	1.6%	41.0	41.0	0.0	0.0%	< MRL	< MRL		

Site	Date	NH ₃ Reg	NH ₃ Rep	Diff (mg/L)	% Diff	SO ₄ Reg	SO ₄ Rep	Diff (µeq/L)	% Diff	Cl Reg	Cl Rep	Diff (µeq/L)	% Diff
SAIRSB	5/23/2013	0.17	0.24	-0.07	41.2%	408	2,421	-2,013	493.4%	6,083	27,280	-21,197	348.5%
SAGAPA	6/6/2013	< MRL	< MRL			125	125	0	0.0%	294	292	2	0.7%
SAGAPA	8/8/2013	< MRL	< MRL			117	117	0	0.0%	440	441	-1	0.2%
ROVASD	8/21/2013	< MRL	< MRL			243	246	-3	1.2%	1,214	1,203	11	0.9%

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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