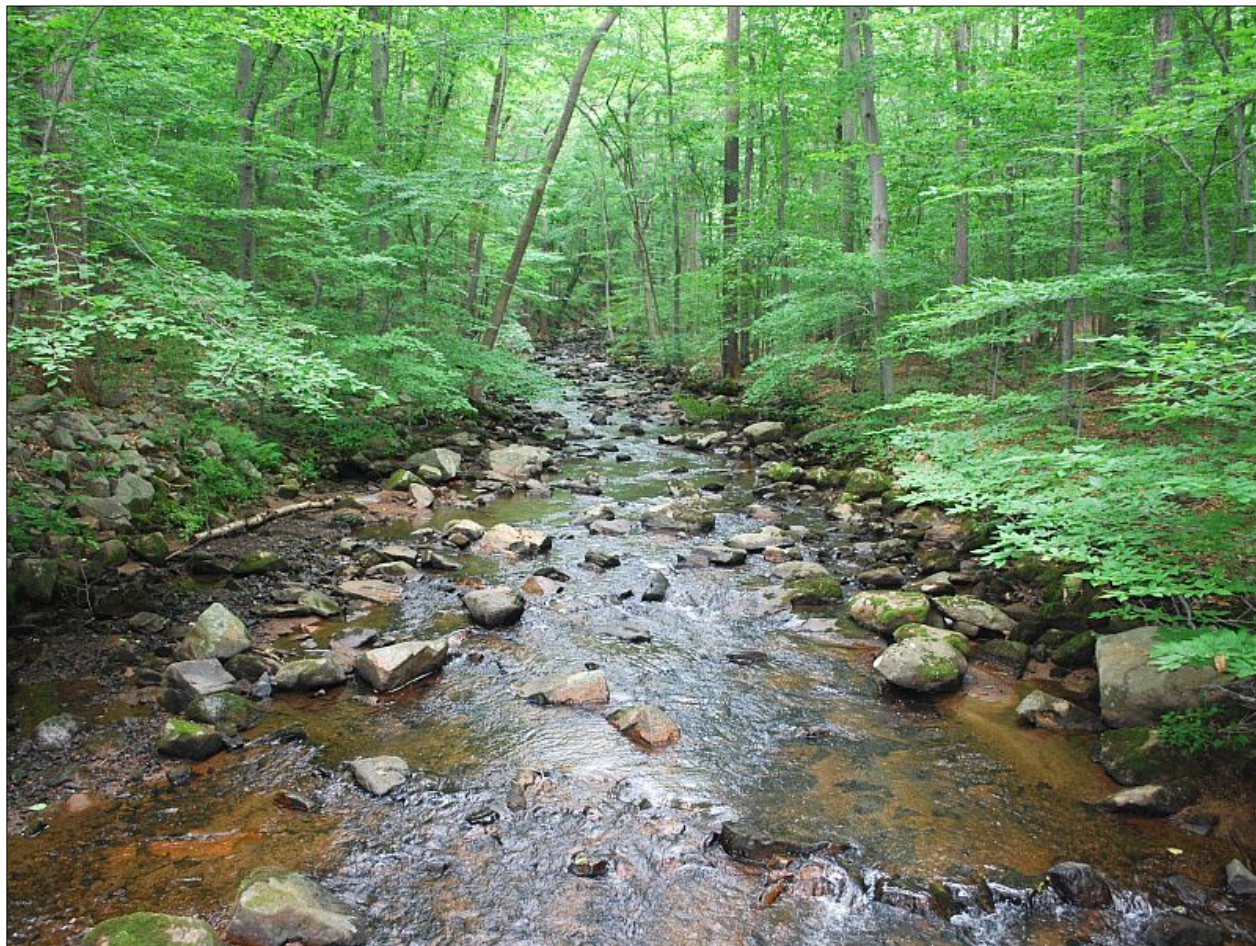




Water Quality Monitoring at Morristown National Historical Park

Northeast Temperate Network 2012 Summary Report

Natural Resource Data Series NPS/NETN/NRDS—2013/540



ON THE COVER

Passaic River, July 2011

Photograph by: Bill Gawley

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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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Introduction

This report on the water quality of Morristown National Historical Park (MORR) generated by the Northeast Temperate Network (NETN) Water Quality Monitoring Program includes data gathered in the 2012 monitoring season and displays these results in graphic form, accompanied by a brief interpretation. Appendix A contains tabular data collected in 2012.

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 5 park streams to be sampled monthly from May through October at MORR. 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

Five water quality monitoring sites were selected at MORR for the NETN monitoring program (Table 1). Sites were chosen to represent the accessible, perennial streams in the Jockey Hollow and New Jersey Brigade Units, the two park units with significant freshwater resources. Historic water quality sampling sites were continued as these stations met the objectives of the vital-signs program (Lombard et al. 2006).

Three of the selected sites are in the Primrose Brook watershed within the Jockey Hollow Unit. These sites are on the East Branch of Primrose Brook, the West Branch of Primrose Brook, and the main stem of Primrose Brook. The other sites are on the Passaic River and Indian Grove Brook in the New Jersey Brigade Unit (Figure 1). All streams monitored by NETN are classified as cold water fisheries (National Park Service 1993), loosely defined as waters that can support, on a year-round basis, wild and stocked brook trout (*Salvelinus fontinalis*) or other species requiring similar conditions.

Table 1. Water quality monitoring sites at Morristown NHP

Water Body	NETN Site Code	Latitude	Longitude	Site Remarks
Primrose Brook East Branch ("Stream A")	MORRSA	40.7701333	-74.5241167	Cold water fisheries
Primrose Brook confluence ("Stream B")	MORRSB	40.7643333	-74.5293667	Cold water fisheries
Primrose Brook West Branch ("Stream C")	MORRSC	40.7696667	-74.5362000	Cold water fisheries
Indian Grove Brook ("Stream D")	MORRSD	40.7446500	-74.5654167	Cold water fisheries
Passaic River ("Stream E")	MORRSE	40.7518667	-74.5514333	Cold water fisheries

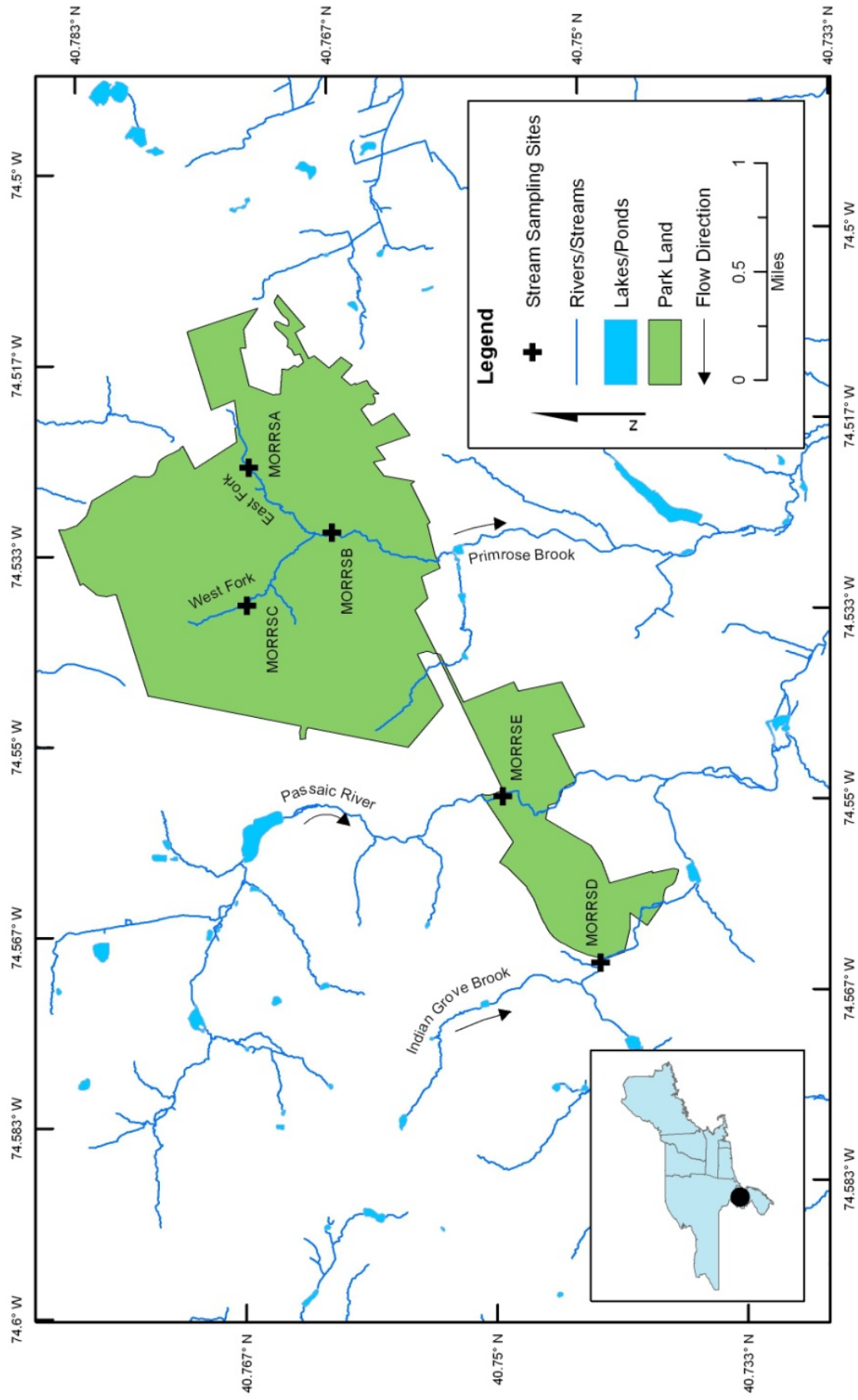


Figure 1. Map of water monitoring sites at Morristown NHP.

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. In Prep). Monthly sampling parameters included in-situ water quality measures (pH, specific conductance, temperature, and dissolved oxygen) determined with a YSI 600XL sonde, 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 obtained by using a folding wooden ruler (engineering scale) to measure from a fixed datum point on large boulders to the surface of the water. Bolts were installed to permanently mark the datum points in July 2011.

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 Jersey water quality standards (Table 2; State of New Jersey Administrative Code 2004) designate the general surface-water classification applied to fresh waters as FW. FW1 means those fresh waters that are to be maintained in their natural state of quality and not subjected to any man-made wastewater discharges or increases in runoff from anthropogenic activities. These waters are set aside for posterity because of their clarity, color, scenic setting, or other characteristic of aesthetic value, unique ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).

“FW1 surface waters shall be maintained as to quality in their natural state” (State of New Jersey Administrative Code 2004). The tributaries in the Passaic River watershed in MORR are all listed as FW2 waters. Surface-water quality criteria for FW2 Waters states that “FW2 TP [Trout Production] waters shall have DO concentrations that shall not be less than 7.0 mg/L at any time. pH shall range from 6.5 to 8.5 standard units at all times. Phosphorus concentration as total P shall not exceed 0.05 mg/L in any lake, pond or reservoir, or in a tributary at the point where it enters such waterbodies. Concentrations of total P shall not exceed 0.1 mg/L [100 µg/L] in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses” (State of New Jersey Administrative Code 2004).

Table 2. New Jersey stream water quality standards.

Water quality classification code	Minimum Dissolved Oxygen (mg/L)	pH range (standard units)	Maximum Total Nitrogen (µg/L)	Maximum Total Phosphorus (µg/L)
FW2	7.0	6.5-8.5	--	100

EPA Ecoregion 9 water quality criteria (Table 3; 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 9 nutrient criteria for streams.

Nutrient Criteria	Value
Total Phosphorus	36.56 µg/L
Total Nitrogen	0.69 mg/L

These criteria were developed specifically for Ecoregion 9 (which includes Morristown NHP) 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 2012 are displayed in scatter-plot graphs showing all data for each site for a given parameter. The scatter plots of 2012 data are overlaid on box plots representing the overall range and distribution of data values collected from 2006 through 2012 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.

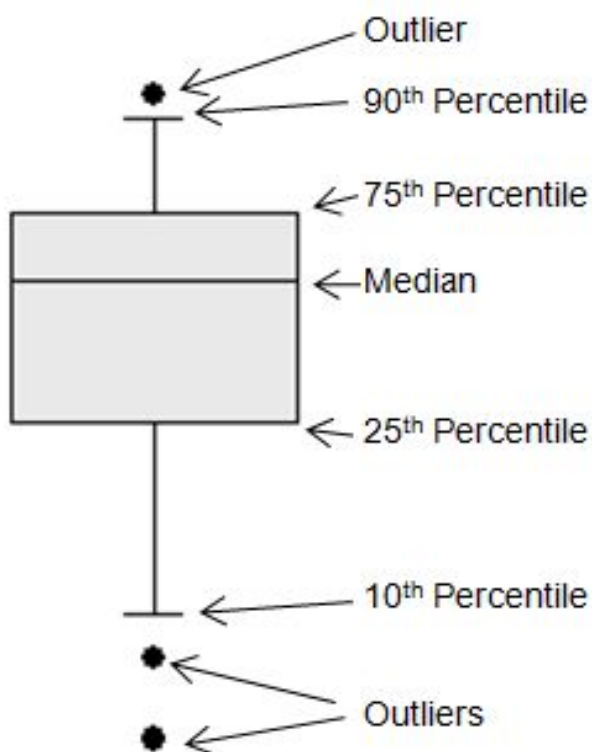


Figure 2. Explanation of box plot graph.

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 2012 were within the appropriate range for high ionic strength waters, and were generally within the range of the data from previous years.

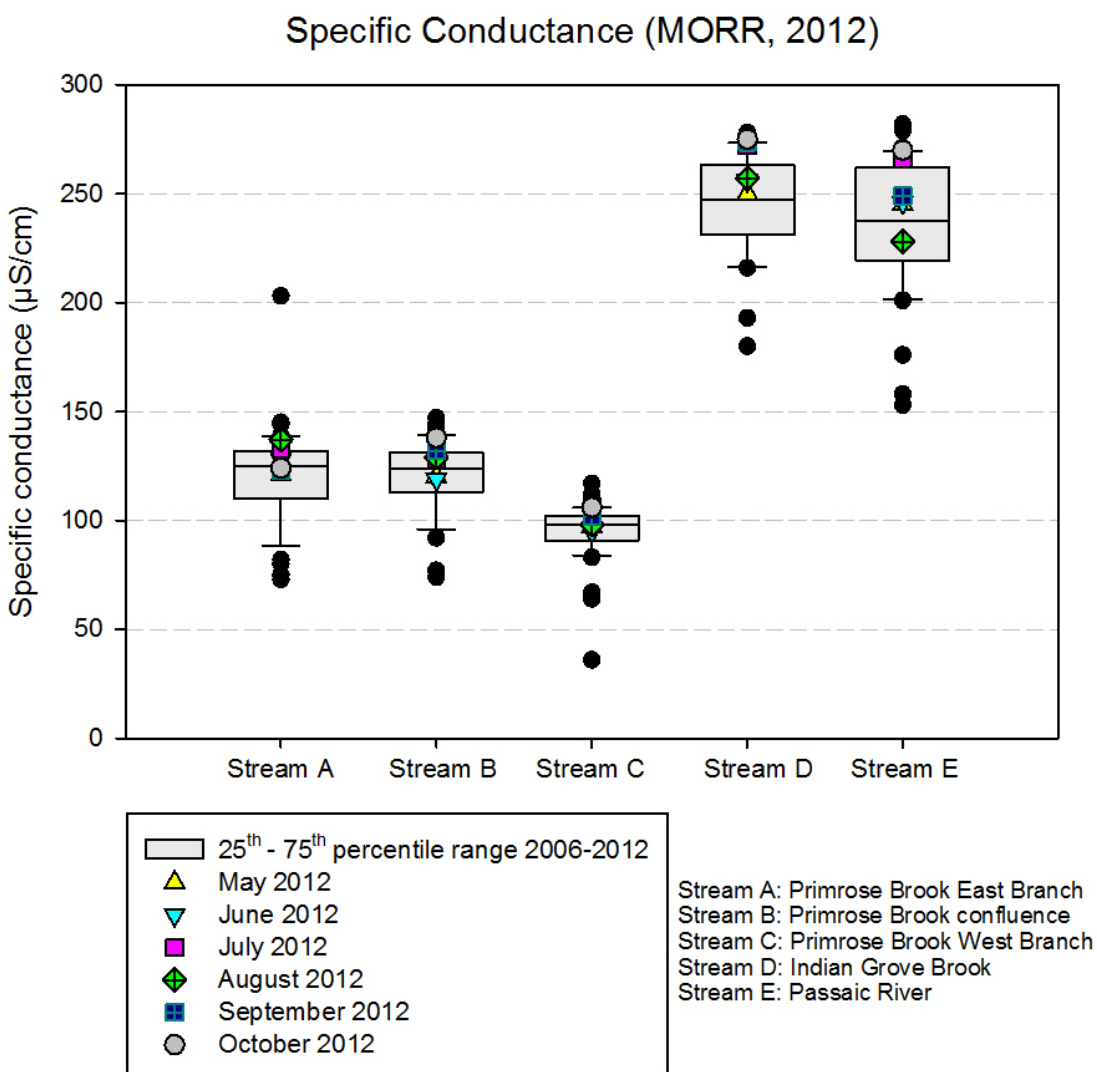


Figure 3. Specific conductance from 2012 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2012.

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 Jersey standards, like those of most northeast states, indicate that a pH between 6.5 and 8.5 is within the acceptable range. Most pH values from the 2012 monitoring season (Figure 4) were circumneutral, or slightly basic and were all between the upper and lower New Jersey water quality standards.

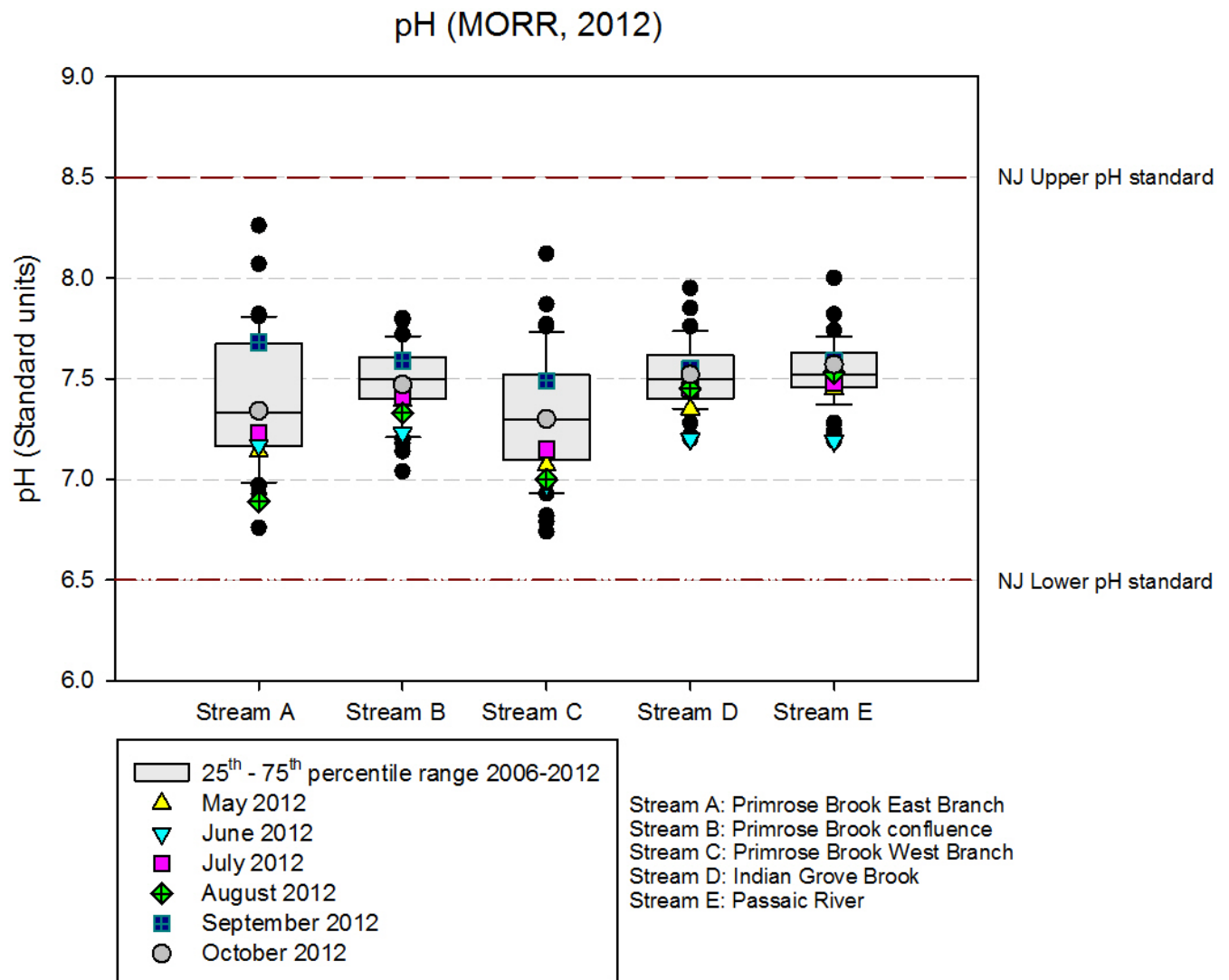


Figure 4. pH from 2012 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2012.

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 2012.

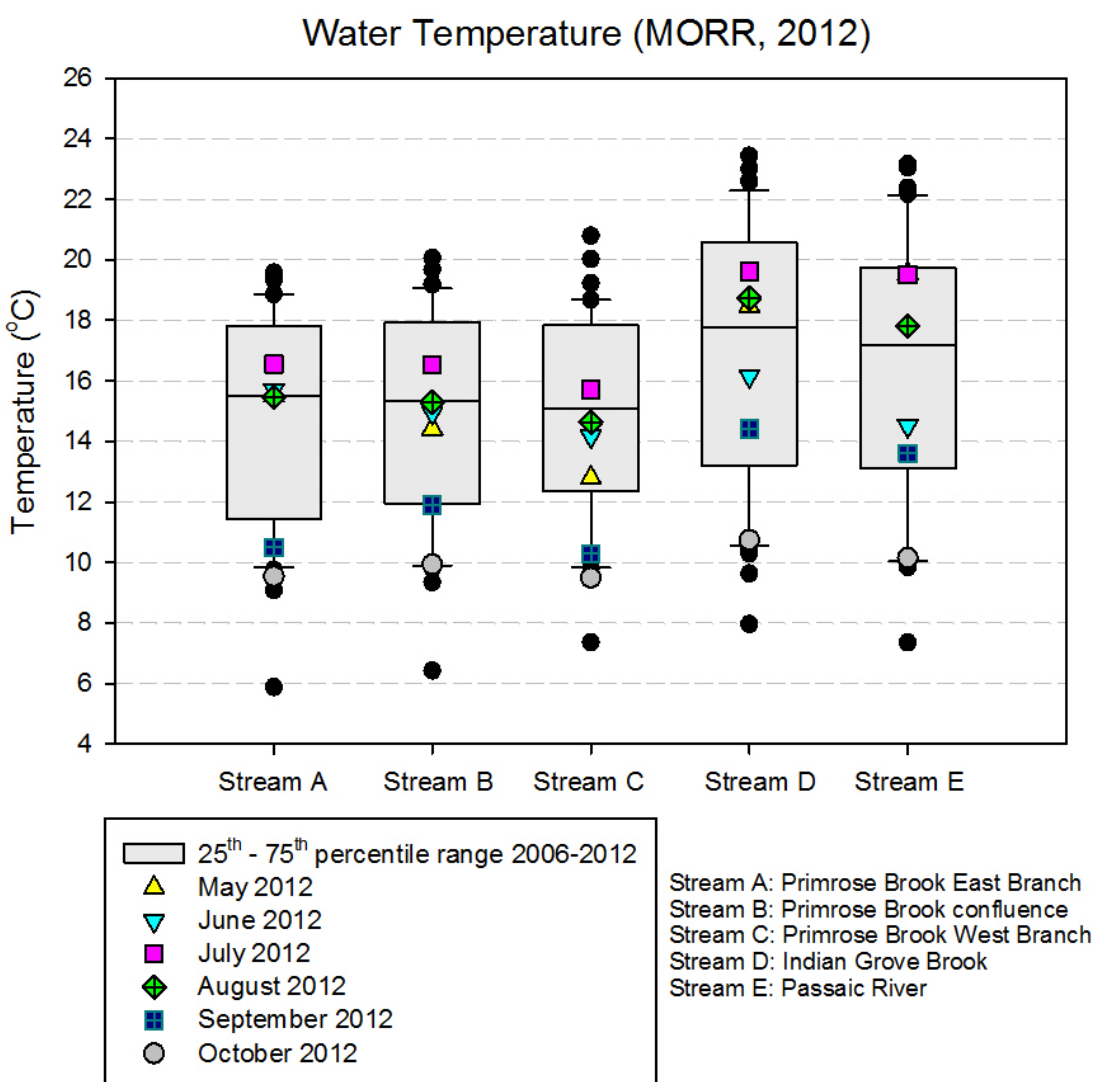


Figure 5. Water temperature (surface) from 2012 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2012.

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 MORR sites were well oxygenated in 2012 (Figure 6), and above the most stringent (7 mg/L) state DO standard.

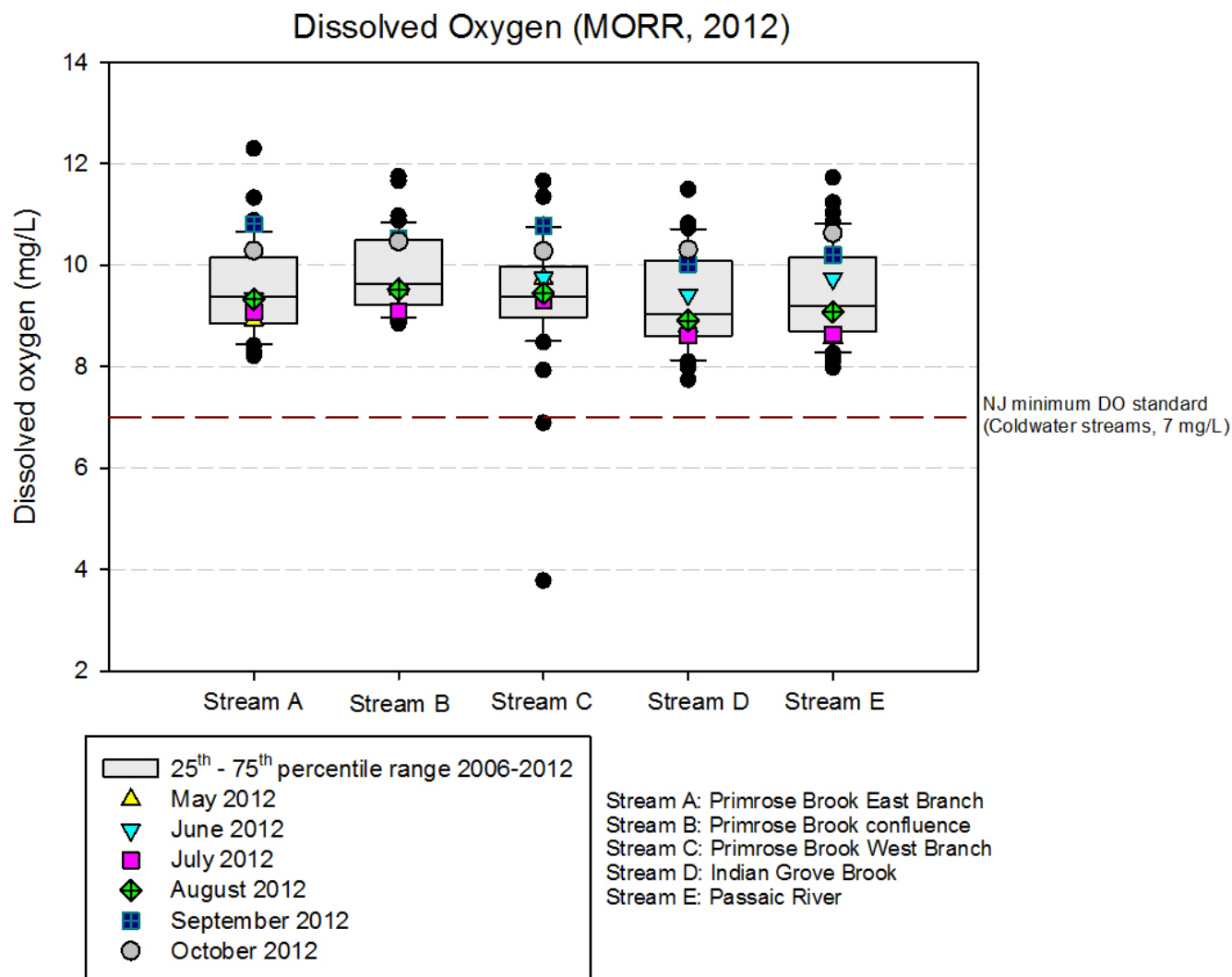


Figure 6. Dissolved oxygen (surface) from 2012 YSI sonde in-situ measurements overlaid on a box plot of measurements taken from 2006-2012.

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 2012 samples (Figure 7) illustrates that MORR streams were well-buffered, likely due to the underlying geology.

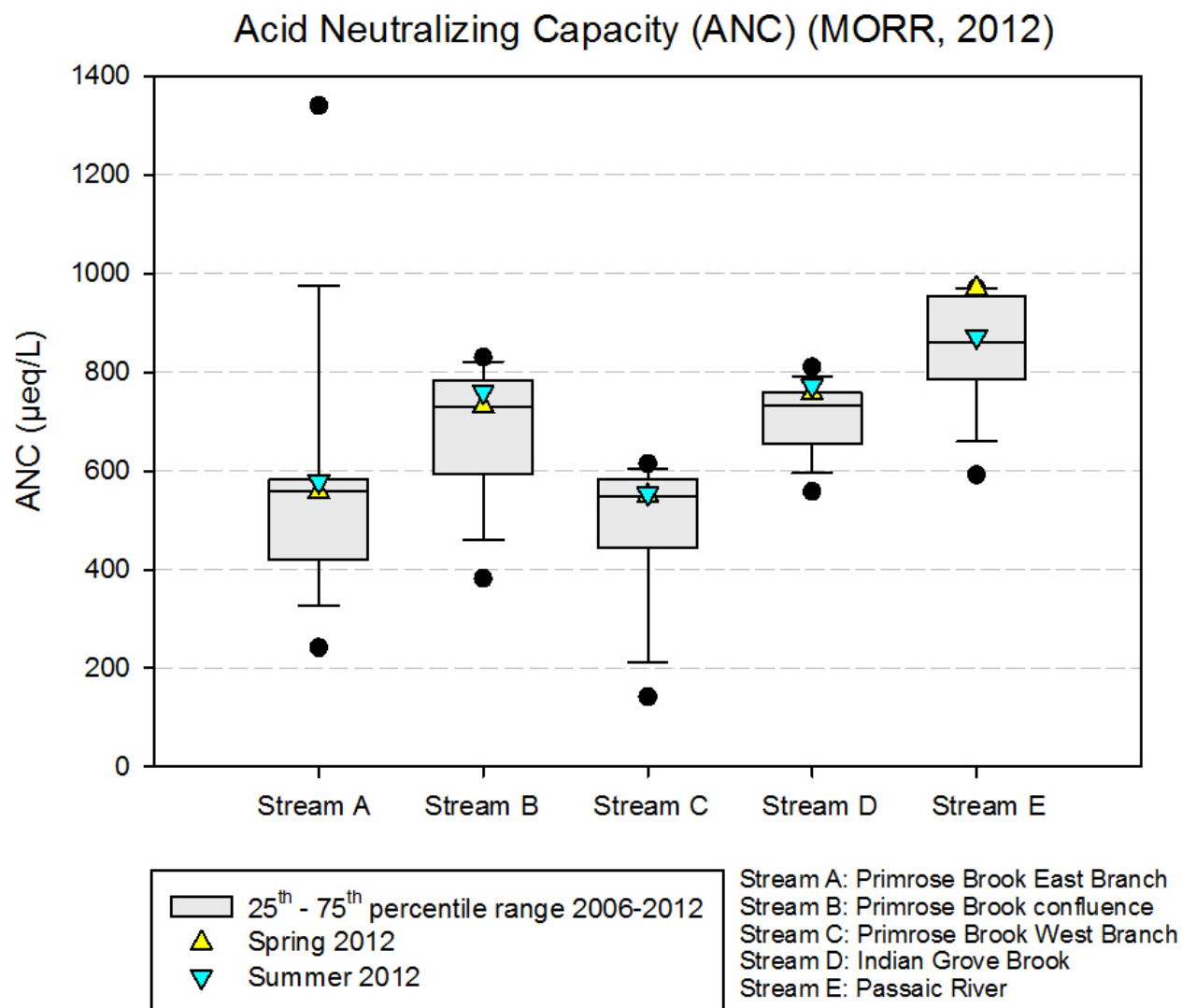


Figure 7. Acid neutralizing capacity from 2012 water samples overlaid on a box plot of measurements taken from 2006-2012.

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”.

Median color values from 2006 to 2012 monitoring (Figure 8) show most MORR streams to be moderately colored. The higher color measured in the May 2012 Passaic River sample indicates the possibility of runoff and sediment input to the stream prior to the May monitoring visit, especially since the color samples are not filtered before analysis. An extreme graph outlier (the August 2011 sample from Primrose Brook West Branch) is not shown on the graph. The sample was collected during a heavy rain event that caused extremely turbid water (described as appearing “like chocolate milk”) and had an exceptionally high apparent color measurement of 886 PCU.

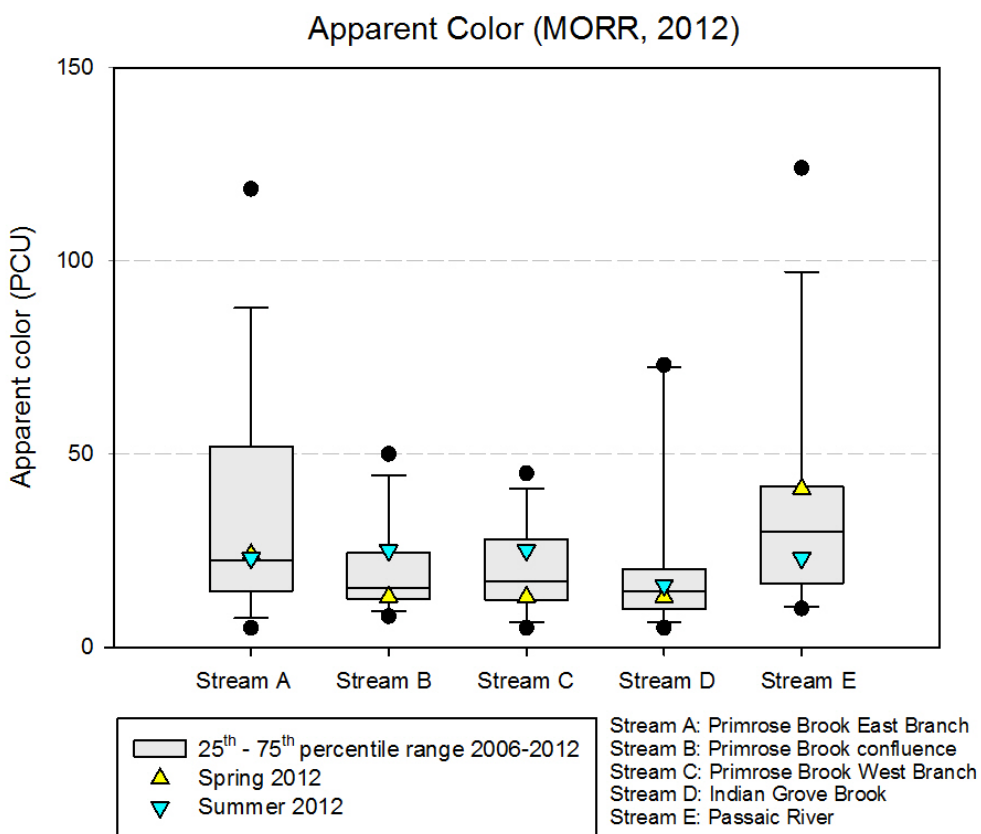


Figure 8. Apparent color from 2012 water samples overlaid on a box plot of measurements taken from 2006-2012. One outlier value was excluded (see text).

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). MORR DOC concentrations (Figure 9) were low in 2012.

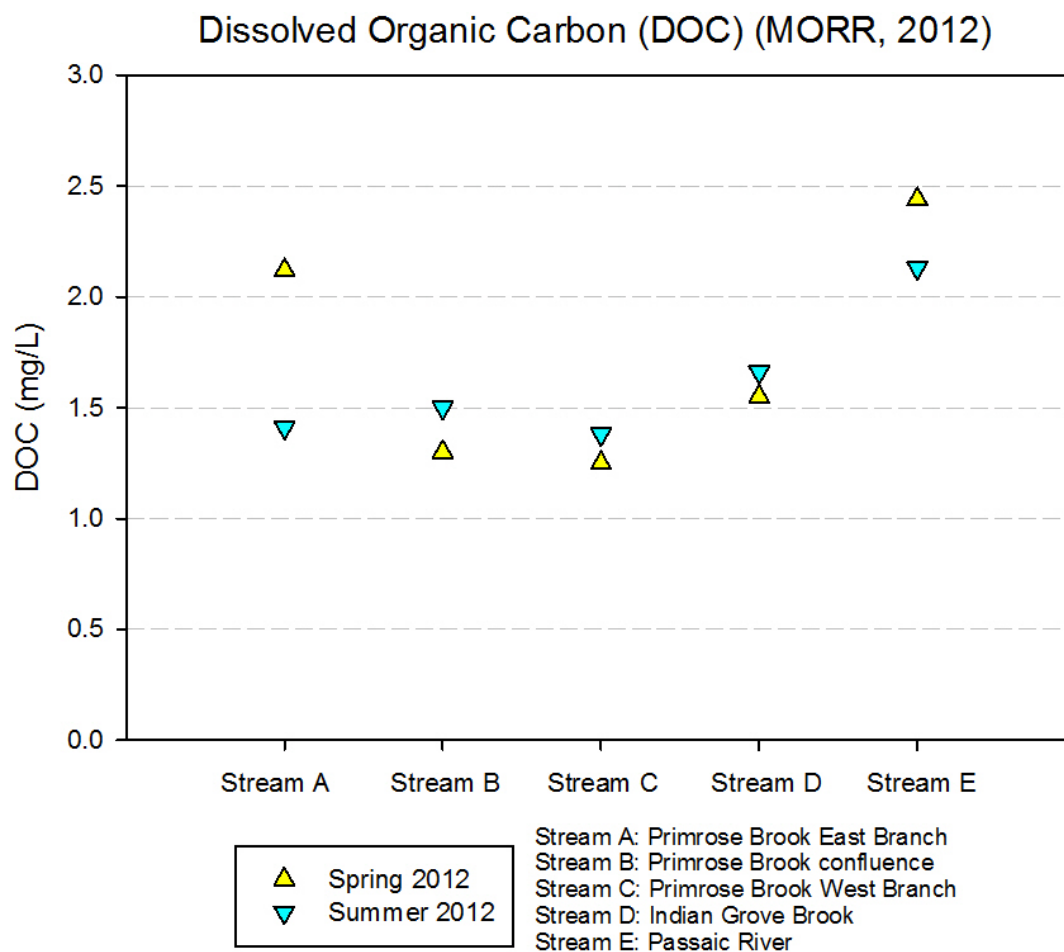


Figure 9. Dissolved organic carbon (DOC) from 2012 spring and summer water samples.

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). Turbidity values measured in all MORR streams during 2012 (Figure 10), the first year of NETN turbidity testing, were all in the low range of dry-weather turbidity of surface waters, which normally ranges from 0 to 10 NTU (U.S. Environmental Protection Agency 1999). The three outlying values in streams C, D, and E may indicate sediment input from episodic runoff events.

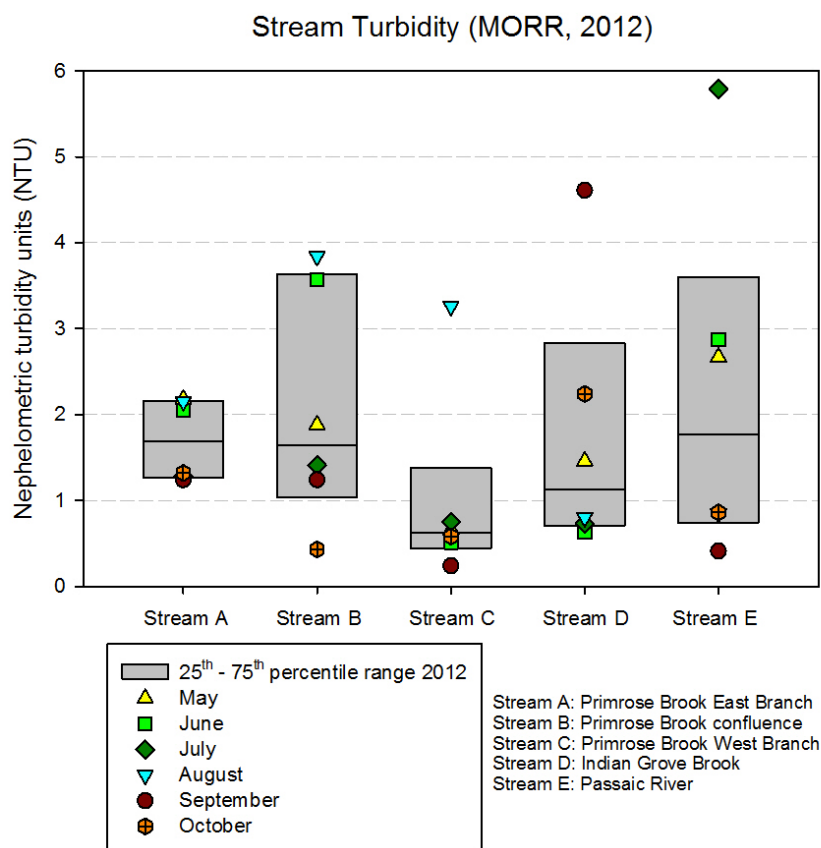


Figure 10. Stream turbidity from 2012 monthly measurements. The data are overlaid on a box plot of measurements taken in 2012.

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 2012 all total phosphorus concentrations (Figure 11) were in the moderate range, and most values were near or below the EPA Region 9 criterion of 31.25 µg/L. As described above (“Water Quality Standards”), the EPA criteria do not have any regulatory meaning. There are no numeric New Jersey TP standards. An extreme graph outlier (the August 2011 sample from Primrose Brook West Branch) is not shown on the graph. The sample was collected during a heavy rain event and had an exceptionally high TP measurement of 1,910 µg/L.

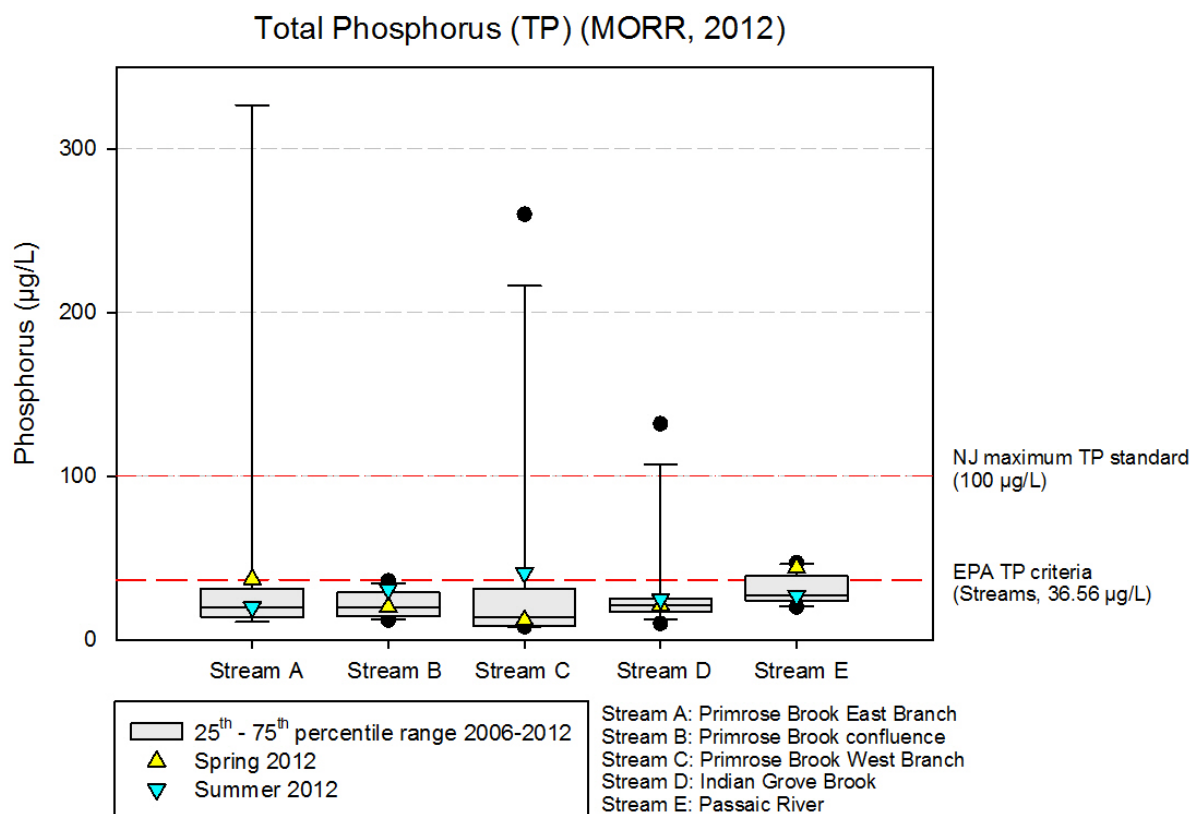


Figure 11. Total phosphorus (TP) from spring and summer water samples. The data are overlaid on a box plot of measurements taken from 2006-2012. One outlier value was excluded (see text).

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 (denitrification). 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. Half of the 2012 TN values exceeded the EPA Region 9 criterion of 0.69 mg/L, although as with TP this criterion does not have regulatory meaning. All of the TN results were below 2.0 mg/L, the value used as a TN standard in several northeast states (New Jersey has no numeric TN standard). Nitrate levels were moderate, nitrite test results in all streams were low, and all 2012 ammonia test results were below the method reporting limit of 0.08 mg/L. An extreme graph outlier (TN value of 11.8 mg/L representing the August 2011 sample from the Primrose Brook confluence site that was collected during a heavy rain event) was omitted from the graph.

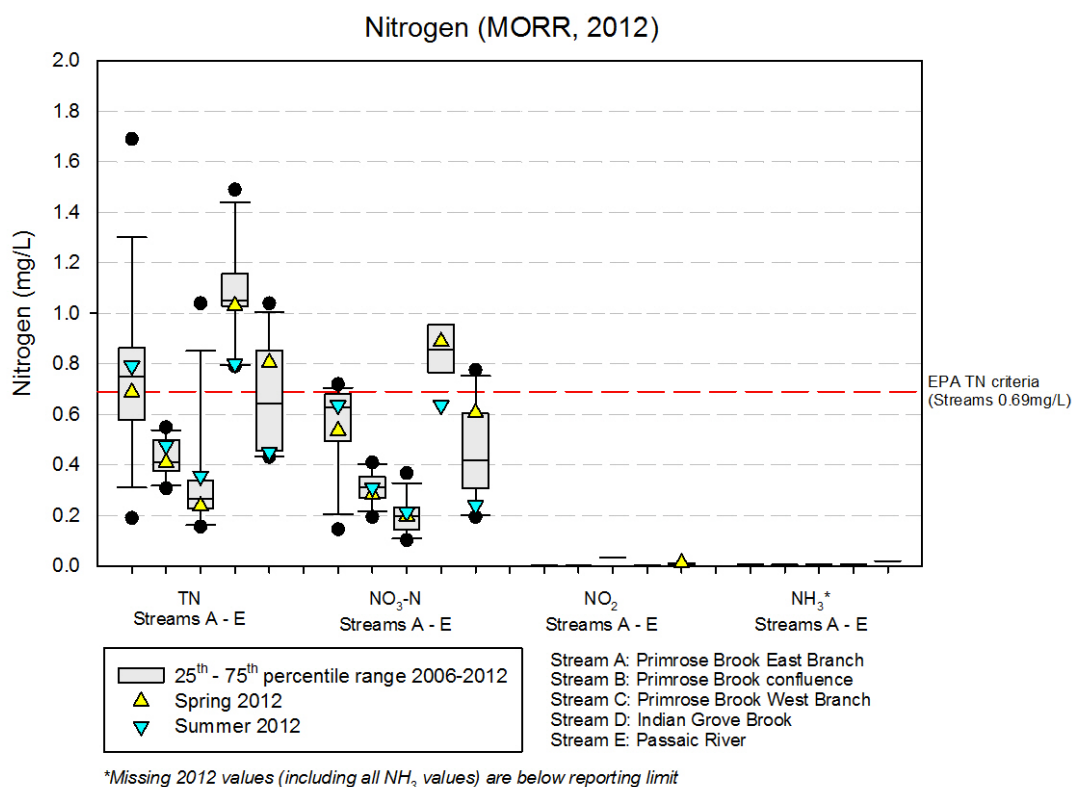


Figure 12. Total nitrogen (TN), nitrate ($\text{NO}_3\text{-N}$), nitrite (NO_2) and ammonia (NH_3) from 2012 water samples. The data are overlaid on a box plot of measurements taken from 2006-2012. One outlier value was excluded (see text).

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). Several chloride values in MORR samples were relatively high in 2012 (Figure 13), especially at Indian Grove Brook, which is in close proximity to a major road, and the Passaic River (higher values may indicate upstream road salt influence).

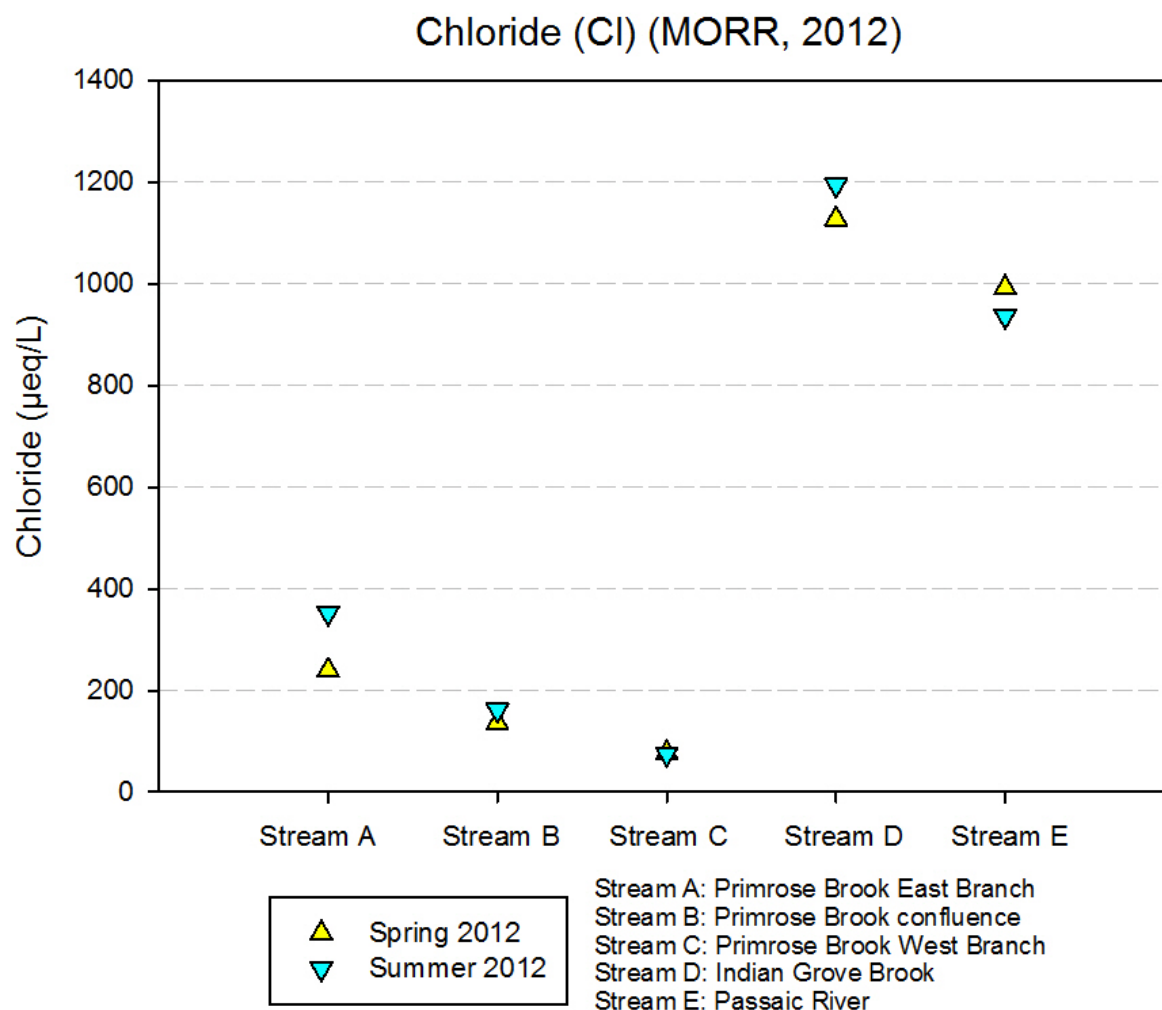


Figure 13. Chloride from 2012 spring and summer water samples.

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 MORR were moderate in 2012 (Figure 14).

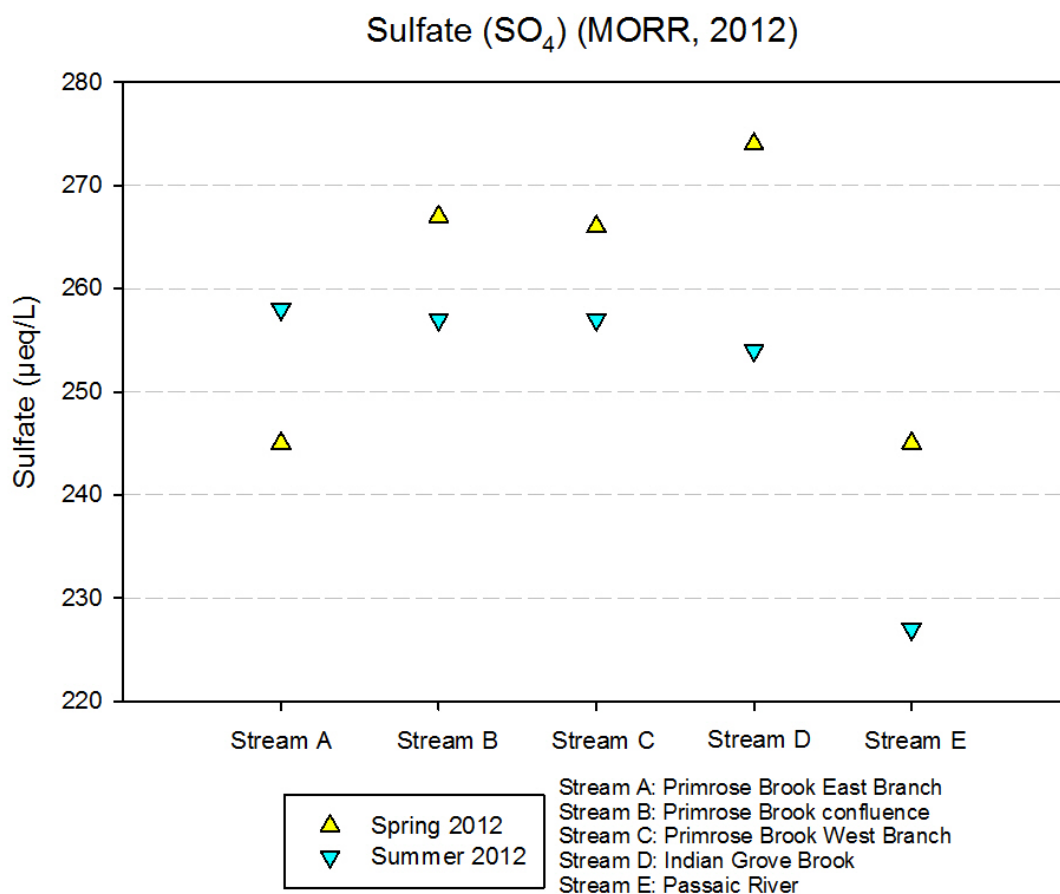


Figure 14. Sulfate from 2012 spring and summer water samples.

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 2012 are graphed in Figure 15. Discharge and stage measurements from 2012 are listed in Table A3 in Appendix A. Streamflow was moderate and fairly consistent through the 2012 season, with the exception of two higher discharge measurements at Indian Grove Brook and the Passaic River in May. NETN staff are continuing to review 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.

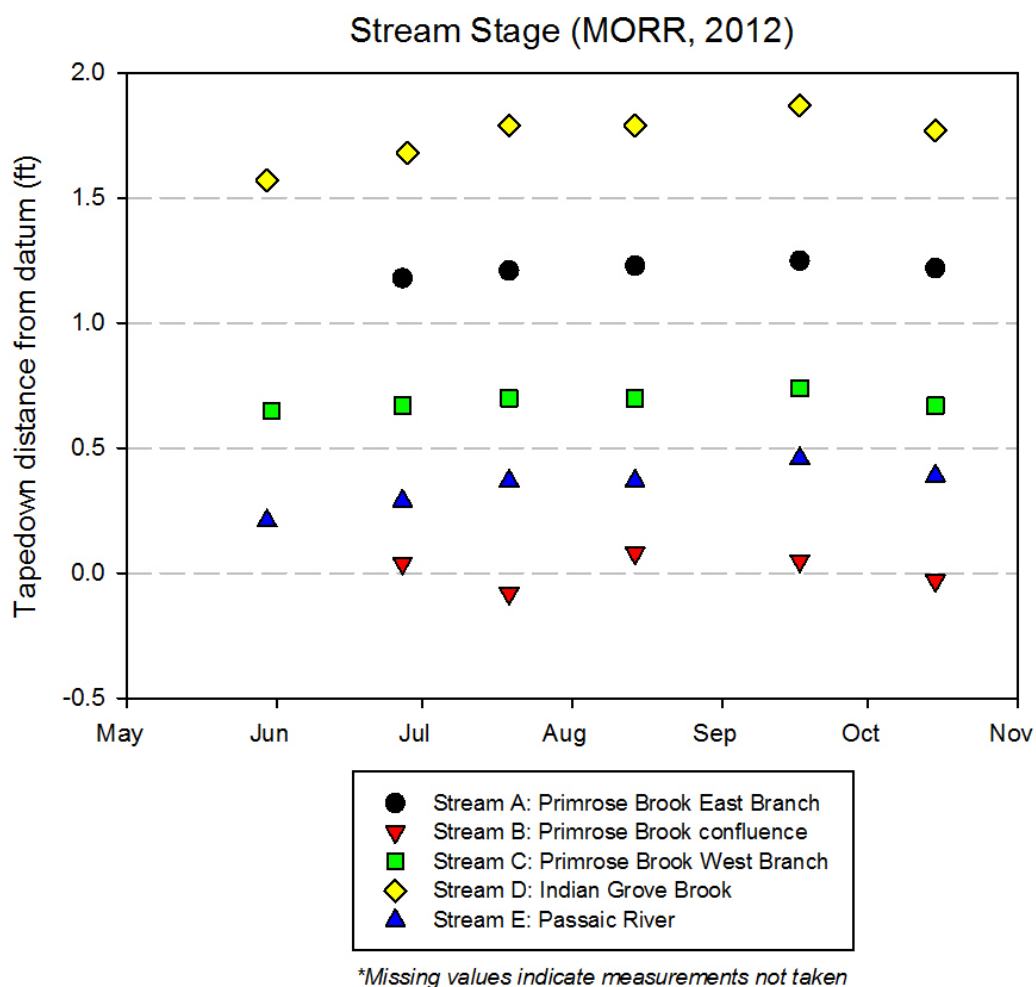


Figure 15. Stream stage obtained in 2012 by measuring from a permanent datum point down to the water surface. *Note: Larger tapedown distances indicate LOWER water levels.*

Invasive Aquatic Plants

Invasive aquatic plant monitoring was not conducted at MORR during the 2012 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. In Prep).

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.

Summary

Most water quality parameters for the monitored streams were within state standards, and were generally within the range of EPA criteria, where applicable. The majority of values were within the ranges of the historic NETN monitoring data from MORR. 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.

Test results for TN and NO₃ were moderate in most 2012 samples. Results for NO₂ were very low at all sites. All ammonia (NH₃) test results were below the method reporting limit of 0.08 mg/L. All total phosphorus results for 2012 were moderate, and generally below the EPA Region 9 criterion of 36.56µg/L. All TP results were well below the New Jersey state TP standard of 100µg/L.

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 Morristown 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, will 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.

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Appendix A. Morristown National Historical Park (MORR) Water Monitoring Data, 2012.

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

Site	Date	Depth (m)	Temp (C)	DO (mg/L)	pH	SpCond (µS/cm)
East Primrose Brook (Stream A)	5/30/2012	0.06	15.51	8.92	7.14	121.00
East Primrose Brook (Stream A)	6/27/2012	0.22	15.70	9.34	7.17	128.00
East Primrose Brook (Stream A)	7/19/2012	-0.18	16.55	9.08	7.23	133.00
East Primrose Brook (Stream A)	8/14/2012	0.00	15.46	9.33	6.89	137.00
East Primrose Brook (Stream A)	9/17/2012	-0.08	10.50	10.81	7.68	123.00
East Primrose Brook (Stream A)	10/15/2012	0.11	9.55	10.29	7.34	124.00
Primrose Brook Confluence (Stream B)	5/31/2012	0.17	14.42	9.54	7.39	120.00
Primrose Brook Confluence (Stream B)	6/27/2012	0.22	14.94	9.49	7.23	119.00
Primrose Brook Confluence (Stream B)	7/19/2012	-0.04	16.53	9.10	7.41	128.00
Primrose Brook Confluence (Stream B)	8/14/2012	0.06	15.30	9.52	7.33	129.00
Primrose Brook Confluence (Stream B)	9/17/2012	-0.02	11.90	10.54	7.59	132.00
Primrose Brook Confluence (Stream B)	10/15/2012	0.14	9.94	10.47	7.47	138.00
West Primrose Brook (Stream C)	5/31/2012	0.17	12.80	9.74	7.07	97.00
West Primrose Brook (Stream C)	6/27/2012	0.18	14.17	9.75	6.97	95.00
West Primrose Brook (Stream C)	7/19/2012	-0.13	15.71	9.30	7.15	106.00
West Primrose Brook (Stream C)	8/14/2012	-0.03	14.64	9.45	7.00	98.00
West Primrose Brook (Stream C)	9/17/2012	-0.01	10.29	10.78	7.49	102.00
West Primrose Brook (Stream C)	10/15/2012	0.10	9.50	10.28	7.30	106.00
Indian Grove Brook (Stream D)	5/30/2012	0.18	18.47	8.80	7.35	250.00
Indian Grove Brook (Stream D)	6/28/2012	0.31	16.16	9.42	7.20	256.00
Indian Grove Brook (Stream D)	7/19/2012	-0.10	19.61	8.61	7.45	272.00
Indian Grove Brook (Stream D)	8/14/2012	0.04	18.74	8.91	7.45	257.00
Indian Grove Brook (Stream D)	9/17/2012	-0.02	14.41	10.02	7.55	274.00
Indian Grove Brook (Stream D)	10/15/2012	0.27	10.75	10.31	7.52	275.00
Passaic River (Stream E)	5/30/2012	0.53	19.54	8.57	7.45	245.00
Passaic River (Stream E)	6/27/2012	0.24	14.51	9.74	7.19	246.00
Passaic River (Stream E)	7/19/2012	-0.11	19.51	8.64	7.48	266.00
Passaic River (Stream E)	8/14/2012	0.12	17.81	9.08	7.53	228.00
Passaic River (Stream E)	9/17/2012	-0.01	13.60	10.20	7.59	249.00
Passaic River (Stream E)	10/15/2012	0.20	10.16	10.63	7.57	270.00

Appendix A. Morristown National Historical Park (MORR) Water Monitoring Data, 2012 (continued).

Table A2. Laboratory nutrient chemistry data for MORR. “<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)	Apparent Color (PCU)	DOC (mg/L)	TP (µg/L)	TN (mg/L)	NO ₃ (µeq/L)	NO ₃ - N [calc.] (mg/L)	NO ₂ (mg/L)	NH ₃ (mg/L)	Cl (µeq/L)	SO ₄ (µeq/L)
East Primrose Brook (Stream A)	5/30/2012	557.00	24	2.12	37	0.687	38	0.536	<MRL	<MRL	239	245
East Primrose Brook (Stream A)	8/14/2012	578.00	23	1.41	20	0.791	45	0.635	<MRL	<MRL	352	258
Primrose Brook Confluence (Stream B)	5/31/2012	730.00	13	1.30	20	0.409	20	0.282	<MRL	<MRL	136	267
Primrose Brook Confluence (Stream B)	8/14/2012	760.00	25	1.50	31	0.477	22	0.310	<MRL	<MRL	161	257
West Primrose Brook (Stream C)	5/31/2012	549.00	13	1.25	12	0.237	14	0.197	<MRL	<MRL	77	266
West Primrose Brook (Stream C)	8/14/2012	554.00	25	1.38	41	0.356	15	0.212	<MRL	<MRL	75	257
Indian Grove Brook (Stream D)	5/30/2012	757.00	13	1.55	21	1.030	63	0.888	<MRL	<MRL	1,127	274
Indian Grove Brook (Stream D)	8/14/2012	772.00	16	1.66	25	0.800	45	0.635	<MRL	<MRL	1,194	254
Passaic River (Stream E)	5/30/2012	970.00	41	2.44	44	0.805	43	0.606	0.011	<MRL	992	245
Passaic River (Stream E)	8/14/2012	872.00	23	2.13	27	0.450	17	0.240	<MRL	<MRL	936	227

Appendix A. Morristown National Historical Park (MORR) Water Monitoring Data, 2012 (continued).

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

Site	Date	Tapedown from datum (ft)	Total cross section area (sqft)	Average velocity (f/s)	Discharge (cfs)
East Primrose Brook (Stream A)	5/30/2012		1.00	0.17	0.17
East Primrose Brook (Stream A)	6/27/2012	1.18	0.61	0.16	0.10
East Primrose Brook (Stream A)	7/19/2012	1.21	0.70	0.21	0.15
East Primrose Brook (Stream A)	8/14/2012	1.23	0.56	0.19	0.11
East Primrose Brook (Stream A)	9/17/2012	1.25	0.60	0.06	0.04
East Primrose Brook (Stream A)	10/15/2012	1.22	0.51	0.11	0.06
Primrose Brook Confluence (Stream B)	5/31/2012		2.94	0.40	1.16
Primrose Brook Confluence (Stream B)	6/27/2012	0.04	3.14	0.42	1.33
Primrose Brook Confluence (Stream B)	7/19/2012	-0.08	2.77	0.31	0.89
Primrose Brook Confluence (Stream B)	8/14/2012	0.08	2.87	0.36	1.03
Primrose Brook Confluence (Stream B)	9/17/2012	0.05	2.45	0.16	0.40
Primrose Brook Confluence (Stream B)	10/15/2012	-0.03	2.48	0.15	0.38
West Primrose Brook (Stream C)	5/31/2012	0.65	1.63	0.26	0.42
West Primrose Brook (Stream C)	6/27/2012	0.67	1.20	0.32	0.39
West Primrose Brook (Stream C)	7/19/2012	0.70	1.08	0.18	0.20
West Primrose Brook (Stream C)	8/14/2012	0.70	1.19	0.22	0.26
West Primrose Brook (Stream C)	9/17/2012	0.74	0.85	0.07	0.06
West Primrose Brook (Stream C)	10/15/2012	0.67	1.39	0.05	0.07
Indian Grove Brook (Stream D)	5/30/2012	1.57	13.85	0.18	2.48
Indian Grove Brook (Stream D)	6/28/2012	1.68	13.53	0.14	1.92
Indian Grove Brook (Stream D)	7/19/2012	1.79	12.01	0.11	1.31
Indian Grove Brook (Stream D)	8/14/2012	1.79	12.14	0.12	1.51
Indian Grove Brook (Stream D)	9/17/2012	1.87	11.15	0.08	0.94
Indian Grove Brook (Stream D)	10/15/2012	1.77	12.51	0.10	1.22
Passaic River (Stream E)	5/30/2012	0.21	14.16	0.37	5.29
Passaic River (Stream E)	6/27/2012	0.29	12.15	0.28	3.35
Passaic River (Stream E)	7/19/2012	0.37	9.85	0.27	2.64
Passaic River (Stream E)	8/14/2012	0.37	11.67	0.19	2.25
Passaic River (Stream E)	9/17/2012	0.46	10.83	0.14	1.50
Passaic River (Stream E)	10/15/2012	0.39	11.50	0.17	1.99

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