



National Capital Region Network 2007-2008

Water Resources Monitoring Data Report

Water Chemistry, Nutrient Dynamics, and Surface Water Dynamics Vital Signs

Natural Resource Data Series NPS/NCR/NCRN/NRDS—2010/105



ON THE COVER

James Pieper, Jr. sampling Owens Creek in Catoctin Mountain Park, Thurmont, MD

Photograph by: Marian Norris

National Capital Region Network 2007-2008 Water Resources Monitoring Data Report

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Abbreviations & Acronyms

°C	Degrees Centigrade or Celsius
µeq/L	Microequivalents per liter
µg/L	Micrograms per liter (equivalent to parts per billion)
µm	Micrometer
µS/cm	Microsiemens per centimeter
ac	Acres
ANC	Acid-Neutralizing Capacity
ANTI	Antietam National Battlefield
APHA	American Public Health Association
APPA	Appalachian Trail
ASBS	Area of Special Biological Significance
ASTM	American Society for Testing and Materials
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BOR	U.S. Bureau of Reclamation
BSS	Biological Stream Survey
BU	Beneficial Use
Ca	Calcium
CaCO ₃	Calcium carbonate
CALM	Consolidated Assessment and Listing Methodology (EPA)
CATO	Catoctin Mountain Park
CBF	Chesapeake Bay Foundation
CBP	Chesapeake Bay Program
CCC	Chronic Concentration Criteria
CFC	Chlorofluorocarbon
cfs or ft ³ /s	Cubic feet per second
CHOH	Chesapeake and Ohio Canal National Historical Park
CLP	Contract Laboratory Program
cm	Centimeters
CO ₂	Carbon dioxide
CO ₃ ²⁻	Carbonate
COE	(Army) Corps of Engineers
COG	Metropolitan Washington Council of Governments
CWA	Clean Water Act
DC	District of Columbia
DI	Deionized water
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOI	Department of Interior
DOT	Department of Transportation
DPD	N,N-diethyl-p-phenylenediamine
DQO	data-quality objective
EDI	Equal Discharge Increment
EPA	Environmental Protection Agency

EWI	Equal Width Increment
FDA	Food and Drug Administration
FIB	Fecal Indicator Bacteria
ft	Feet
g	Gram
g/L	Gram per liter
gal	Gallons
gal/min	Gallon per minute
GIS	Geographic Information System
GPRA	Government Performance and Results Act
GPS	Global positioning system
GWMP	George Washington Memorial Parkway
H ₂ SO ₄	Hydrogen sulfide
ha	Hectares
HAFE	Harpers Ferry National Historical Park
HCO ₃ ⁻	Carbonate
HIF	Hydrologic Instrumentation Facility (USGS)
HNO ₃	Nitrate
HPLC	High Performance Liquid Chromatography
HUC	Hydrologic Unit Code
I&M	Inventory & Monitoring Program
IBWC	International Boundary and Water Commission
ICPRB	Interstate Commission on the Potomac River Basin
in	Inch
IPM	Integrated Pest Management
IPT	Inflection Point Titration
IQR	Interquartile Range
ISE	Ion-Specific Electrode
JHA	Job Hazard Analysis
km	Kilometers
L	Liters
LED	Light Emission Diode
m	Meters
MANA	Manassas National Battlefield Park
MBSS	Maryland Biological Stream Survey
MD	Maryland
MD DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDL	Method Detection Limit
meq/L	Milliequivalent per liter
MF	Membrane filtration
Mg	Magnesium
mg/L	Milligrams per liter (equivalent to parts per million)
Mgal/d	Million gallons per day
mi	Miles

mL	Milliliters
MONO	Monocacy National Battlefield
MPN	Most Probable Number (of bacteria)
MQO	Measurement Quality Objective
MRL	Minimum reporting level
MSDS	Material Safety Data Sheets
MV	Millivolts
N	Normality
NACE	National Capital Parks - East
NAWQA	National Water Quality Assessment (USGS Program)
NCRN	National Capital Region Network Inventory and Monitoring Program
NELAC	National Environmental Lab Accreditation
NFM	National Field Manual (USGS)
NGO	Nongovernmental organizations
NIST	National Institute of Standards and Testing
NMFS	National Marine Fisheries Service
NO ₃	Nitrate
NOAA	National Oceanic and Atmospheric Association
NPDES	National Point Discharge Elimination System
NPS	National Park Service
NPSTORET	National Park Service version of EPA's STORET database
NPS-WRD	National Park Service – Water Resources Division
NRC	Natural Resource Challenge
NTU	Nephelometric Turbidity Unit
NWIS	National Water Information System
ONRWs	Outstanding Natural Resource Waters
ORP/Eh	Oxidation-Reduction Potential
PCB	Polychlorinated Biphenyls
PO ₄	Phosphate
POGO	Potomac Gorge, covers parts of CHOH and GWMP.
POPs	Persistent Organic Pollutants
POTW	Publicly Owned Treatment Work
ppb	Parts per billion (equivalent to microgram per liter)
PPE	Personal Protective Equipment
ppm	Parts per million (equivalent to milligram per liter)
ppt	Parts per thousand
PQL	Practical Quantitation Limit
PRWI	Prince William Forest Park
pt	Pints
PVC	Polyvinyl Chloride
QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
ROCR	Rock Creek Park
SOC	Suspended organic carbon
SOPs	Standard Operating Procedures

SSC	Suspended Sediment Concentration
STORET	STOrage and RETrieval (EPA's Water Quality database)
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total organic carbon
TSS	Total Suspended Solids
TTS	Turbidity Threshold Sampling
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
VCF	Vertical at centroid of flow
WASA	Washington Area Sewer Authority
WOTR	Wolf Trap National Park for the Performing Arts
WRD	Water Resources Division (National Park Service)
WSP	Water Supply Paper
WTP	Water Treatment Plant
YSI	Yellow Springs Instruments

Executive Summary

In 2005, the National Capital Region Inventory and Monitoring Network (NCRN) initiated a long-term water quality and quantity monitoring program, funded in part by the Water Resources Division. The program is carried out through monthly sampling at more than 40 sites within 10 of the NCRN parks. The FY2007 - 2008 Annual Report on water quality in the National Capital Region parks focuses on data collected under the Surface Water Dynamics Protocol (2007) and the Water Chemistry Monitoring Protocol (2007) of the NCRN I&M Program.

Parks monitored for this report include Antietam National Battlefield(ANTI), Catoctin Mountain Park(CATO), Harpers Ferry National Historical Park(HAFE), George Washington Memorial Parkway(GWMP), Manassas National Battlefield Park(MANA), Monocacy National Battlefield(MONO), National Capital Parks – East (NACE), Prince William Forest Park(PRWI), Rock Creek Park(ROCR), and Wolf Trap National Park for the Performing Arts(WOTR). The streams monitored are all part of the Potomac River Watershed. The Potomac is the second largest drainage of the nine river basins that form the 64,000 square mile Chesapeake Bay watershed.

Water chemistry is important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans. Water quality can provide insights into overall system productivity, shift species abundances and distributions, and alter nutrients cycles. Water quality parameters such as pH, specific conductance, dissolved oxygen, and temperature are good measurements that provide an overview of water quality. Water quality monitoring is required to comply with relevant environmental legislation and NPS mandates and to evaluate potential stressors in NCRN waters.

Acid neutralizing capacity (ANC) always failed to meet desired condition in Carters Run (PRWI) and only occasionally failed in Hardings Run (MONO), Sow Run, Mawavi Run, and Taylor's Run (PRWI). In the 2006 report we stated that none of the parks or their streams were in danger of succumbing to acidification. Carter's Run was not monitored in 2005. This stream was added at the beginning of FY 2007. Neither Sow Run nor Hardings Run indicated acidification problems in FY2006. Very few corresponding undesirable pH measurements were found in 2007 – 2008: Turkey Run and Pimmit Run (GWMP), Flowing Springs (HAFE) above 8.5, Dogans Branch and Youngs Branch (MANA), Bush Creek and Gambril Mill (MONO), Henson Creek and Oxon Run (NACE)

Dissolved oxygen (DO) met threshold more often in 2007-2008 than in 2005-2006. Fenwick Branch, Normanstone Creek, Rock Creek, Fenwick Branch, and Luzon Branch (ROCR), Still Creek and unnamed tributary of Accokeek Creek (NACE) and Wolf Trap Creek had incidents of low DO.

Ammonia rarely exceeded threshold. Exceedances occurred occasionally in Broad Branch, Fenwick branch, and Pinehurst Branch (ROCR), Ft. Dupont, Oxon Run, and Still Creek (NACE), and Wolf Trap Creek.

Nitrate exceeded threshold occasionally in Sharpsburg Creek, Flowing Springs, all MONO streams, all NACE streams except UT Accokeek Creek, and Wolf Tap Creek. Nitrate always exceeded the threshold in GWMP's Minnehaha Creek.

One of the major findings, though not unexpected, of this program is that phosphorus levels across all sites exceed the ecological eutrophication threshold 78.5% of the time. Though this is a decrease from the previous years' data, it is still a concern. Several of the sites also showed elevated levels of nitrate that failed to meet desired condition, though this was much decreased from the previous year. Nitrate and phosphorus are nutrients of primary concern in efforts to improve the ecological condition of the Potomac River and the Chesapeake Bay. Sources for these nutrients are not known.

Upon reviewing four years of hydrology data, the following sites were found to have intermittent flow and were dropped from the sampling pool: Hardings Run in MONO, Chinns Branch, Dogans Branch and Holkums Branch in MANA, Ft. Dupont and the unnamed tributary of Accokeek Creek. The following streams, though to all appearances perennial, did go dry during the drought of 2006- 2007 and therefore bear future consideration as to their flow status: Flowing Springs (HAFE), Gambrill Mill Creek (MONO), Whiskey Still Creek (CATO), Owens Creek (CATO), Youngs Branch (MANA), Sow Run, Taylors Run, Carters Run, Mary Bird Branch (PRWI), Pinehurst Branch, Luzon Branch, Broad Branch, Hazen Creek, Piney Branch, and Palisades Creek (ROCR), Still Creek and Oxon Run (NACE), Wolf Trap Creek and Courthouse Creek (WOTR).

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

Introduction

Almost all of the parks in the National Capital Region Inventory and Monitoring Network (NCRN I&M) lie within the Potomac River watershed with the exception of parts of the Suitland Parkway and Baltimore and Washington Parkway within National Capital Parks – East (NACE), which are located in the Patuxent River watershed.

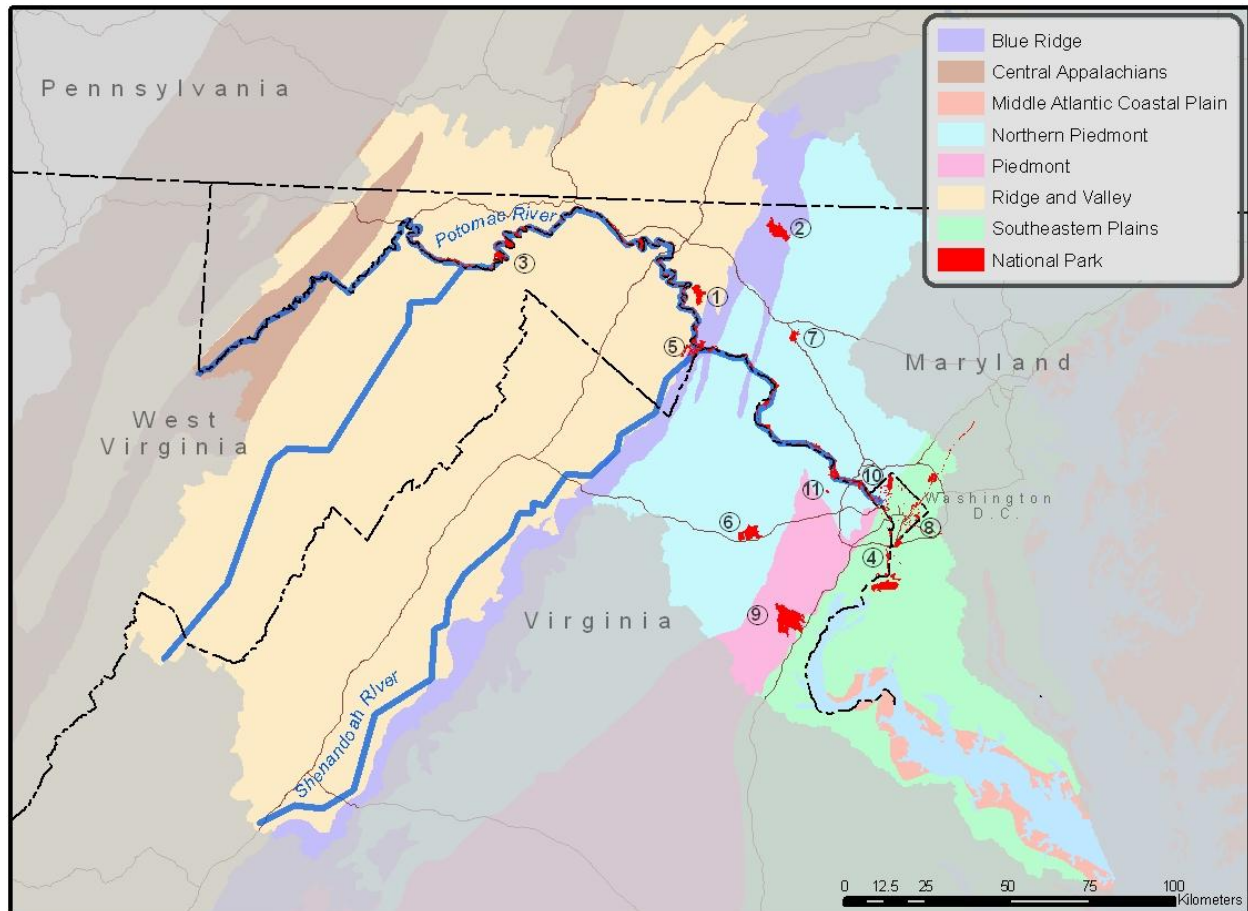


Figure 1 : Locations of the National Parks (red) in the National Capital Region within the Potomac River watershed (brighter outline within map) and Patuxent River watersheds:

The Level III Ecoregions (Woods et al. 1999) are indicated by the pastel areas.

1. Antietam National Battlefield (ANTI);
2. Catocin Mountain Park (CATO);
3. Chesapeake & Ohio Canal National Historical Park (CHOH);
4. George Washington Memorial Parkway (GWMP);
5. Harpers Ferry National Historical Park (HAFE);
6. Manassas National Battlefield Park (MANA);
7. Monocacy National Battlefield (MONO);
8. National Capital Parks–East (NACE);
9. Prince William Forest Park (PRWI);

10. Rock Creek Park (ROCR); and
11. Wolf Trap National Park for the Performing Arts (WOTR).

The Potomac River Watershed covers seven physiographic regions and subregions: Blue Ridge, Central Appalachians, Middle Atlantic Coastal Plain, Northern Piedmont, Piedmont, Ridge and Valley, and the Southeastern Plains (see figure 2). Though several parks (CHOH, GWMP, HAFE, and NACE), are adjacent to the river, the parks do not manage the waters of the Potomac. The Potomac is the second largest drainage of the nine river basins that form the 64,000 square mile Chesapeake Bay watershed. The Chesapeake Bay is the largest estuary in the United States, providing habitat for abundant and diverse wildlife populations and supporting an economy that includes fishing, shipping, and recreation (1999). The National Park Service is a co-signer of the Chesapeake Bay Agreements for restoration of the Chesapeake Bay.

The NCRN's long-term water monitoring program, funded in part by the Water Resources Division (WRD), is designed to ensure the National Capital Region's (NCR) parks possess science-based information needed for effective natural resource management. To achieve this, program staff collect data for the following vital signs¹:

- water chemistry
- nutrient dynamics
- surface water dynamics
- physical habitat index
- aquatic macroinvertebrates
- fish

A Water Chemistry Monitoring Protocol was developed in house which includes nutrient dynamics. In collaboration with the USGS, we developed a Surface Water Dynamics protocol (Norris et al. 2008), and in collaboration with researchers from Frostburg State University and The Maryland Department of Natural Resources, we worked to adapt the Maryland Biological Stream Survey (MBSS) (Kazyak et al. 2007) for use in NCRN parks, which includes the physical habitat index, aquatic macroinvertebrates, and fishes vital signs (Norris and Sanders 2009). This year's report will contain the Water chemistry monitoring and Surface Water Dynamics data. Data analysis on the Biological Stream Survey (BSS) data will be published every six years when a full survey of the parks is completed. The next BSS summary report is expected in 2014.

Measurable Objectives of the Water Quality and Quantity Monitoring Protocol:

1. Assess variance in temperature, specific conductance, pH, dissolved oxygen, nutrients and ANC in priority streams of the NCRN, on a diurnal and seasonal basis as well as over the long term.

¹ Vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park.

2. Assess trends in temperature, specific conductance, pH, dissolved oxygen, nutrients and ANC within and between watersheds and stream orders with reference to (a) urban reference streams drawn from MBSS and/ or National Water Quality Assessment Program (NAWQA) data in the region and/or (b) comparison of current to past condition.
3. Assess stream condition by identifying single parameters with values out of bounds (a) biologically (determined through literature search), (b) according to drinking water standards, (c) according to EPA and State designated use standards, or (d) of previous variability
4. Monitor the flow volume (discharge) of surface water in major streams of the NCRN parks.
5. Assess the availability of sufficient water for ecological, recreational, and aesthetic purposes of the parks.
6. Develop rating curves for a range of environmental conditions, land use and weather patterns, for each water body (e.g., compare a drought year vs. an El Niño year) in order to gain an overall understanding of hydrologic systems within the NCRN.
7. Determine seasonal and annual trends.
8. Provide support data for other Vital Signs indicators in order to help understand trends in aquatic species populations, pollution transport, erosion/deposition, and other natural processes and features.
9. Share data with state and local groups for Total Maximum Daily Loads (TMDL) and other regulatory decision purposes.

Methods

Sampling Design

The Water Quality Monitoring Program funded by WRD is primarily interested in 1st to 4th order wadeable non-tidal freshwater streams in the parks of NCRN. The sample design for streams is based on stream location (defined at a scale of 1:24,000) bisected by park boundaries. Since water chemistry monitoring sites serve as the pool from which the biological sampling sites are chosen, in-park stream segments less than 75m long were eliminated (the length used for MBSS sampling). Sampling of streams focuses on those segments of streams that are the furthest downstream and still in park boundaries. Measurements downstream generally reflect conditions in the watershed upstream. It was initially envisioned that once the list of potential monitoring locations was developed; a randomization process would be used to determine which sites would be sampled. However the final list was short enough that rather than a random subset, all sites are sampled .

During the 2007-2008 sampling season a total of 45 sites were sampled. These sites will continue to be monitored every month for the extent of this program. Additional sites that were initially rejected due to uncertainty about their flow status (perennial or ephemeral) were added

in the 2007-2008 sampling season. Park Personnel and outside researchers have noted that the National Hydrography Dataset (NHD) is missing a few streams known to be perennial and contain sufficient flow to support fish and that many of the streams depicted as 1st order are ephemeral or never contain flow. Several streams were dropped upon review of the hydrologic data presented in this report.

No sites are monitored in CHOH at this time. The linear nature of the park and the large number of streams that cross it provide additional challenges to water monitoring. Each individual stream is within the park for only a short distance, and drains only a small portion of the park. Due to these factors the park has little control over the water quality of most of these streams, and each individual stream has a small impact on the park as a whole. Therefore it is difficult to design an appropriate sampling effort that is both affordable and meaningful. However, the unique orientation of the park and its length may actually be a benefit with respect to water sampling. The state of Maryland's Department of Natural Resources has a comprehensive biological sampling program that is spatially and temporally designed to provide statistically valid estimates of stream health across the state and within specific watersheds based on a stratified random sampling design. In future versions of this report we will attempt to summarize this data collected by the state and local governments.

One of the biggest advantages of using a modified version of the Maryland Biological Stream Survey to sample waters in the region is that all of the data is collected in the same way; the only thing that differs is the spatial design of the sampling in the parks. For example, 169 locations in Allegheny County watersheds draining into the Potomac River have been sampled during the two rounds of MBSS sampling so far, and additional sites are planned for the next round. Any data collected in ANTI, HAFE, MONO, CATO, ROCR, or the Clara Barton parkway of GWMP would also apply to a water quality summary for CHOH, since their streams flow into watersheds that cross the park. For more information see the Biological Stream Survey Protocol for the NCRN (Norris and Sanders 2009).

Table 1: Water Chemistry Monitoring Sites for 2007-2008 excluding CHOH streams

Site	Watershed	Physiographic Region	State	County	Stream Order
Antietam National Battlefield					
Sharpsburg Creek	Antietam Creek	Ridge and Valley	MD	Washington	1
Catoctin Mountain Park					
Big Hunting Creek	Upper Monocacy River	Blue Ridge	MD	Frederick	2
Owens Creek	Upper Monocacy River	Blue Ridge	MD	Frederick	2
Whiskey Still Creek	Upper Monocacy River	Blue Ridge	MD	Frederick	1
George Washington Memorial Parkway					
Difficult Run	Difficult Run	Northern Piedmont	VA	Fairfax	5
Minnehaha Creek	Cabin John	Northern Piedmont	MD	Montgomery	2
Mine Run	Difficult Run	Northern Piedmont	VA	Fairfax	2
Pimmit Run	Rock Creek	Northern Piedmont	VA	Arlington	3
Turkey Run	Difficult Run	Northern Piedmont	VA	Fairfax	2

Site	Watershed	Physiographic Region	State	County	Stream Order
Harpers Ferry National Historical Park					
Flowing Springs Run	North Fork Shenandoah River	Ridge and Valley	WV	Jefferson	2
Manassas National Battlefield					
Chinn Branch	Bull Run	Northern Piedmont	VA	Prince William	2
Dogan Branch	Bull Run	Northern Piedmont	VA	Prince William	1
Holkums Branch	Bull Run	Northern Piedmont	VA	Prince William	2
Youngs Branch	Bull Run	Northern Piedmont	VA	Prince William	3
Monocacy National Battlefield					
Bush Creek	Lower Monocacy River	Northern Piedmont	MD	Frederick	3
Hardings Run	Lower Monocacy River	Northern Piedmont	MD	Frederick	1
Gambrill Mill (Visitor's Center) Creek	Lower Monocacy River	Northern Piedmont	MD	Frederick	2
National Capital Parks – East					
Fort DuPont	Anacostia River	Southeastern Plains	MD	Prince Georges	1
Henson Creek	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Oxon Run	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Still Creek	Anacostia River	Southeastern Plains	MD	Prince Georges	1
Unnamed Tributary to Accokeek Creek	Middle Potomac Tidal	Southeastern Plains	MD	Prince Georges	1
Prince William Forest Park					
Carter's Run	Quantico Creek	Southeastern Plains	VA	Prince William	1
Mawavi Run	Quantico Creek	Piedmont	VA	Prince William	1
Mary Bird Branch	Quantico Creek	Southeastern Plains	VA	Prince William	2
Middle Branch Chopawamsic Creek	Quantico Creek	Piedmont	VA	Stafford	2
North Branch Chopawamsic Creek	Quantico Creek	Piedmont	VA	Prince William / Stafford	2
North Fork Quantico Creek	Quantico Creek	Southeastern Plains	VA	Prince William	2
South Fork Quantico Creek	Quantico Creek	Southeastern Plains	VA	Prince William	3
Sow Run	Quantico Creek	Piedmont	VA	Prince William	2
Taylor Run	Quantico Creek	Piedmont	VA	Prince William	1
Rock Creek Park					
Broad Branch	Rock Creek	Northern Piedmont	DC	Washington	2
Dumbarton Oaks	Rock Creek	Northern Piedmont	DC	Washington	1
Fenwick Branch	Rock Creek	Northern Piedmont	DC	Washington	2
Hazen Creek	Rock Creek	Northern Piedmont	DC	Washington	1
Luzon Branch	Rock Creek	Northern Piedmont	DC	Washington	1
Normanstone Creek	Rock Creek	Northern Piedmont	DC	Washington	1
Palisades Creek	Rock Creek	Northern Piedmont	DC	Washington	1
Pinehurst Branch	Rock Creek	Northern Piedmont	DC	Washington	1

Site	Watershed	Physiographic Region	State	County	Stream Order
Piney Branch	Rock Creek	Northern Piedmont	DC	Washington	1
Rock Creek above Fenwick Branch	Rock Creek	Northern Piedmont	DC	Washington	4
Rock Creek below Dumbarton Oaks	Rock Creek	Northern Piedmont	DC	Washington	4
Soapstone Valley Park Stream	Rock Creek	Southeastern Plains	DC	Washington	1
Wolf Trap National Park for the Performing Arts					
Wolf Trap Creek	Difficult Run	Northern Piedmont	VA	Fairfax	2
Courthouse Creek	Difficult Run	Northern Piedmont	VA	Fairfax	1

Sampling Frequency and Replication

All parameters are measured monthly, as stream condition permits. Any gaps in sampling data are described along with each park's monitoring results and are summarized for the year in the Executive Summary.

Data Collection

We collect data for temperature, dissolved oxygen (DO), specific conductance, pH, acid neutralizing capacity (ANC), nutrients (ammonia, nitrate, and total phosphorus), discharge, depth, velocity, wetted width and flow (Norris et al. 2008). These parameters provide information that characterize a waterbody or stream segment, are fundamental components of monitoring and regulatory programs, and are relatively easy to measure with multi-parameter probes or Hach test kits. The Water Resources Specialist and Hydrologic Technician collect in situ data with handheld meters once a month at every perennial wadeable stream (Table 1) in the parks for temperature, dissolved oxygen, specific conductance, and pH. Discharge, depth, velocity, wetted width and flow are collected with a Sontek Flowtracker. At the same time samples are collected and brought back to the lab for acid neutralizing capacity analysis by titration with HACH reagents ammonia, nitrate, and total phosphorus analysis using Hach reagents and equipment. Sites are photographed during each sampling visit to provide a visual record of existing conditions.

Parameters

The NCRN collects data for water temperature, dissolved oxygen, specific conductance, pH, acid neutralizing capacity, ammonia, nitrate, total phosphorus, wetted width, water depth, flow, and discharge (Table 2). These parameters provide information that characterize a water body or stream segment, are fundamental components of monitoring and regulatory programs, and are relatively easy to measure with multi-parameter probes or Hach test kits. Parameters are described in detail below. Park specific information for each parameter is included in each park's summary.

Table 2: Date range, number of site visits (N), and data range for the information covered in this report for NCRN.

Parameter	Units	Period of Record	N	Minimum	Maximum	Mean	Standard Deviation
Air Temperature	°C	10/2/2006 - 9/23/2008	759	-8	35	17	10
ANC	µeq/L	10/2/2006 - 9/23/2008	837	24	5320	1330	1091
Discharge	cfs	10/2/2006 - 9/23/2008	446	0	123	5	11
DO	mg/l	10/2/2006 - 9/23/2008	844	1.7	20.0	8.7	2.4
Flow	ft/sec	10/2/2006 - 9/23/2008	466	0.00	2.24	0.44	0.44
Nitrate	mg/l	10/2/2006 - 9/23/2008	827	0.0	13.5	2.1	1.9
Ammonia	mg/l	10/2/2006 - 9/23/2008	496	0.0	13.5	0.1	0.6
pH	None	10/2/2006 - 9/23/2008	807	4.64	9.61	7.54	0.56
Phosphate	mg/l	10/2/2006 - 9/23/2008	837	0.05	8.80	0.44	0.67
Salinity	ppt	10/2/2006 - 9/23/2008	853	0.0	1.8	0.2	0.2
Specific Conductance	µS/cm	10/2/2006 - 9/23/2008	854	0	3528	389	309
Water Depth	ft	10/2/2006 - 9/23/2008	516	0	4	0	0
Water Temperature	°C	10/2/2006 - 9/23/2008	844	0.1	29.6	13.4	6.5
Wetted Width	ft	10/2/2006 - 9/23/2008	739	0	100	14	12

pH

The pH of water directly affects physiological functions of plants and animals, and is, therefore, an important indicator of the health of a water system (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). pH is measured to determine the acid/base characteristics of water and is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem 1989). The term pH literally means “power of hydrogen.” The more hydrogen ions that are available for reaction, the lower the pH. The concentration of these ions is measured on a log scale that most commonly ranges from 0 (acid) to 14 (base / alkaline), so each pH unit increase represents a 10X decrease in hydrogen ion concentration. Pure water has a pH of 7 (neutral), which means that it is equally able to accept or donate hydrogen ions. At pH < 7, (acid) hydrogen ions are more readily donated (Hem 1989, Stednick and Gilbert 1998).

Generally, dissolution of carbon dioxide to carbonic acid is the most important acidifying factor in extremely fresh natural waters to affect pH (~ pH of 6) in the absence of some other site-specific conditions. However, most natural (fresh and salt) waters are slightly basic (~pH of 8) due to the presence of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-). In freshwater, the $\text{CO}_2 \rightleftharpoons \text{HCO}_3^- \rightleftharpoons \text{CO}_3^{2-}$ equilibrium serves as the primary buffering mechanism. In natural waters, carbonic acid is the main source of hydrogen ions, resulting in a pH of 5.7. Rain-water normally is acid because of its carbon dioxide content and naturally occurring sulfate. Normally these acids are neutralized as rain-water passes through the soil. In catchments of hard rocks, little buffering capacity, and high surface water (as opposed to groundwater) inputs, stream water will be acid even if pollution is absent. Organic acids also contribute to low pH values. Industrial activity has contributed to acid precipitation in many areas. Strong inorganic acids H_2SO_4 and HNO_3 , formed in the atmosphere from oxides of sulfur and nitrogen, have dramatically lowered surface water pH in large areas of Europe and North America, especially in granitic drainages with poor buffering capacity Hem 1989, Stednick and Gilbert 1998).

The pH of water is important in the toxicity and solubility of many constituents. The ideal natural range of pH for aquatic life in streams is 6.5 to 9. Freshwaters can vary widely in acidity

and alkalinity due to natural causes as well as anthropogenic inputs. Extreme pH values, generally those much below 5 or above 9, are harmful to most organisms, and the buffering capacity of water is critical to life. Estimating the toxicity of ammonia, aluminum, and some other contaminants requires accurate pH values. Increases or decreases in pH from their normal range into extreme ranges can result in severe harm to aquatic life (Hem 1989). Changes in pH affect the dissociation of weak acids or bases, which in turn affects the toxicity of many compounds. For example, hydrogen cyanide toxicity to fish increases with lowered pH; rapid increases in pH increase NH₃ concentrations; and the solubility of metal compounds is affected by pH. Metals mobility is also enhanced by low pH which can have a significant impact to water bodies located in areas contaminated by heavy metals (e.g. mining). The desired range of pH for fish depends upon many other factors such as temperature, DO, and the content of various anions and cations. The importance of pH as a parameter for monitoring is reflected by potential impacts to the life cycle stages of aquatic macroinvertebrates and certain salmonids that can be adversely affected when pH levels above 9.0 or below 6.5 occur. Temporal causes of variation of pH can range from primary production by fauna and flora (diurnal and seasonal) to fractionation during snowmelt, changes in runoff processes, and changes in atmospheric deposition (monthly and/or seasonal) (MacDonald et al. 1991).

Limestone (CaCO₃) and dolomite (CaMg(CO₃)₂) are ionic salts that dissociate in pure water to their constituent ions: Ca²⁺ and CO₃²⁻; Ca²⁺ + Mg²⁺ + 2 CO₃²⁻. Groundwater in karst areas can also contain sulfate ions from gypsum beds and weathered sulfite materials, chlorides from deeper circulating ground water, sodium, potassium, dissolved oxygen. There is another background carbonate-bicarbonate-carbonic acid dissolution equilibrium that occurs in most fresh surface waters and provides the buffering against low pH that is known as acid neutralizing capacity. The carbonates and bicarbonates that occur in surface waters neutralize the pH to between 6.5 and 7.5. The calcite and dolomite ions' dissolution increases this carbonate buffering, increasing the pH of the water above neutral to 8 and even 9. This increase in dissolved ions also increases the specific conductance .

NCRN used a Yellow Springs International handheld meter, model number 63 to measure the pH at each site in FY 2007-2008.

Acid Neutralizing Capacity (ANC)

ANC is the prime indicator of a waterbody's susceptibility to acid inputs. ANC is a measure of the amount of carbonate and other compounds in the water that neutralize low pH. ANC refers to the alkalinity of an unfiltered water sample (i.e. alkalinity due to both dissolved and suspended matter). The pH of water does not indicate its "buffering capacity", which is controlled by the amounts of alkalinity and acidity present. ANC is typically caused by anions in natural waters that can enter into a chemical reaction with a strong acid. These are primarily the carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻) ions. Dissolution of these species is most typically caused by the partial pressure of CO₂ in the atmosphere but their presence may be further elevated in areas of carbonate rock dissolution where waters are often of a bicarbonate type (elevated in HCO₃⁻). Borates, phosphates, silicates, arsenate, ammonium, and organic ligands (e.g. acetate and propionate) can also contribute to alkalinity when present. However, except for unusual natural waters or waters significantly impacted by anthropogenic sources, non-carbonate ionized contributors are rarely present in large enough quantities to affect alkalinity or ANC

determinations (Wilde and Radtke 1998). It is particularly important to measure in areas where acid mine drainage (e.g. PRWI) or acid precipitation (entire NCR) is a potential concern. Acid sensitive waters generally have specific conductance below 25 $\mu\text{S}/\text{cm}$, acid neutralizing capacity (ANC) below 100 $\mu\text{eq}/\text{L}$ for episodic acidification (50 $\mu\text{eq}/\text{L}$ for chronic acidification), total base cation (calcium, magnesium, sodium, and potassium) concentration below 100 $\mu\text{eq}/\text{L}$, and pH below 6.0. Turk and Spahr (1989) state that surface waters with ANC less than or equal to 200 $\mu\text{eq}/\text{L}$ are considered sensitive to acidification. In karst terrain, ANC below 600 $\mu\text{eq}/\text{L}$ CaCO_3 is cause for concern. NPS-WRD (1995, 1996, 1997) indicates that surface waters in three parks—ANTI, CHOH and MANA were not susceptible to acidification from atmospheric deposition. However this data ranges in age from 8 to 30 years and circumstances may have changed.

In FY 2009 NCRN used Hach Alkalinity Method 8203 (Sulfuric Acid Method) to determine phenolphthalein and total alkalinity which are used to calculate the acid neutralizing capacity.

Specific conductance

Specific conductance is the electrical conductivity of an aqueous solution (in this case stream water) and is directly related to concentration of ionic species. Conductivity is a measure of the capacity of water to conduct an electrical current and is a function of the types and quantities of dissolved, electrically charged substances (ions) in water (Radtke et al. 1998). The conductivity of solutions of ionic species is highly dependent on temperature and may change as much as 3% for each 1°C change. Thus a significant apparent change in conductivity may simply be a function of the water body's diurnal or seasonal temperature change. In addition, the temperature correction coefficient itself varies with the charge and abundance of the ionic species present (e.g. Na^+ vs Ca^{2+}) so no universally applied algorithm will be exact. A raw conductivity value is not temperature compensated making it difficult to compare measurements of the same or different water bodies when not at the same temperature (e.g. conducting trend analysis over time). When the raw conductivity measurement of a substance is normalized to unit length and unit cross-section at a specified temperature (e.g. a compensation temperature of 25 °C), it is called specific conductance (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). Specific conductance is dependent upon the types and quantities of dissolved substances and is a good indication of total dissolved solids (TDS) and total ion concentration.

Specific conductance is useful in estimating the concentration of dissolved solids in water. Electric current is carried by dissolved inorganic solids such as chloride, carbonate, nitrate, sulfate and phosphate anions (negatively charged particles), as well as sodium, calcium, magnesium, potassium, iron, and aluminum cations (positively charged particles). Common sources of pollution that can affect specific conductance are deicing salts, dust reducing compounds, agriculture (primarily from the liming of fields) and acid mine drainage (AMD) associated with mining operations (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). Organic materials such as oils, phenols, alcohols, and sugars do not carry electric current.

The electrical conductivity of a water body has little or no direct effect on aquatic life but because it is essentially due to the sum of all ionic species, its change (increase) may be detrimental if the particular ionic species or groups of ionic species (e.g. specific salts) causing

the change is toxic to aquatic life. Small quantities of mineral salts are usually contained in natural inland waters, but in waters polluted by brines and various chemical wastes, salt concentrations may rise to levels harmful to living organisms due to the increase in osmotic pressure. Salinity is often expressed as specific electrical conductance in studies of waters used for irrigation and fish production. Collectively, all substances in solution exert osmotic pressure on the organisms living in it, which in turn adapt to the condition imposed upon the water by its dissolved constituents. With excessive salts in solution, osmotic pressure becomes so high that water may be drawn from gills and other delicate external organs resulting in cell damage or death of the organism (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002). The Maryland Biological Stream Survey has found that fish exhibit stress at specific conductances greater than 400 $\mu\text{S}/\text{cm}$ (Morgan II and Cushman 2005).

NCRN averaged multiple measurements displayed by both YSI handheld meters, model numbers 63 and 85 in FY 2007-2008 to determine the specific conductance at each site.

Salinity

Salinity is an important unit-less property of industrial and natural waters. It was originally conceived as a measure of the mass of dissolved salts in a given mass of solution. The only reliable way to determine the true or absolute salinity of natural water is to make a complete chemical analysis. However this method is time-consuming and precision is limited. To determine salinity one normally uses indirect methods involving the measurement of a physical property such as conductivity, density, sound speed, or refractive index. From an empirical relationship of salinity and the physical property determined for a standard solution it is possible to calculate salinity. The resultant salinity is no more accurate than the empirical relationship. The precision of the measurement of a physical property will determine the precision in salinity. Although conductivity has the greatest precision (± 0.0002), it responds only to ionic solutes. Density, though less precise ($\pm 3 \times 10^{-6} \text{ g}/\text{cm}^3$), responds to all dissolved solutes (Eaton et al. 2005).

Salinity refers to the sum of the concentrations of all dissolved ions, and so is a more inclusive term than TDS, although for all practical purposes it is the same quantity. In urban areas, the runoff of salts and other deicing compounds applied to roads can significantly elevate the salinity of receiving waters and cause large fluctuations at short time scales. In the United States, some 1-15 million tons of road salt are used each year (Benbow and Merritt 2005), primarily in the Northeast and Midwest, and quantities have increased dramatically since 1950 (Jackson and Jobbágy 2005). Kaushal et al. (2005) report chloride concentrations as high as 25% of seawater in some northeastern streams during winter, and the long-term trend is increasing (Allan and Castillo 2007). Freshwater is defined as 0.5 ppt salinity or less. Water with a salinity above 0.5 ppt is considered brackish.

NCRN averaged multiple measurements displayed by both YSI handheld meters, model numbers 63 and 85 in FY 2007-2008 to determine the salinity at each site.

Nitrogen

Nitrogen in surface water may occur in dissolved or particulate form and result from inorganic or organic sources. The dissolved, inorganic forms of nitrogen most available for biological uptake

and chemical transformation that can lead to eutrophication of water bodies are ammonia (NH_3), ammonium ion (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-).

Nitrogen-Ammonia

Ammonia is a major limiting nutrient in most aquatic systems, an increase of which may result in eutrophication. It is typically indicative of agricultural pollution or anaerobic degradation of nitrogen containing compounds such as humic matter or urea from animal or human waste (agricultural waste lagoons or POTWs). Ammonia (NH_3) is a more toxic form of nitrogen with an aquatic life toxicity that varies with pH and temperature. Ammonia is also bioavailable to plants including phytoplankton. When ammonium ions are in high concentrations in natural waters containing oxygen, it is oxidized to nitrate by bacteria in the nitrification process. This microbial facilitated redox reaction consumes oxygen at a ratio of 4.5 mg of O_2 to every 1 mg of NH_4^+ , thus rapidly depleting available oxygen for aquatic organism respiration. At higher pH (above 7.5 or 8.0), the $\text{NH}_4^+ \rightleftharpoons \text{NH}_3$ equilibrium reaction begins to favor ammonia, which is directly toxic to aquatic life because it may be taken up through membranes, and interferes with cell metabolism. Higher temperatures also favor the uptake of ammonia (movement across membranes, e.g. gills) by aquatic organisms causing the CCC for aquatic organisms to be lowered as temperature increases. The lowest value for CCC is 0.442 mg/L NH_3 , which we use as our threshold (EPA 2000).

NCRN used Hach Methods 10023 (Nitrogen, ammonia, Salicylate Method, Low-Range Test 'N Tube) and 10031 (Nitrogen, ammonia, Salicylate Method, High-Range Test 'N Tube) to determine the concentration of ammonia in a sample in FY 2009.

Nitrogen-Nitrate

Nitrate is the oxidized form of aqueous nitrogen reported as mg/L NO_3 or mg/L $\text{NO}_3 - \text{N}$. Nitrate is a bioavailable form of nitrogen which aquatic plants can absorb and incorporate into proteins, amino acids, nucleic acids, and other essential molecules. Nitrate is highly mobile in surface and groundwater and may seep into streams, lakes, and estuaries from groundwater enriched by animal or human wastes and commercial fertilizers. High concentrations of nitrate can enhance the growth of algae and aquatic plants in a manner similar to enrichment in phosphorous and thus cause eutrophication of a water body. Nitrate also presents a human health concern particularly to infants that can develop blue-baby syndrome at relatively low levels of nitrate in water supplies. In most natural waters, inorganic nitrogen as ammonium or nitrate is not the growth-limiting nutrient unless phosphorous is unusually high (see section below for sensor discussion). Nitrate is typically indicative of agricultural pollution. Nitrate in surface water is considered a nutrient and may occur in dissolved or particulate form resulting from inorganic sources. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation. The drinking water standard is 10 mg/L. Nitrate also travels freely through soil and therefore may pollute ground waters. Nitrate above 2.0 mg/L can lead to eutrophication of water bodies (EPA 2000).

Hach Method 10020 (Nitrate, Chromotropic Acid Method, Test 'N Tube) is currently utilized to determine nitrate levels and has been since July 2007. During the month of July 2007, NCRN utilized Hach Method 8171 (Nitrate, Cadmium Reduction Method, Mid-Range AccuVac ampuls) to determine nitrate levels after all reagents were lost to a refrigeration malfunction and resulting

mold infestation. NCRN previously utilized Hach Methods 8039 (Nitrate, Cadmium Reduction Method, High-Range powder pillows), 8171 (Nitrate, Cadmium Reduction Method, Mid-Range powder pillows), and 8192 (Nitrate, Cadmium Reduction Method, Low-Range powder pillows) to determine nitrate levels from May 2005 until July 2007.

Phosphate

Phosphate is frequently a limiting nutrient in aquatic systems. A minor increase in phosphorous concentration can significantly affect water quality by changing the population and community dynamics of algae and diatoms leading to eutrophication (Allan 1995). Sources of phosphorous include sediments, fertilizer application (e.g. irrigation return flow), soaps, and detergents. The published threshold for eutrophication of flowing surface waters is 0.1 mg/L PO₄ (EPA 2000).

Hach Method 8048 (Phosphorus, reactive, PhosVer 3 Method, Low-Range Test 'N Tube) is currently being de-activated as the utilized methodology for determining phosphorus levels. This test will continue to be used for QA/QC purposes until all stocks are depleted. This test has been used since March 2007. Data collection with the two methods (PhosVer3 and Amino Acid) overlapped from March through July 2007. Data from both states are located on the data sheets. For the month of July 2007, NCRN utilized AccuVac ampuls (Hach method 8048) after all reagents were lost to a refrigeration malfunction and resulting water and microbe contamination. NCRN previously utilized Hach Method 8190 (Phosphorus, total digestion, Organic and Acid Hydrolyzable, Acid Persulfate Digestion Method) and Hach Method 8178 (Phosphorus, reactive, Orthophosphate, Amino Acid Method) to determine phosphorus levels from May 2005 until July 2007. In January 2007, glassware maintenance changed from acid triple rinse and the reuse of analytical values to >48 hour leaching and the one-time-use of disposable analytical vials

Dissolved Oxygen (DO)

DO is a measure of the amount of oxygen in solution. DO enters the water one of two ways—photosynthesis of plants and directly from the atmosphere via diffusion or mechanical aeration (e.g., waves, waterfalls). The primary losses of DO from water are respiration and biochemical oxygen demand (BOD). Dissolved oxygen (DO) concentration of surface water is dependent on water temperature and air pressure, and, to a lesser extent, the amount of dissolved ions (measured as salinity or conductivity - correction factors for salinity are normally applied after measuring DO). The higher the pressure and cooler the temperature, the more oxygen from the atmosphere can be dissolved into the water until a balance or equilibrium is reached; this is called saturation (Hem 1989, Radtke et al. 1998). Oxygen has strong daily and seasonal variability. In organically enriched streams, DO is often lowest just before sunrise because plants have not been photosynthesizing and only respiration has been occurring. Conversely, DO increases after sunrise until the sun's angle of incidence is greatest because the rate of photosynthesis is dependent on sunlight. In less enriched streams, this pattern may be less apparent or absent because stream temperatures are lower at night and thus can contain more dissolved oxygen. Therefore it is important to always monitor a particular site at the same time of day. Because oxygen is sparingly soluble, the balance between sources and sinks can be easily upset leading to oxygen extremes of supersaturation or total/near total depletion (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002).

DO is necessary in aquatic systems for the survival and growth of many aquatic organisms. The presence and amount of dissolved oxygen in surface water also determines the extent to which many chemical and biological reactions will occur (Wilde and Radtke 1998). Low dissolved oxygen is of greatest concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation and shallow gradients (streams), organic matter inputs, and high respiration rates. Decay of excessive organic debris that are in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause dissolved oxygen concentrations to be undersaturated or depleted. Insufficient DO can lead to unsuitable conditions for aquatic life, and its absence can result in the unpleasant odors associated with anaerobic decomposition. Furthermore, the presence of toxic substances such as cyanides and some metals can exacerbate the lethal effects of low concentrations of DO. Minimum required DO concentration to support fish varies because the oxygen requirements of fish vary with a number of factors, including the species and age of the fish, prior acclimatization, temperature, and concentration of other substances in the water.

It is essential that consideration of the natural regimes of DO be included in applying criteria to specific water bodies. Higher absolute concentrations of dissolved oxygen (mg/L) at saturation are achievable in the natural environment under conditions of higher atmospheric pressure and lower temperature and lower dissolved solids content of the water. Thus, water bodies occurring at higher elevations, subject to a barometric low pressure system, or having warmer temperatures and/or higher dissolved solids content would be expected to contain less dissolved oxygen at saturation. Supersaturation of surface water with respect to dissolved oxygen may also result from turbulence associated with high gradient streams or waterfalls. In rocky, high gradient streams, mechanical aeration is often great enough that even streams with highly elevated oxygen demand are at or near saturation levels. In low gradient coastal plain systems, even moderate oxygen demand (referred to as BOD or biochemical oxygen demand) can result in DO levels that are low enough to harm aquatic biota (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002).

When DO drops below 5 mg/L early life stages and sensitive species become stressed. Because oxygen is sparingly soluble, the balance between sources and sinks can be easily upset leading to oxygen extremes of supersaturation or total/near total depletion (U.S. Geological Survey 1980, Stednick and Gilbert 1998, National Park Service 2002).

NCRN used a Yellow Springs Institute (YSI) handheld meter model number to measure the percent saturation and concentration of dissolved oxygen

Wetted Width

Wetted width is measured from water's edge to water's edge of the stream. NCRN has no defined desired value other than >0 feet. Wetted width is used to calculate discharge and determine the number of chemistry readings taken at a site. NCRN used a Luftkin fiberglass 50m tape to measure wetted width.

Depth

Depth is measured for every flow measurement location and averaged for that transect. Desired values are based on equipment requirements. The Flowtracker requires a minimum of 0.2 feet to function. The hydrolab and YSI continuous loggers require a minimum of 0.5 feet.

Flow

Flow is used to calculate discharge. NCRN has no defined desired value other than >0 ft/s. Streamflow at any point in time is an integration of the streamflow generation and routing mechanisms in a watershed at that time. This integration also defines the water quality at that time, including land use activities, point source discharges, and natural sources. Streamflow measurements are useful for water quality data comparisons over time, interpretation of water quality data, and calculation of parameter loads. Streamflow monitoring is necessary to calibrate and verify ground-water-flow models. Streamflow measurements are made periodically to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation. Understanding the relationship between flow and concentrations and loading helps determine when it is logical to concentrate sampling (Stednick and Gilbert 1998).

Surface Water Dynamics such as flow are also a key component in calculating chemical and physical loading of a flowing water body that are the basis for Total Maximum Daily Load (TMDL) studies. Data must be normalized by flow, especially in freshwater streams, because many constituents have strong relationships with flow (trend work in running waters is typically difficult unless one calculates flow-adjusted concentrations).

Discharge

We currently have no defined desired condition value other than >0 cfs.

Surface Water Dynamics such as flow or discharge for flowing waterbodies and stage or level for non-flowing waterbodies are in many instances a critical component of monitoring. The most fundamental of hydrological measurements that characterize all river and stream ecosystems is that of discharge, the volume of water flowing through a cross section of a stream channel per unit time. The amount of water flowing past a given point, when combined with the slope of the stream channel, yields an indication of stream power or the ability of the river to do work. This potential energy is dissipated as frictional heat loss on the stream bed and when the stream picks up and moves material. The work performed by the stream is important to lotic ecologists because it influences the distribution of suspended sediment, bed material, particulate organic matter, and other nutrients. The distribution of these materials has substantial influence on the distribution of riverine biota (Vannote et al. 1980, Vannote and Minshall 1982, Statzner et al. 1988). In addition, discharge and stream power combine with other basin conditions to influence meander pattern and floodplain dynamics (Leopold et al. 1964, Gore 1996), which are important in providing habitat for flora and fauna.

An analysis of the manner in which discharge varies over time, or the hydrograph, allows a lotic scientists to examine the characteristics of the watershed that influence such conditions as runoff and storage. A hydrograph can be plotted from gauging records to display yearly, monthly, daily, or instantaneous discharges (Gore 1996). A hydrograph can also provide information on daily

and monthly total flow, mean monthly discharge, base (often groundwater maintained) flow, stage height, and periods of high and low flow.

Examination of the shape of a daily hydrograph during a storm event can indicate the condition of the stream and its watershed. The rising limb of the curve is usually concave and is an index of infiltration capacity of the watershed. In a small watershed, the time from the onset of precipitation to the rise in the ascending limb of the hydrograph curve represents the time to reach soil saturation. A watershed with a large storage capacity, absorptive surface, or large channel will have a lower stage-height peak than a similar size basin with little storage (e.g., small channel, lower vegetation density, more clay in soils, greater human development, etc.). Agricultural land produces a more rapid response in the hydrograph than woodlands (Gregory and Walling 1973) because densely wooded areas restrict surface flow and enhance infiltration. The shape of the hydrograph also reflects the longitudinal profile and watershed shape. A steep watershed gradient is reflected in a rapid response curve, whereas a gentle watershed gradient will produce a hydrograph with a slow and prolonged response curve. A watershed with many headwater streams but few tributaries in lower reaches will produce a hydrograph with a sharp flood peak. However, the peak is delayed from the onset of the precipitation event. An elongated watershed with many tributaries has a hydrograph that rises rapidly and falls over a longer period of time. A watershed with many subwatersheds often produces a hydrograph with several flood peaks depending upon distribution of rainfall in the area (Gore 1996).

Discussion of Findings

Each park will be discussed individually. The Region's water quality as a whole is reviewed in the Executive Summary. These measures constitute a snapshot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

Antietam National Battlefield (ANTI)

The park is located near the town of Sharpsburg in Washington County, Maryland. As part of the Great Valley of the Ridge and Valley, the park exhibits classic features of a karst landscape.

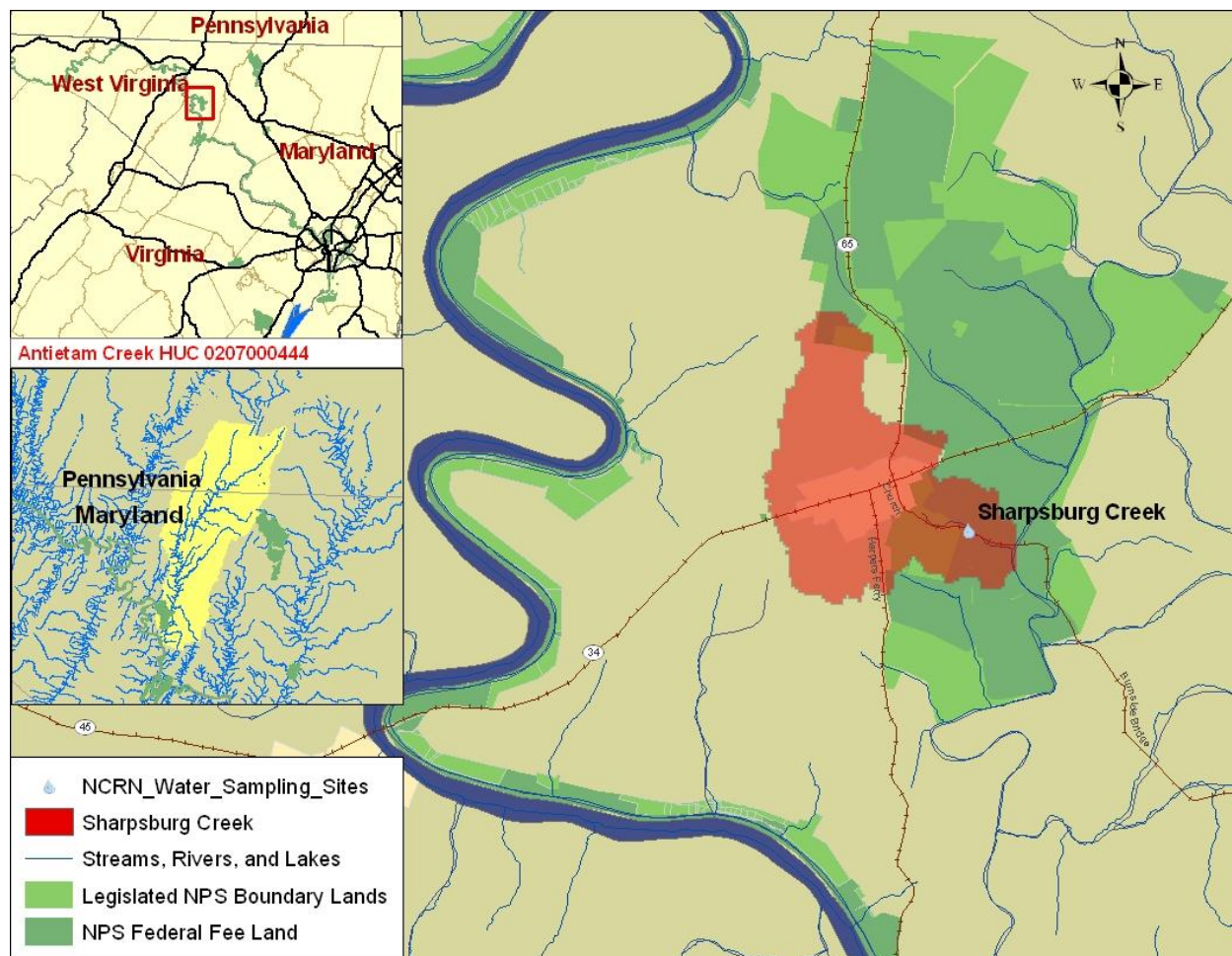


Figure 2: Relationship of the Sharpsburg Creek monitoring site to the watershed and the park boundary

Sharpsburg Creek is part of the Antietam Creek drainage basin (see Figure 3). Antietam Creek passes through ANTI, then through private land and into CHOH before emptying into the Potomac River. Water resources are threatened by contamination and overuse in the urban and agricultural settings of these park units. The most severe threats to park hydrology are presented by existing and future development in the rapidly growing region. Maintaining an agricultural setting at ANTI creates a situation in which runoff from fields both within the park and in neighboring farms in the Antietam Creek watershed can potentially contaminate both the surface water and groundwater systems including springs. Knowledge of the chemicals used in regional agriculture and an understanding of the hydrogeologic system, including groundwater flow patterns are essential to protect the park's ecosystem. In addition to agricultural runoff, industrial, sewer, street and commercial runoff are also potential sources of water contamination at Antietam (NPS 2005).

This report discusses data collected October 2006 through September 2008 in Sharpsburg Creek. Summary Statistics for the time period are shown in Table 3.

Table 3: Date range, number of site visits (N), and data range for the information covered in this report for ANTI.

Parameter	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/12/2006 - 9/18/2008	20	0	30	18	20	10
ANC	µeq/L	10/12/2006 - 9/18/2008	23	4140	5320	4811	4820	369
Discharge	cfs	10/12/2006 - 9/18/2008	12	1.05	6.30	2.99	3.09	1.52
DO	mg/l	10/12/2006 - 9/18/2008	23	7.77	12.09	9.43	9.41	1.08
Flow	ft/sec	10/12/2006 - 9/18/2008	13	0.127	1.920	0.901	0.862	0.482
Nitrate	mg/l	10/12/2006 - 9/18/2008	23	1.55	10.90	6.69	7.78	2.59
Ammonia	mg/l	10/12/2006 - 9/18/2008	13	0.008	0.559	0.100	0.045	0.149
pH	None	10/12/2006 - 9/18/2008	22	7.38	8.41	8.15	8.24	0.26
Phosphate	mg/l	10/12/2006 - 9/18/2008	23	0.06	1.80	0.36	0.23	0.38
Salinity	ppt	10/12/2006 - 9/18/2008	23	0.2	0.3	0.3	0.3	0.0
Specific conductance	µS/cm	10/12/2006 - 9/18/2008	23	339.1	691.0	590.3	595.0	64.5
Water Depth	ft	10/12/2006 - 9/18/2008	14	0.188	0.315	0.248	0.243	0.043
Water Temperature	°C	10/12/2006 - 9/18/2008	23	7.4	17.9	13.5	14.3	2.6
Wetted Width	ft	10/12/2006 - 9/18/2008	18	0.00	16.25	10.54	9.05	4.19

One site was monitored in the park on a monthly basis for dissolved oxygen, ph, specific conductance, temperature, acid neutralizing capacity, nitrate, ammonia, and total phosphorus. We do not yet have enough data to observe seasonal trends. However we are evaluating the data in reference to water quality thresholds.

Nitrate and phosphate levels are high in the park, though conditions were slightly better in 2007. There were fewer instances of Nitrate (NO₃) threshold exceedance in 2007 than 2006 and 2008 (Figure 4). Nitrate peaked in late fall 2006 and mid-to late summer 2007. It remained consistently high throughout 2008. The human drinking water standard of 10 mg/L was also exceeded twice in October 2006. Phosphate was also high in the late fall / early winter 2006 and late summer 2007, as was nitrate. Phosphate was lower and constant throughout 2008 but still consistently above threshold (Figure 5). Ammonia (NH₃) exceeded the threshold once in 2007, it never did in 2006 (Figure 6). Ammonia had a high value in December 2006 which corresponded to a high nitrate level. Ammonia is a problematic parameter. We frequently get readings below zero and the estimated detection limit of 0.032 with the very low readings we normally get means that much of the data is excluded from analysis (10 of 23 readings in the case of ANTI FY2007-2008). There were no DO readings below threshold in 2007 or 2008, an improvement over 2006. Though readings were only taken around mid-day, which is peak photosynthesis and therefore peak DO. Respiration, particularly at night when it is not offset by photosynthesis, may consume DO to the point it is below threshold (Figure 7).

Specific conductance exceeded desired condition in all but one sample in 2007 and in all samples in 2008. This is most likely due to the limestone and dolomite bedrock in the area, though fertilizers, pesticides, and livestock runoff may also contribute. Limestone (CaCO_3) and dolomite ($\text{CaMg}(\text{CO}_3)_2$) are ionic salts that dissociate in pure water to their constituent ions: Ca^{2+} and CO_3^{2-} ; $\text{Ca}^{2+} + \text{Mg}^{2+} + 2 \text{CO}_3^{2-}$. Groundwater in karst areas can also contain sulfate ions from gypsum beds and weathered sulfite materials, chlorides from deeper circulating ground water and seawater mining, sodium, potassium, dissolved oxygen. The calcite and dolomite ion dissolution increases the pH of the water above neutral to 8 and even 9. This increase in dissolved ions also increases the specific conductance (White and McDonnell 1988) (Figure 8). pH in Sharpsburg Creek ranges from 7.38 to 8.4 (Figure 10). Acid neutralizing capacity (Figure 9) was well above the threshold of 600 $\mu\text{S}/\text{cm}$ for karst waters.

Water Depth in Sharpsburg Creek never exceeded 0.6 feet (Table 4). The region experienced a drought in 2007. Several small streams in the region dried out, however Sharpsburg Creek did not. Due to its location in a karst landscape, Sharpsburg Creek has consistent groundwater-based flow. Based on the data collected so far, normal water levels for Sharpsburg Creek can be defined as discharge between 3 cfs and 10 cfs, with a flow of 1 f/s or higher in a channel with a wetted width of 13 or more feet. There was not sufficient flow to measure discharge in spring and summer 2005 and summer 2007 through spring 2008 (Figure 12).

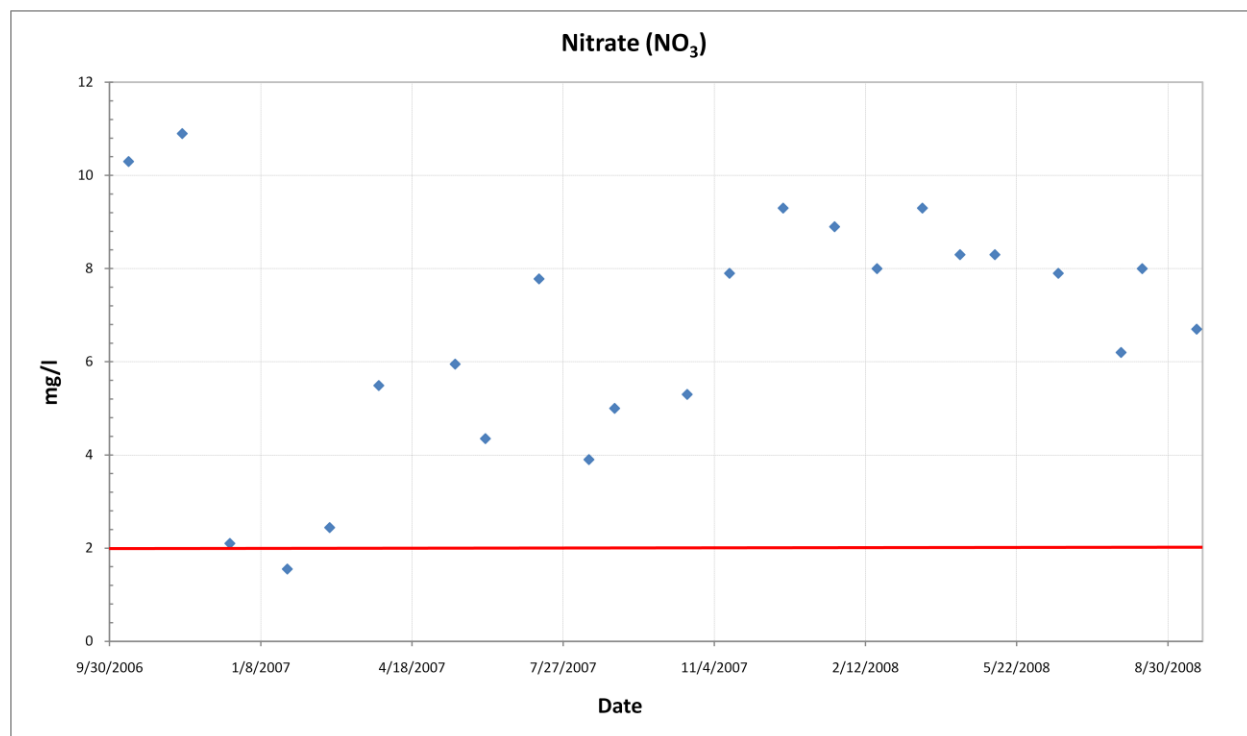


Figure 3: Nitrate in Sharpsburg Creek. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

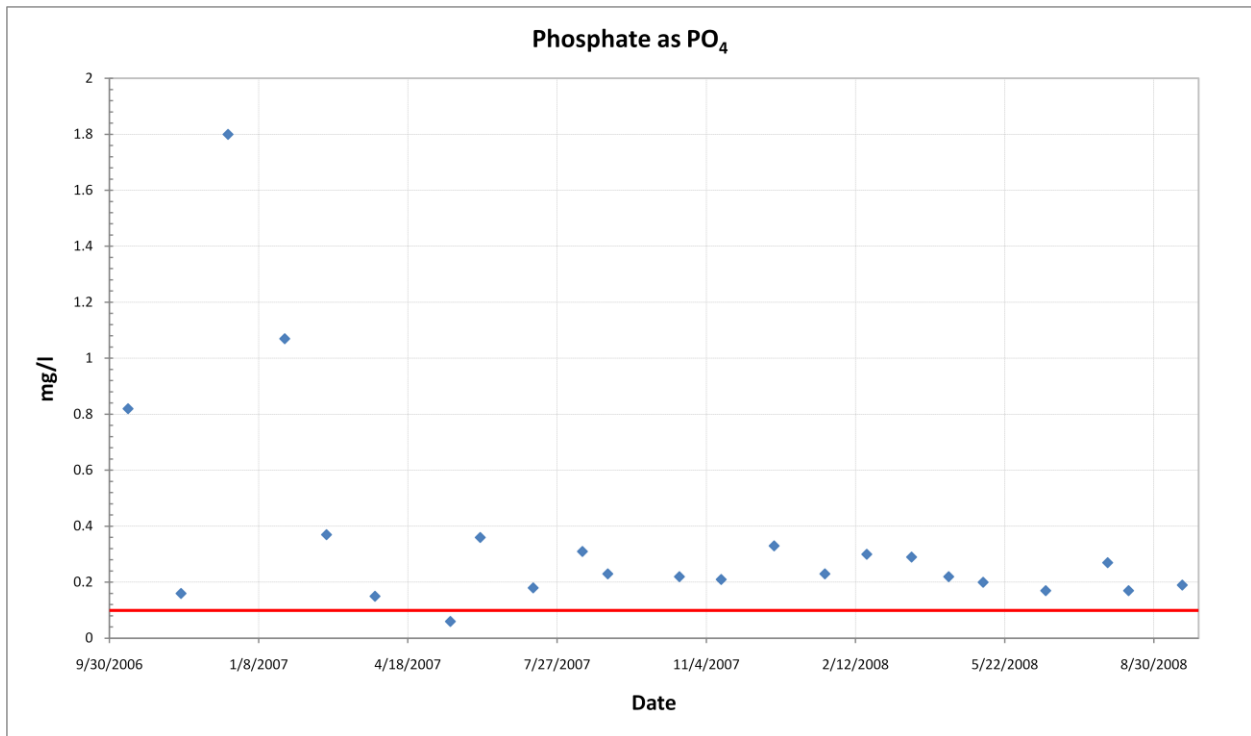


Figure 4: Phosphorus (measured as phosphate) in Sharpsburg Creek FY 2007 - 2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

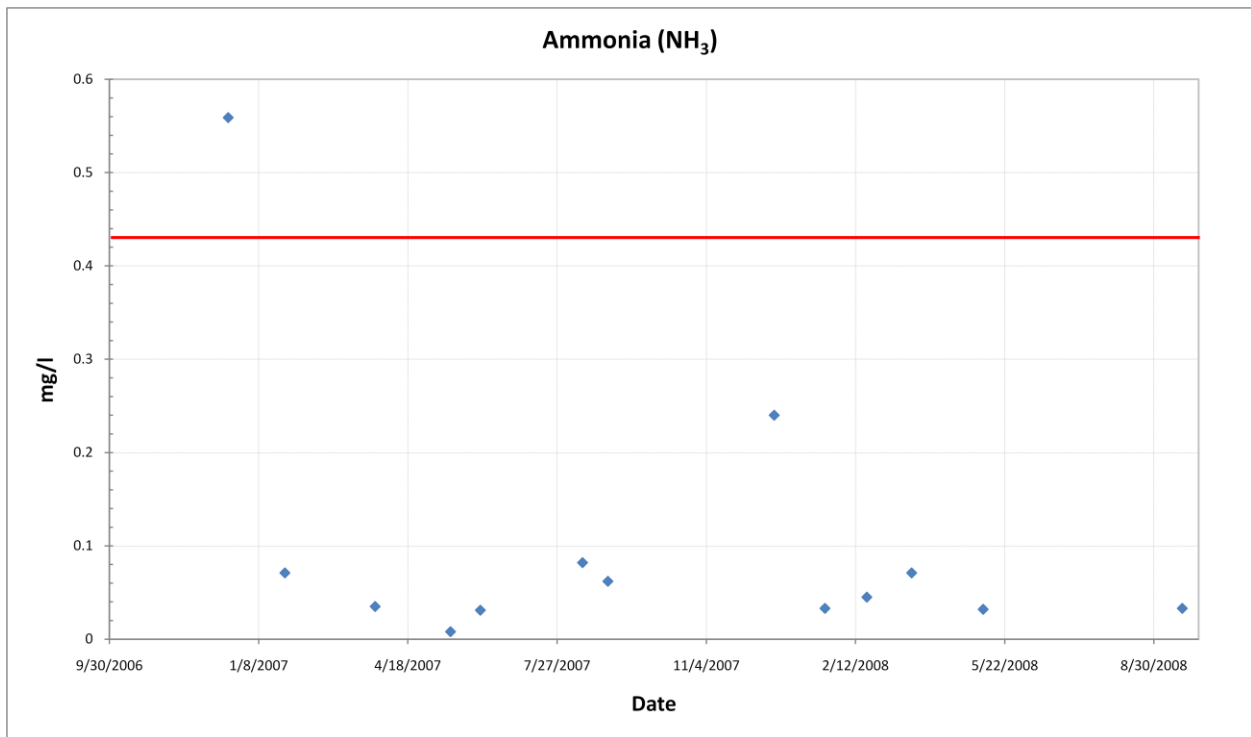


Figure 5: Ammonia in Sharpsburg Creek FY 2007 – 2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

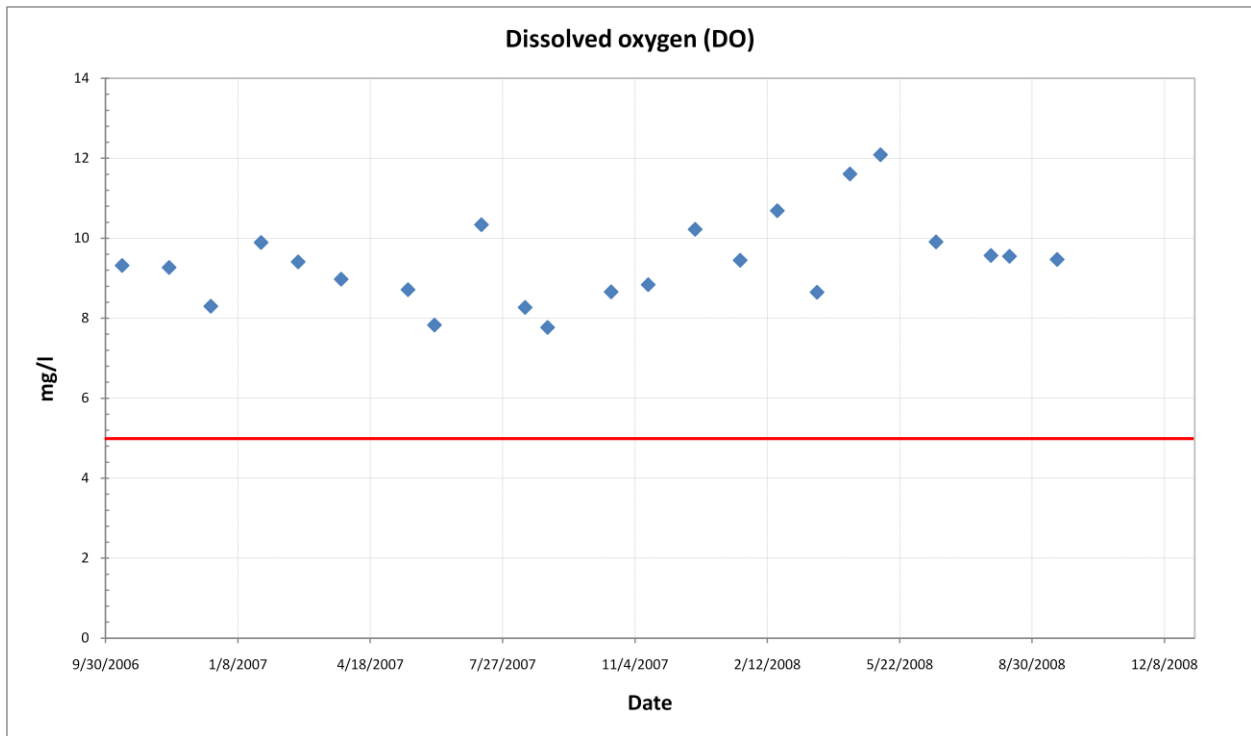


Figure 6: Dissolved oxygen in Sharpsburg Creek FY 2007- 2008. Healthy water should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

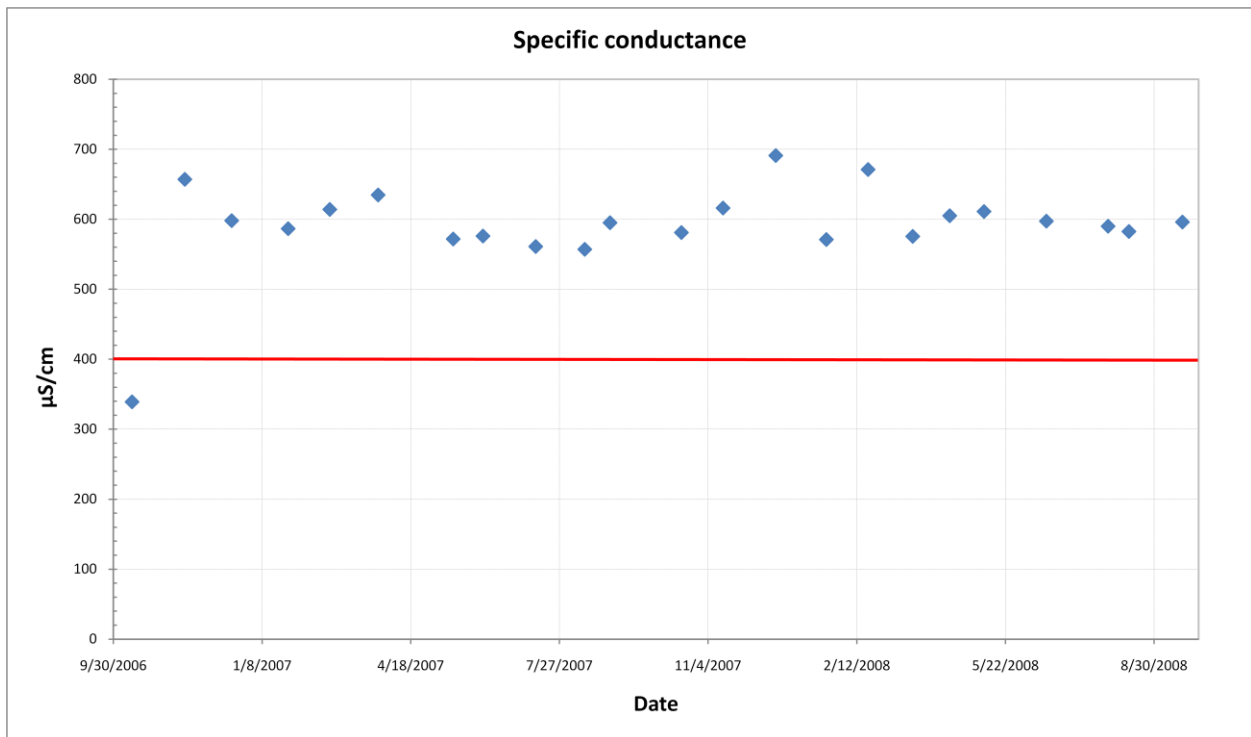


Figure 7: Specific Conductance in Sharpsburg Creek FY 2007 - 2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

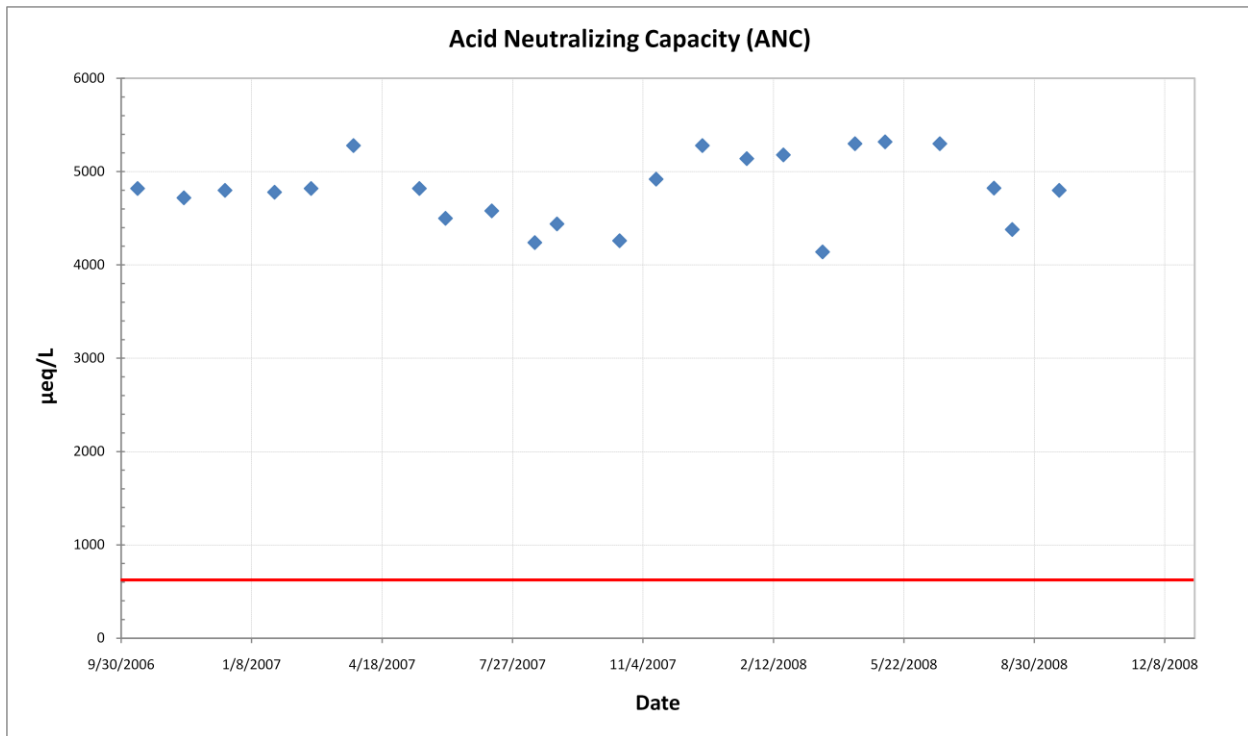


Figure 8: Acid Neutralizing Capacity in Sharpsburg Creek in FY 2007 - 2008. Karst waters should have ANC above 600 µeq/L (the red line on the graph).

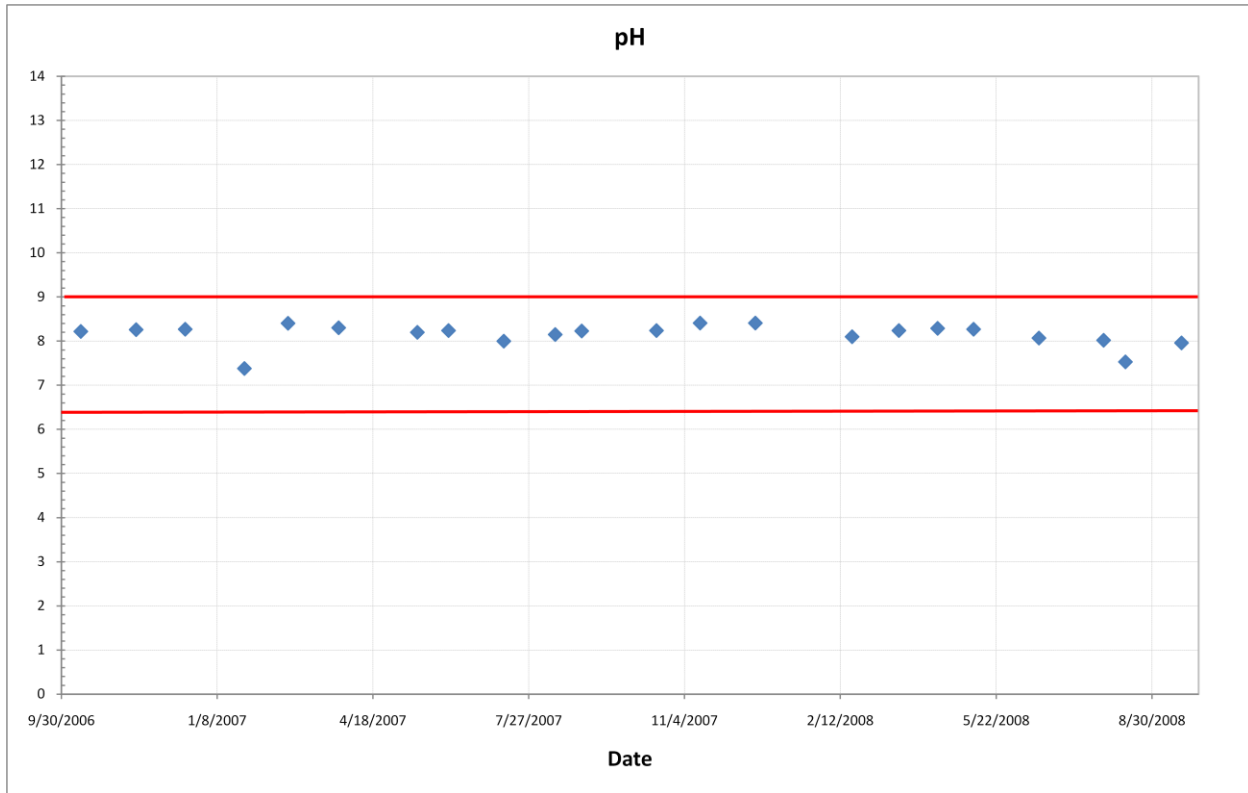


Figure 9: pH in Sharpsburg Creek, FY 2007- 2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

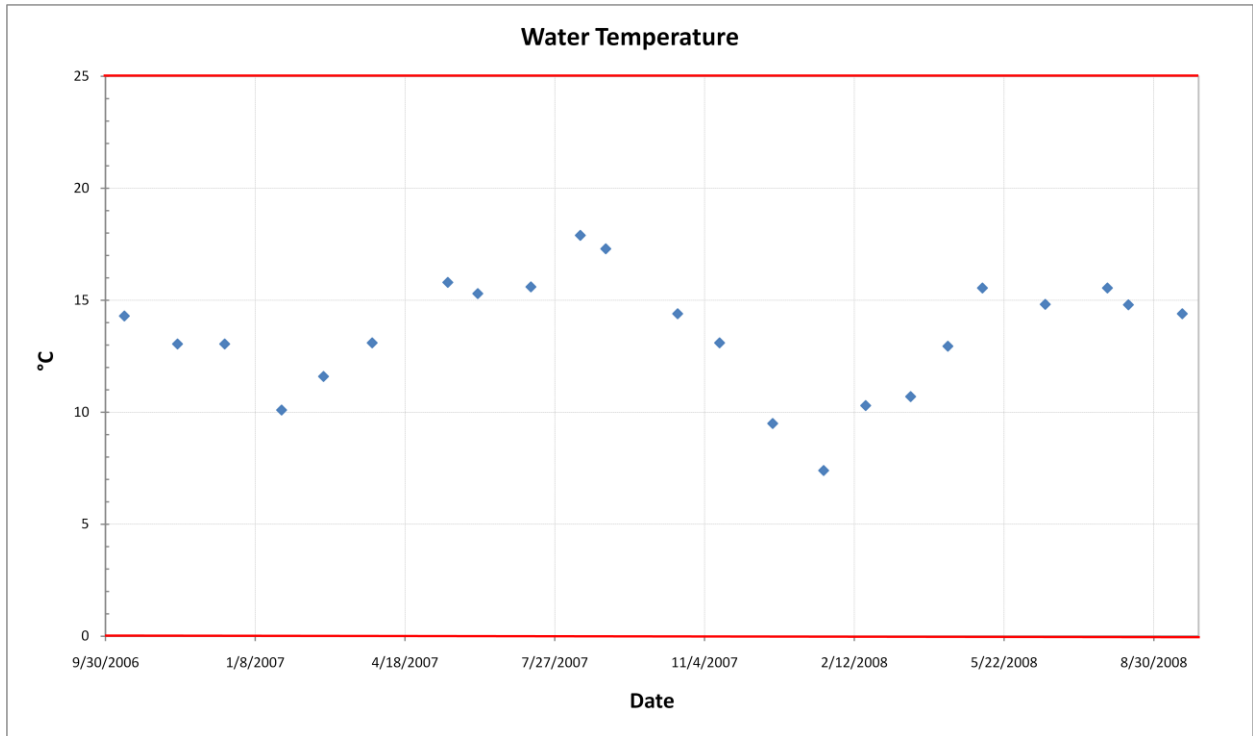


Figure 10: Water temperature in Sharpsburg Creek, FY 2007-2008. Temperatures between 0 and 25° C are ideal for aquatic life

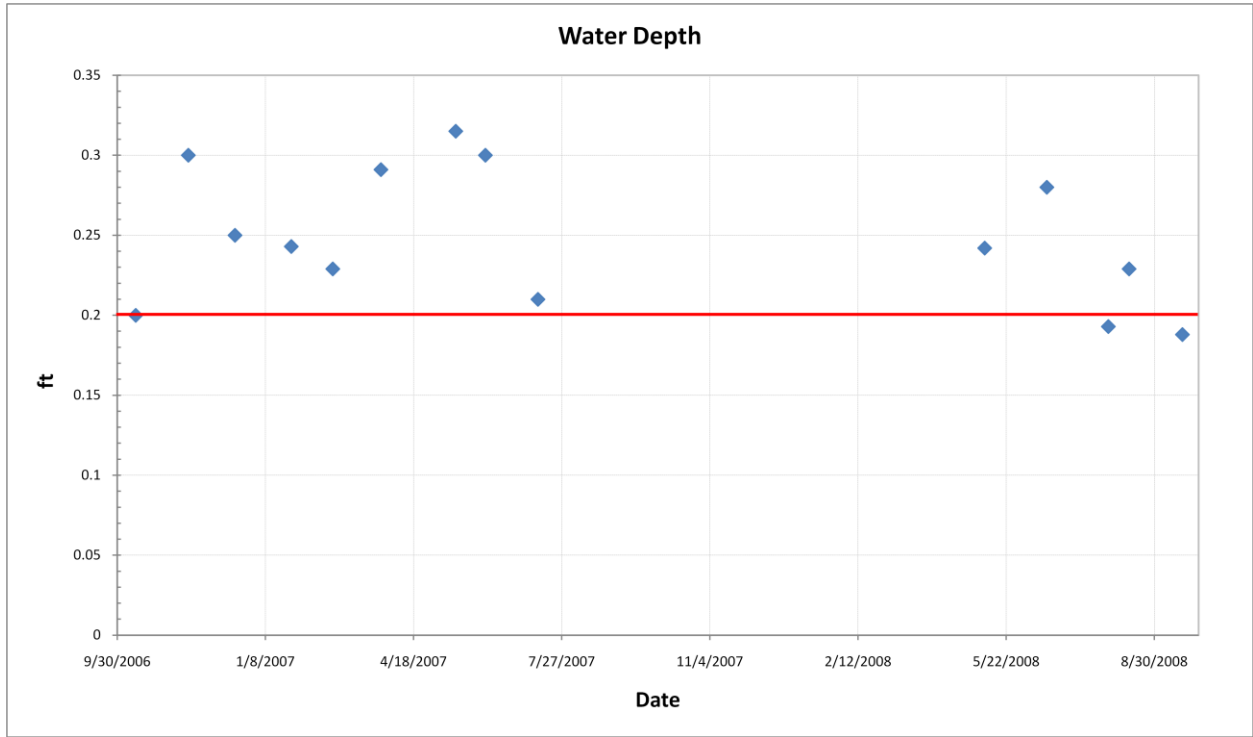


Figure 11: Water Depth (feet) in Sharpsburg Creek in FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline).

Table 4: Hydrology data for Sharpsburg Creek, Antietam National Battlefield May 2005 to September 2009

Date	Discharge	Flow	Flow, below freezing	Wetted Width
5/23/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
6/2/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
6/30/2005	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
10/11/2005	*Not Reported	1.09	LOW	*Not Reported
11/17/2005	*Not Reported	1.49	LOW	*Not Reported
12/14/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
1/26/2006	4.848	1.30	NORMAL	15
2/28/2006	7.154	1.46	NORMAL	14.0
3/23/2006	8.280	4.32	NORMAL	7.67
4/12/2006	1.528	0.89	LOW	8.0
5/18/2006	0.754	0.29	LOW	13.0
6/28/2006	12.657	1.83	ABOVE NORMAL	13.83
7/26/2006	1.505	0.35	LOW	7.16
8/14/2006	6.108	1.61	NORMAL	13.08
10/12/2006	2.782	1.07	LOW	13
11/17/2006	*Not Reported	.85	LOW	*Not Reported
12/18/2006	3.937	1.10	NORMAL	14.58
1/25/2007	3.645	1.071	NORMAL	14.917
2/22/2007	1.050	0.246	LOW	15.083
3/27/2007	4.149	0.862	NORMAL	16.25
5/16/2007	2.082	0.612	LOW	10.167
6/5/2007	1.791	0.65	LOW	9.17
7/11/2007	*Not Reported	*Not Reported	LOW	8.25
8/13/2007	*Not Reported	*Not Reported	LOW	7.5
8/30/2007	*Not Reported	*Not Reported	LOW	8.250
10/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/14/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/19/2007	*Not Reported	*Not Reported	NORMAL	0
1/22/2008	*Not Reported	*Not Reported	LOW	8.3
2/19/2008	*Not Reported	*Not Reported	LOW	*Not Reported
3/20/2008	*Not Reported	*Not Reported	LOW	*Not Reported
4/14/2008	*Not Reported	*Not Reported	LOW	8.667
5/7/2008	3.74	1.920	NORMAL	8
6/18/2008	6.3	1.560	NORMAL	15.03
7/30/2008	3.4	.127	NORMAL	15.67
8/13/2008	1.91	.937	LOW	8.92
9/18/2008	1.07	.712	LOW	8

Catoctin Mountain Park (CATO)

The park encompasses 2,336 ha of forested landscape located in the mountains of the Catoctin Ridge in the north-central portion of Maryland. The park is located near Thurmont in Frederick County, Maryland in the Blue Ridge Physiographic Province. Within the eastern scarp (line of cliffs), Catoctin Mountain is a discontinuous ridge that extends from near the Pennsylvania / Maryland border to the Potomac River at Point of Rocks, Maryland. Slopes in the park are generally between 10% and 20%, but occur up to 60% (Trombley and Zynjuk 1985). Local relief is high and both the side slopes and the channel gradients are steep. Streams are cool and clear and have many riffle sections; they support a different, less diverse fish assemblage than the streams of the valleys below, which are warmer, lower in gradient, and more turbid.

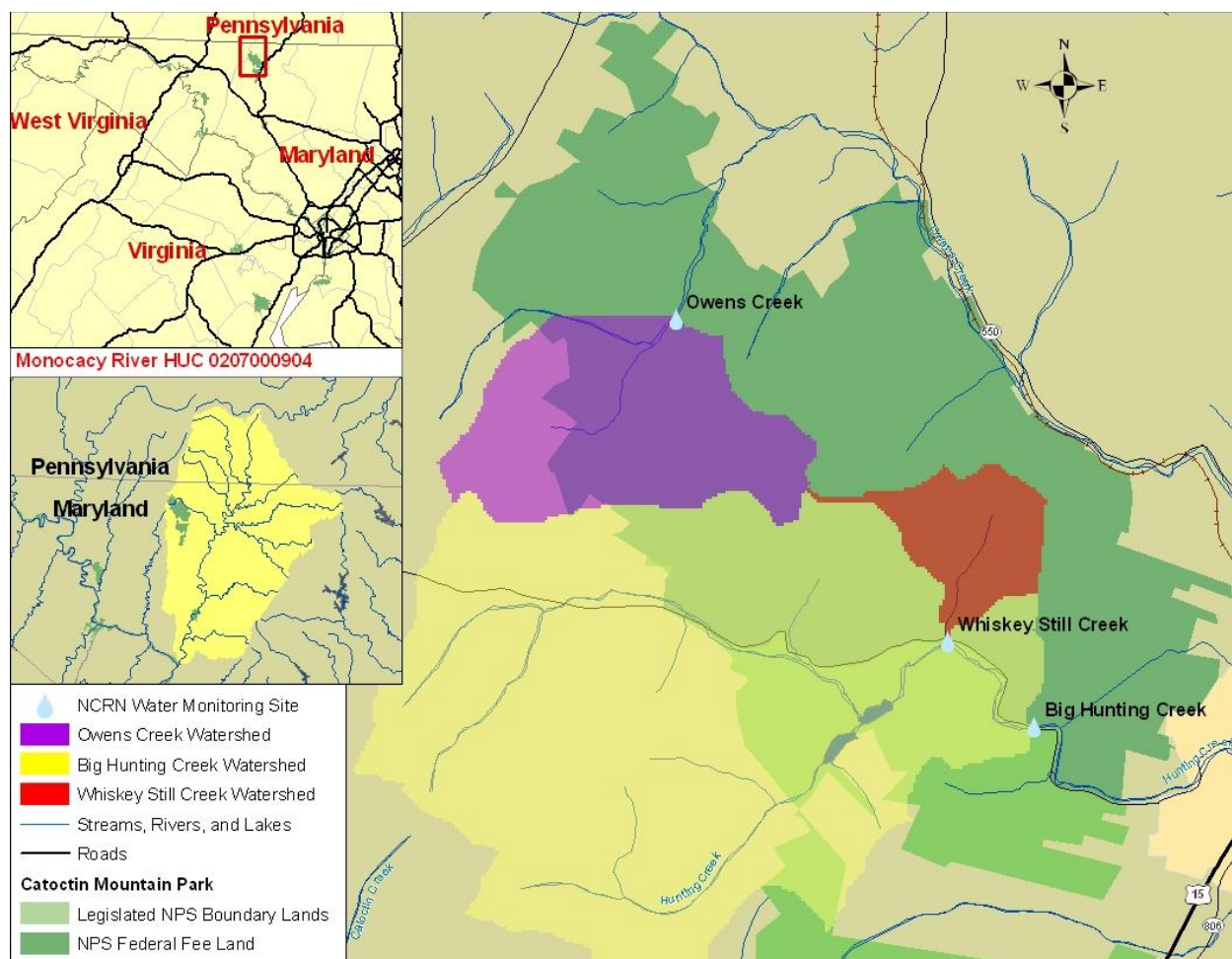


Figure 12: Relationship of CATO stream monitoring sites to their watersheds and the park boundary

Groundwater comprises 55%-57% of annual stream flow. Overland flow is mostly subsurface through the thick loamy soil (30-40%) (Trombley and Zynjuk 1985, Means 1995). Most precipitation is collected and absorbed by the very loamy and rocky surface soils. The result is that the water drains into streams as subsurface runoff. Of the 44 inches of precipitation that fall annually, 57% will leave the park as stream water. In the case of Big Hunting Creek this source of water contributes about 40% of the total stream flow. This subsurface flow is fairly steady but

is affected by fluctuations in precipitation. For example during particularly wet periods upon saturation of the soil, many small intermittent creeks become active delivering the excess water above ground instead of through the soil. Access to the aquifer is available through springs and wells, which supply the parks tap water (Trombley and Zynjuk 1985). Aquifers within the Blue Ridge and Piedmont provinces are characteristically small. The springs that occur in the region typically have low flow rates and many are seasonal (Otton and Hilleary 1985). The high topographic position affects the ecological characteristics – because of the relief and narrowness most of the streams that drain the Blue Ridge are headwater tributaries of larger streams in the Great Valley or Piedmont. In Maryland the Blue Ridge forms the major divide within the basin – all stream-flow west of Blue Ridge passes through a gap at Harper's Ferry to the Great Valley. Stream-flow on the east flows to the Piedmont (Blomquist et al. 1996). Streams are mostly rocky and may meander through wide floodplains or cascade down steep mountainsides. Some, like Owens Creek, even course through wetland glades that resemble the Coastal Plain.

The park area is separated from the main ridge by two streams (Figure 13): Big Hunting Creek to the south and Owens Creek to the west, north, and east. Big Hunting Creek is 41.8 square miles in drainage, 15 miles long with a discharge of 3 to 5 cfs (2,238 gallons). It is a tributary of the Monocacy River and forms the boundary between the National and State Parks. Big Hunting Creek flows in and out of the CATO boundary for roughly 4 miles. The headwaters of Big Hunting Creek are outside of the park, putting this creek at risk for potential problems that cannot be completely controlled by the park (Means 1995). Before entering the park, Big Hunting Creek runs off farms and lots and along MD Rte 77. The national park contains 7% of the creek's drainage basin. Developed areas in the park (Greentop, Round Meadow, Misty Mount, Maintenance Yard, Visitors Center, Administration Office, Park Central Road, Route 77, and Camp 3) contribute runoff to the creek. Water quality in the creek is very good, with bank erosion and flow rate the most significant problems. Tributaries of Big Hunting Creek include Still Creek, Whiskey Still Creek (completely contained within CATO), Hauver Branch (within the state park) and Bear Branch (within the state park).

Owens Creek has a 39.8 square mile drainage and is managed for native brook and for naturally producing brown trout (Means 1995). The headwaters of Owens Creek begin inside the park. As the creek leaves through the park's north boundary it passes through an agricultural area and flows back into the park. The park contains 14.5% of Owens Creek's watershed, but fewer developed areas of the park contribute runoff to the creek (Round Meadow, Naval Housing Facilities, Owens Creek picnic area, Chestnut picnic area, Camp 3, and Owens Creek campground). A new wastewater treatment plant was located at the head of Owens Creek in the late 1990s. The plant discharges directly into the stream and wetland where Owens Creek originates.

This report discusses data collected October 2006 through September 2008 in Big Hunting Creek, Whiskey Still Creek, and Owens Creek. Summary Statistics for the time period are shown in Table 5.

Table 5: Date range, number of site visits (N), and data range for the information covered in this report in CATO.

Parameter	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/16/2006 - 9/22/2008	60	-5	29	16	19	10
ANC	µeq/L	10/16/2006 - 9/22/2008	65	302	1058	610	558	197
Discharge	cfs	10/16/2006 - 9/22/2008	37	0.0	73.4	8.1	2.6	14.1
DO (mg/L)	mg/l	10/16/2006 - 9/22/2008	64	5.2	14.5	9.4	9.1	2.3
Flow	ft/sec	10/16/2006 - 9/22/2008	38	0.000	2.183	0.683	0.543	0.561
Nitrate	mg/l	10/16/2006 - 9/22/2008	64	0.2	2.9	1.1	1.1	0.5
Ammonia	mg/l	10/16/2006 - 9/22/2008	37	0.007	0.147	0.054	0.046	0.026
pH	None	10/16/2006 - 9/22/2008	61	6.79	8.18	7.50	7.53	0.28
Phosphate	mg/l	10/16/2006 - 9/22/2008	64	0.07	3.13	0.33	0.23	0.42
Salinity	ppt	10/16/2006 - 9/22/2008	64	0.0	0.2	0.1	0.1	0.0
Specific conductance	µS/cm	10/16/2006 - 9/22/2008	64	77.05	188.30	131.80	132.90	26.92
Water Depth	ft	10/16/2006 - 9/22/2008	44	0.0	1.3	0.5	0.4	0.3
Water Temperature	°C	10/16/2006 - 9/22/2008	64	0.2	20.1	10.8	11.7	6.2
Wetted Width	ft	10/16/2006 - 9/22/2008	59	0	28	15	18	9

The one parameter for which CATO streams significantly and consistently fail to meet threshold is phosphate (Figure 15). Owens Creek and Big Hunting Creek are probably receiving inputs from off-property fertilizing. Owens Creek receives water from a sewage treatment plant inside the park. Whiskey Still Creek should not have an elevated phosphorus level based on current knowledge of its drainage, since there are no known un-natural sources of phosphorus for it. Perhaps the threshold requires reconsideration. Potential sources of phosphorus within the watersheds should be investigated. Nitrate (Figure 14) was at or above threshold in Owens Creek in February 2007 and December 2008, although the mean value is significantly below the threshold. All other parameters occurred within desired relationship to thresholds (Figures 16-21).

The region experienced a drought in 2007. Several small streams in the region dried out, however Big Hunting Creek did not (Table 5). Based on the data collected so far, normal water levels for Big Hunting Creek can be defined as discharge between 6 cfs and 46 cfs, with a flow of 0.5 f/s or higher in a channel with a wetted width of 20 or more feet. Flows have not been observed to be above normal during site visits. There was only sufficient depth (Figure 22) for flow measures at all sites September 2006 to June 2007 and March through June 2008. Big Hunting Creek maintains sufficient depth most of the year (Figure 22). Whiskey Still Creek is frequently too shallow for discharge measurements.

Whiskey Still Creek had no flow on four occasions (Table 6): October 2005, September and October 2007, and August 2008. It appears that this stream may experience seasonal drying in the fall, in which case it is not perennial and does not meet our sampling criteria. We will keep

an eye on the streams flow in the future to determine if it is in fact ephemeral. Based on the data collected so far, normal water levels for Whiskey Still Creek can be defined as discharge between 2.5 cfs and 7 cfs, with a flow of 0.3 f/s or higher in a channel with a wetted width of 6 or more feet. Flows have not been observed to be above normal during site visits.

Owens Creek had 2 occurrences of no flow (Table 7): December 2005 and October 2007. Based on the data collected so far, normal water levels for Owens Creek can be defined as discharge between 3 cfs and 12 cfs, with a flow of 0.5 f/s or higher in a channel with a wetted width of 21 or more feet.

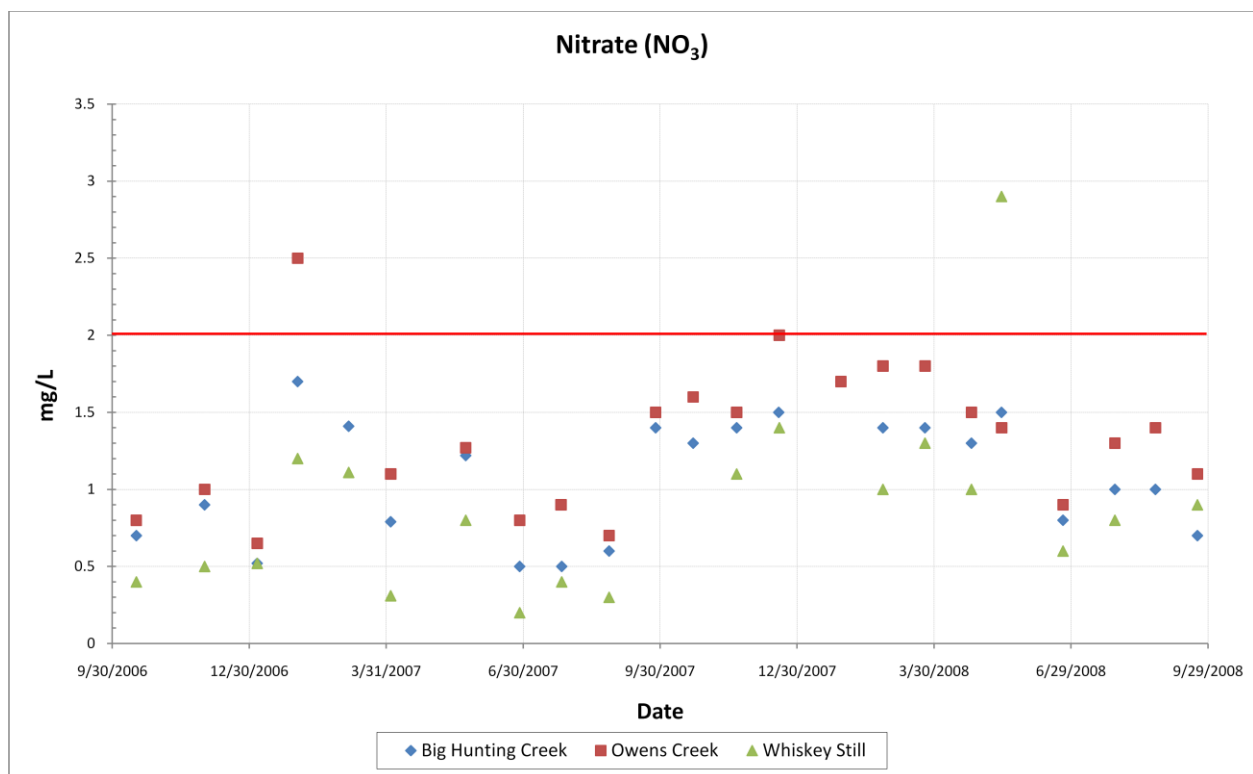


Figure 13: Nitrate in CATO stream, FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

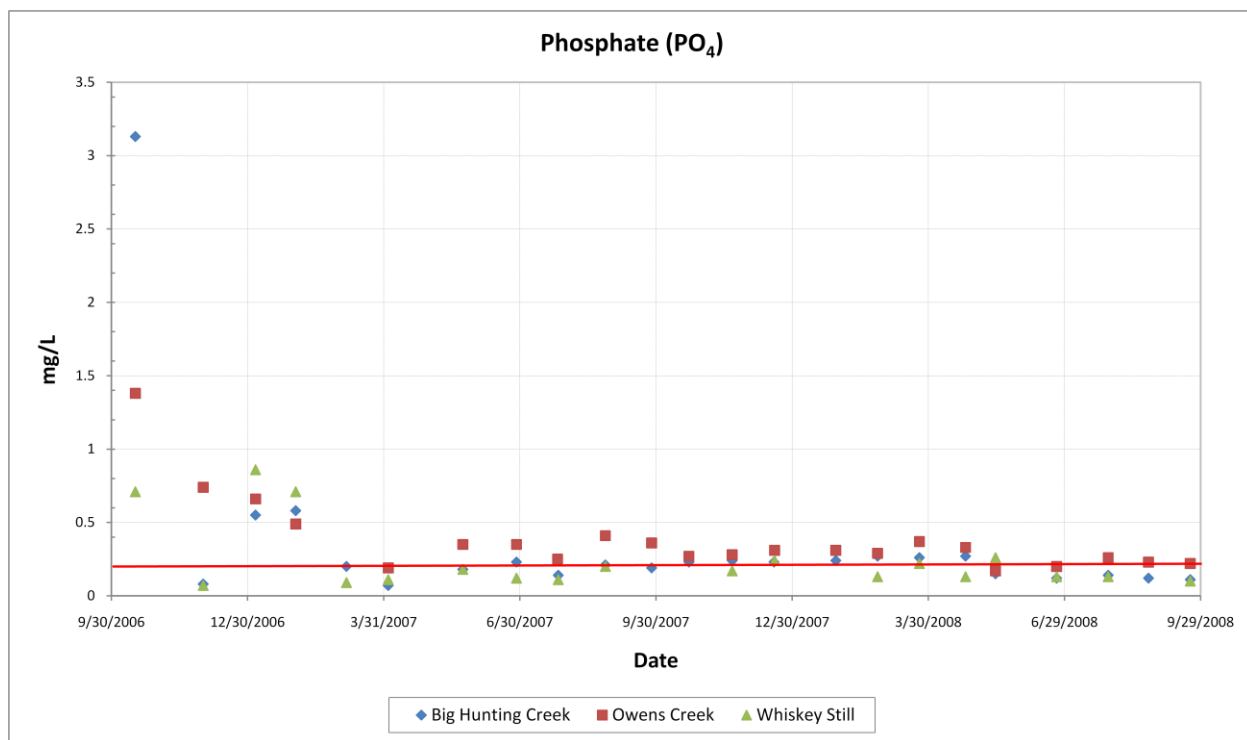


Figure 14: Phosphate in CATO streams, FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO_4 (red line).

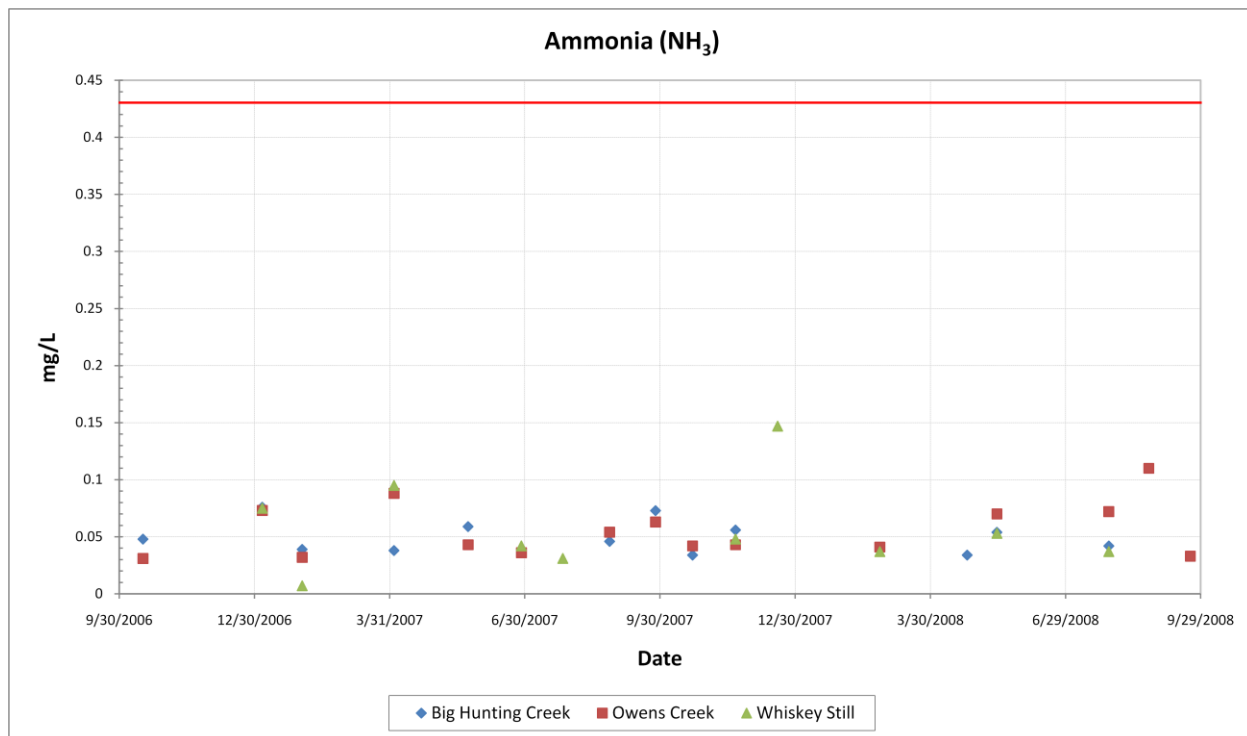


Figure 15: Ammonia in CATO streams FY 2007 – 2008. Healthy waters would ideally have less than 0.433 mg/L NH_3 (red line).

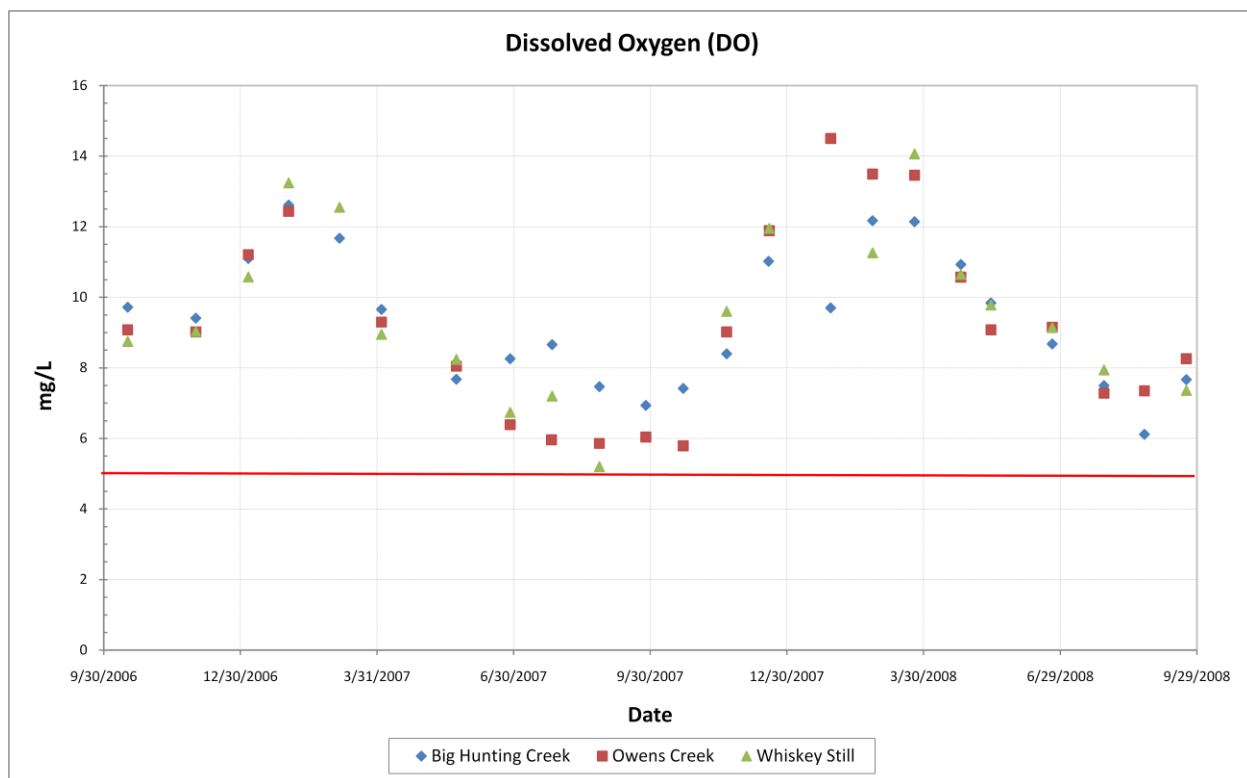


Figure 16: Dissolved oxygen in CATO streams, FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

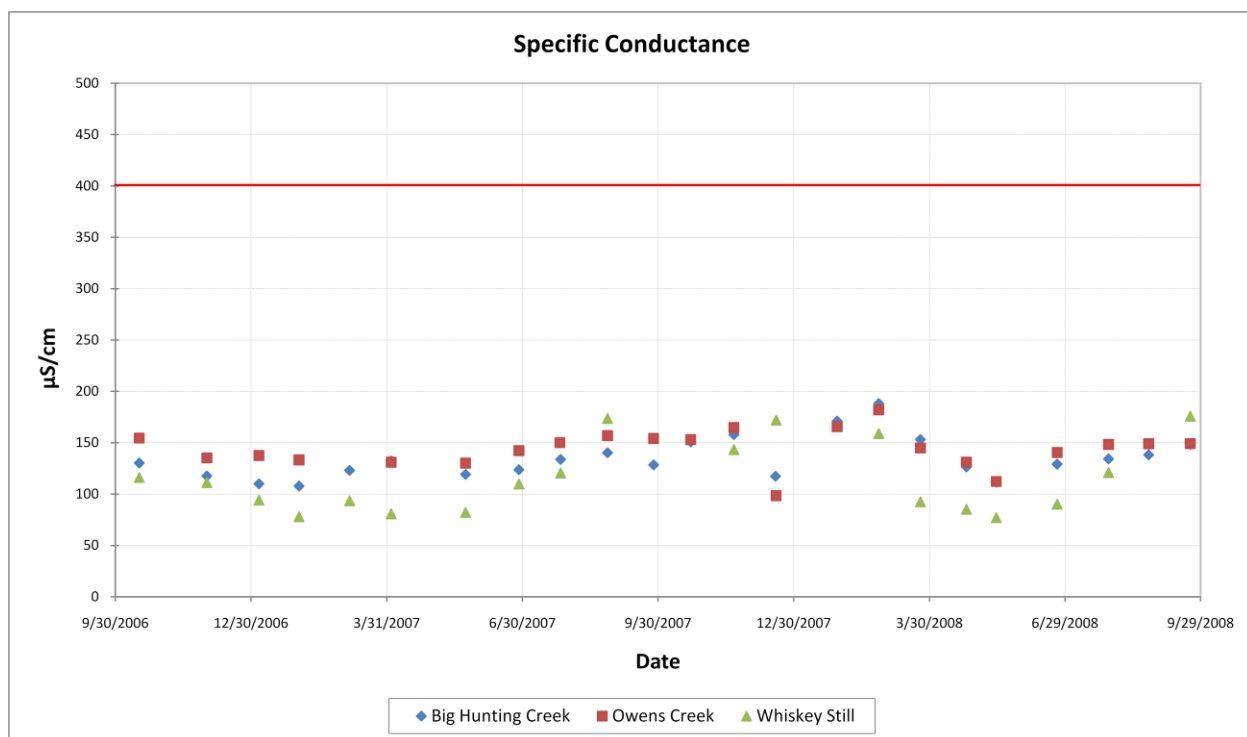


Figure 17: Specific Conductance in CATO streams, FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

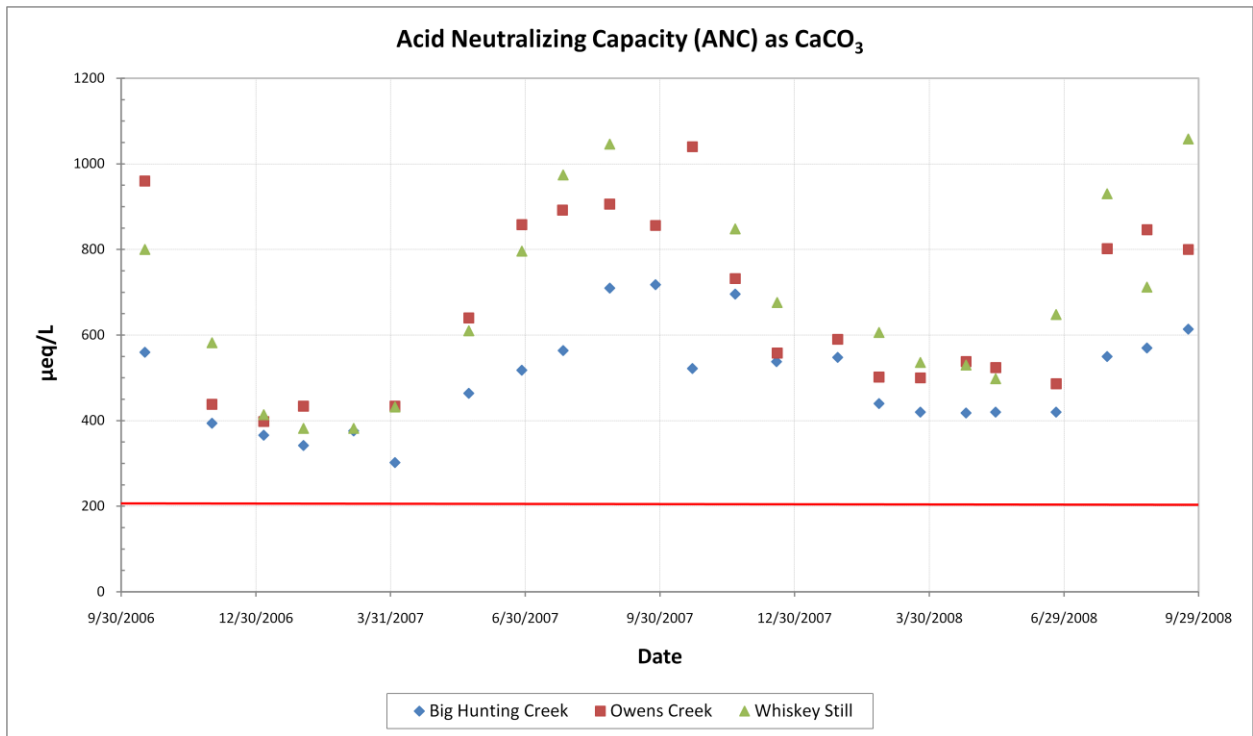


Figure 18: Acid Neutralizing Capacity in CATO streams, FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq/L}$ (the red line on the graph).

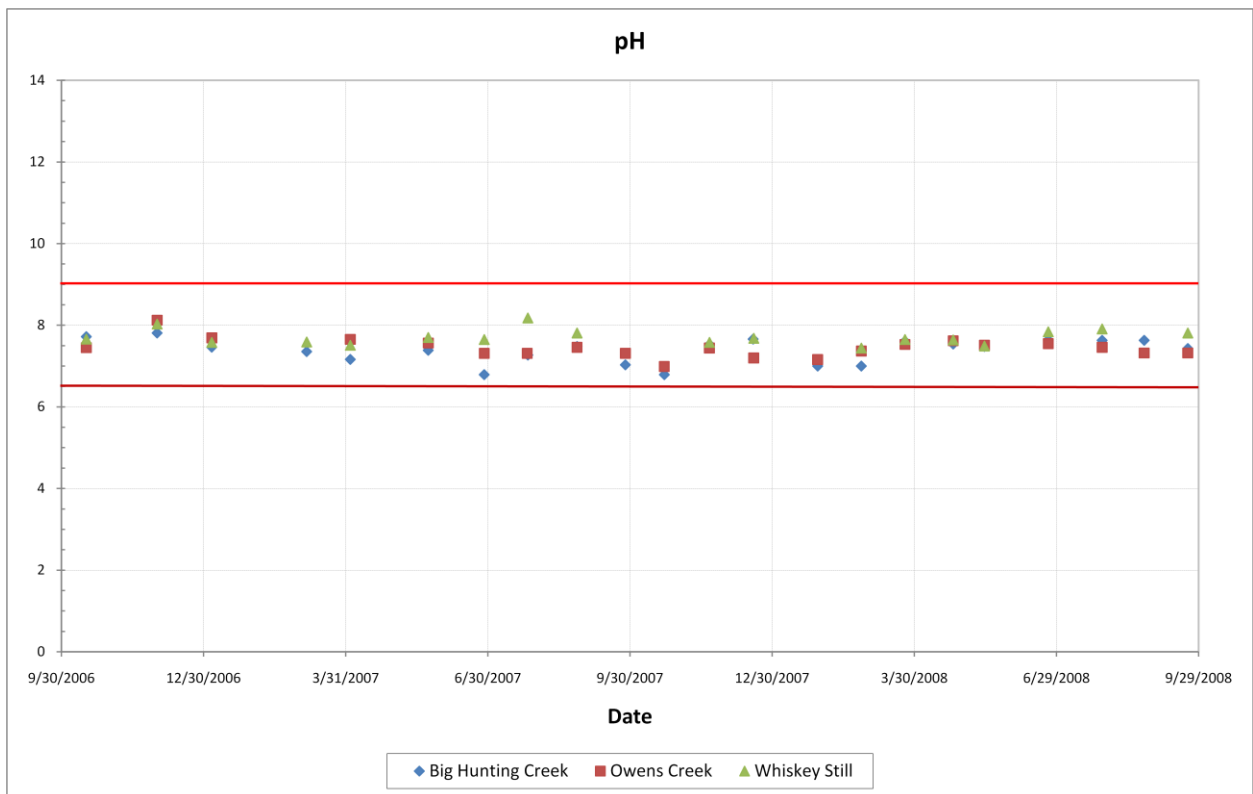


Figure 19: pH in CATO streams, FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

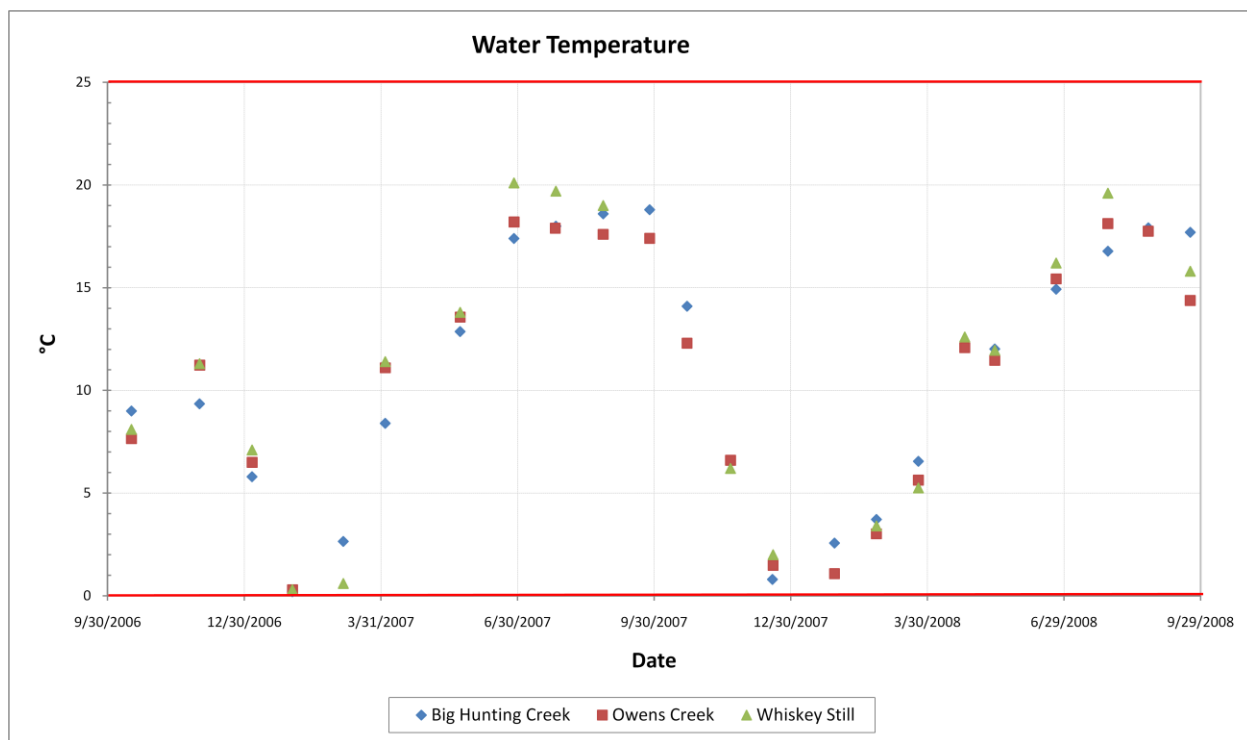


Figure 20: Water temperature in CATO streams, FY 2007-2008. Temperatures between 0 and 25° C are ideal for aquatic life.

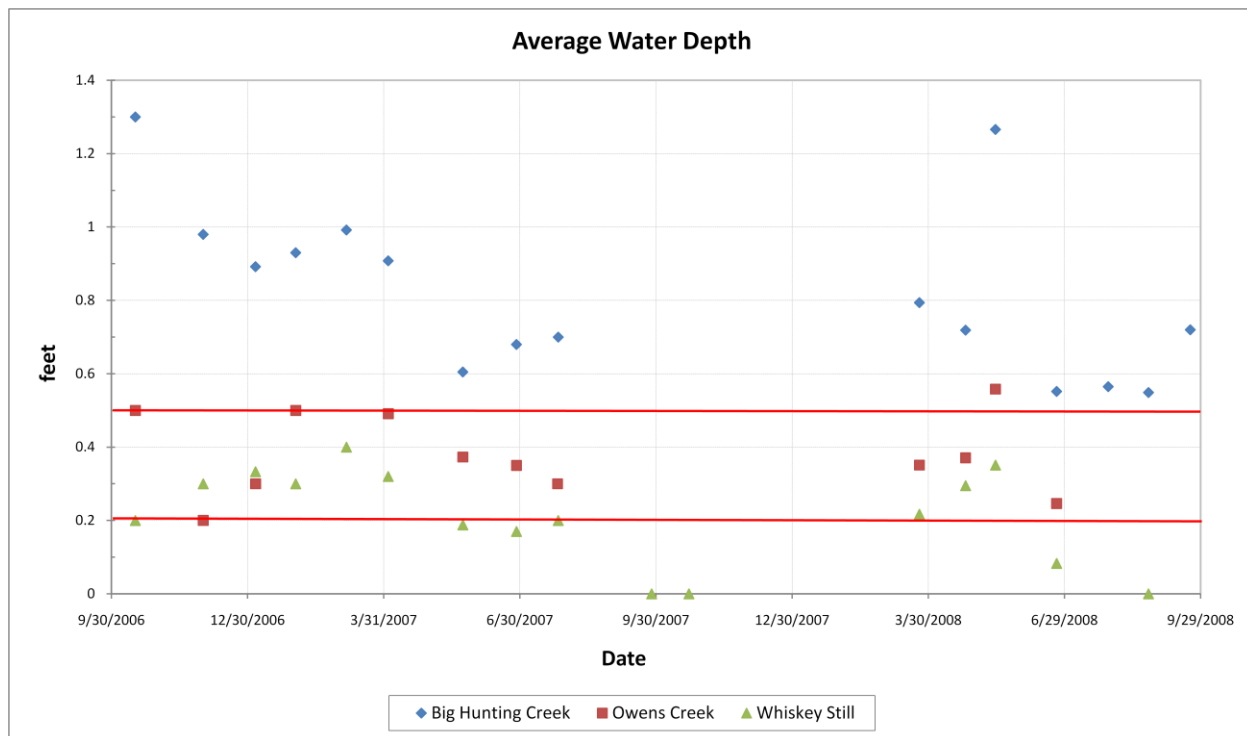


Figure 21: Water Depth (feet) in CATO streams, FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline).

Table 6: Hydrology data for Big Hunting Creek, CATO, October 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/6/2005	*Not Reported	0.25	LOW	*Not Reported
11/8/2005	*Not Reported	0.63	LOW	*Not Reported
12/12/2005	*Not Reported	0.99	LOW	*Not Reported
1/23/2006	46.518	1.51	NORMAL	26.75
2/23/2006	28.530	1.0	NORMAL	24.9
3/21/2006	9.138	0.40	NORMAL	22.33
4/10/2006	4.417	0.187	LOW	19.67
5/16/2006	39.754	1.33	NORMAL	25.59
6/26/2006	*Not Reported	2.61	LOW	54.75
7/24/2006	4.82	0.3	LOW	20.0
8/15/2006	7.379	0.17	NORMAL	31.33
9/13/2006	2.8	0.08	LOW	28
10/16/2006	4.420	0.16	LOW	21.3
11/30/2006	*Not Reported	0.53	LOW	*Not Reported
1/4/2007	22.114	0.714	NORMAL	25.5
1/31/2007	2.996	0.213	LOW	15.083
3/6/2007	39.349	1.23	NORMAL	26.5
4/3/2007	17.724	0.596	NORMAL	26.0
5/23/2007	2.118	0.157	LOW	18.750
6/28/2007	*Not Reported	*Not Reported	LOW	20.583
7/26/2007	*Not Reported	*Not Reported	LOW	18.667
8/27/2007	*Not Reported	*Not Reported	LOW	18.083
9/27/2007	*Not Reported	*Not Reported	LOW	23.167
10/22/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/20/2007	*Not Reported	*Not Reported	LOW	18.583
12/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/28/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/25/2008	*Not Reported	*Not Reported	LOW	22.7
3/24/2008	21.95	1.043	NORMAL	27.03
4/24/2008	22.47	1.216	NORMAL	25.75
5/14/2008	73.4	2.072	ABOVE NORMAL	28
6/24/2008	5.88	.505	LOW	21.2
7/29/2008	2.89	.270	LOW	18.92
8/25/2008	2.36	.233	LOW	18.5
9/22/2008	6.02	.408	NORMAL	20.5

Table 7: Hydrology data for Whiskey Still Creek, CATO, October 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/6/2005	*Not Reported	0	NO FLOW	*Not Reported
11/8/2005	*Not Reported	0.07	LOW	*Not Reported
12/12/2005	*Not Reported	0.87	LOW	*Not Reported
1/23/2006	6.56	0.8	NORMAL	10.25
2/23/2006	2.590	0.3	NORMAL	12.33
3/21/2006	2.688	0.28	NORMAL	12.0
4/10/2006	0.385	0.048	LOW	12
5/16/2006	1.864	0.18	LOW	11.0
6/26/2006	*Not Reported	2.01	LOW	14.58
7/24/2006	0.579	0.62	LOW	4.66
8/15/2006	*Not Reported	0	LOW	6.58
9/12/2006	0.043	.03	LOW	7.1
10/16/2006	0.205	0.15	LOW	6.8
11/30/2006	1.303	0.66	LOW	6.58
1/4/2007	0.864	0.293	LOW	9.5
1/31/2007	0.259	0.45	LOW	1.917
3/6/2007	1.253	0.94	LOW	3.333
4/3/2007	1.861	0.974	LOW	5.417
5/23/2007	0.566	0.608	LOW	4.167
6/28/2007	*Not Reported	*Not Reported	LOW	3.167
7/26/2007	*Not Reported	*Not Reported	LOW	2.333
8/27/2007	*Not Reported	*Not Reported	LOW	2.083
9/27/2007	0	0	DRY	0
10/22/2007	0	0	DRY	0
11/20/2007	*Not Reported	*Not Reported	LOW	3.167
12/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
2/25/2008	*Not Reported	*Not Reported	LOW	4.8
3/24/2008	1.17	1.111	LOW	4.05
4/24/2008	2.62	1.776	NORMAL	5
5/14/2008	4.58	2.183	NORMAL	6.0
6/24/2008	0.18	0.354	LOW	6.33
7/29/2008	*Not Reported	*Not Reported	LOW	3.03
8/25/2008	0	0	DRY	0
9/22/2008	*Not Reported	*Not Reported	LOW	2.75

Table 8: Hydrology data for Owens Creek, CATO, October 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/6/2005	*Not Reported	0.1	LOW	*Not Reported
11/8/2005	*Not Reported	1.18	LOW	*Not Reported
12/12/2005	*Not Reported	*Not Reported	NO FLOW	*Not Reported
1/23/2006	*Not Reported	1.34	LOW	*Not Reported
2/23/2006	*Not Reported	*Not Reported	NORMAL	25
3/21/2006	15.054	1.053	ABOVE NORMAL	21.6
4/10/2006	1.421	0.15	LOW	27
5/16/2006	9.792	0.69	NORMAL	25.42
6/26/2006	*Not Reported	2.72	NORMAL	23.5
7/24/2006	3.560	0.53	NORMAL	21.0
8/15/2006	1.084	0.17	LOW	21.25
9/13/2006	0.737	0.08	LOW	17.8
10/16/2006	1.580	0.14	LOW	22.6
11/30/2006	1.615	0.38	LOW	21.25
1/4/2007	5.081	0.991	NORMAL	13.250
1/31/2007	0.724	0.36	LOW	13.17
4/3/2007	7.648	0.555	NORMAL	21.833
5/23/2007	2.060	0.224	LOW	22.583
6/28/2007	*Not Reported	*Not Reported	NORMAL	20.833
7/26/2007	*Not Reported	*Not Reported	LOW	19.250
8/27/2007	*Not Reported	*Not Reported	LOW	18.417
9/27/2007	*Not Reported	*Not Reported	LOW	18.000
10/22/2007	*Not Reported	*Not Reported	NO FLOW	*Not Reported
11/20/2007	*Not Reported	*Not Reported	LOW	15.5
12/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/28/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/25/2008	*Not Reported	*Not Reported	LOW	19
3/24/2008	7	.864	NORMAL	23
4/24/2008	11.59	1.419	NORMAL	22.083
5/14/2008	18.23	1.419	ABOVE NORMAL	23
6/24/2008	4.18	0.773	NORMAL	22
7/29/2008	*Not Reported	*Not Reported	LOW	18.06
8/25/2008	*Not Reported	*Not Reported	LOW	16.92
9/22/2008	*Not Reported	*Not Reported	LOW	19.42

George Washington Memorial Parkway (GWMP)

The George Washington Memorial Parkway runs from Mt. Vernon through Arlington and Fairfax Counties in Virginia to Great Falls and supervises additional property at Glen Echo in Montgomery County, Maryland. Though the park crosses the Piedmont Uplands, Northern Inner Piedmont and Chesapeake Rolling Coastal Plain physiographic regions, all of the NCRN sampling sites occur in the Piedmont Uplands.

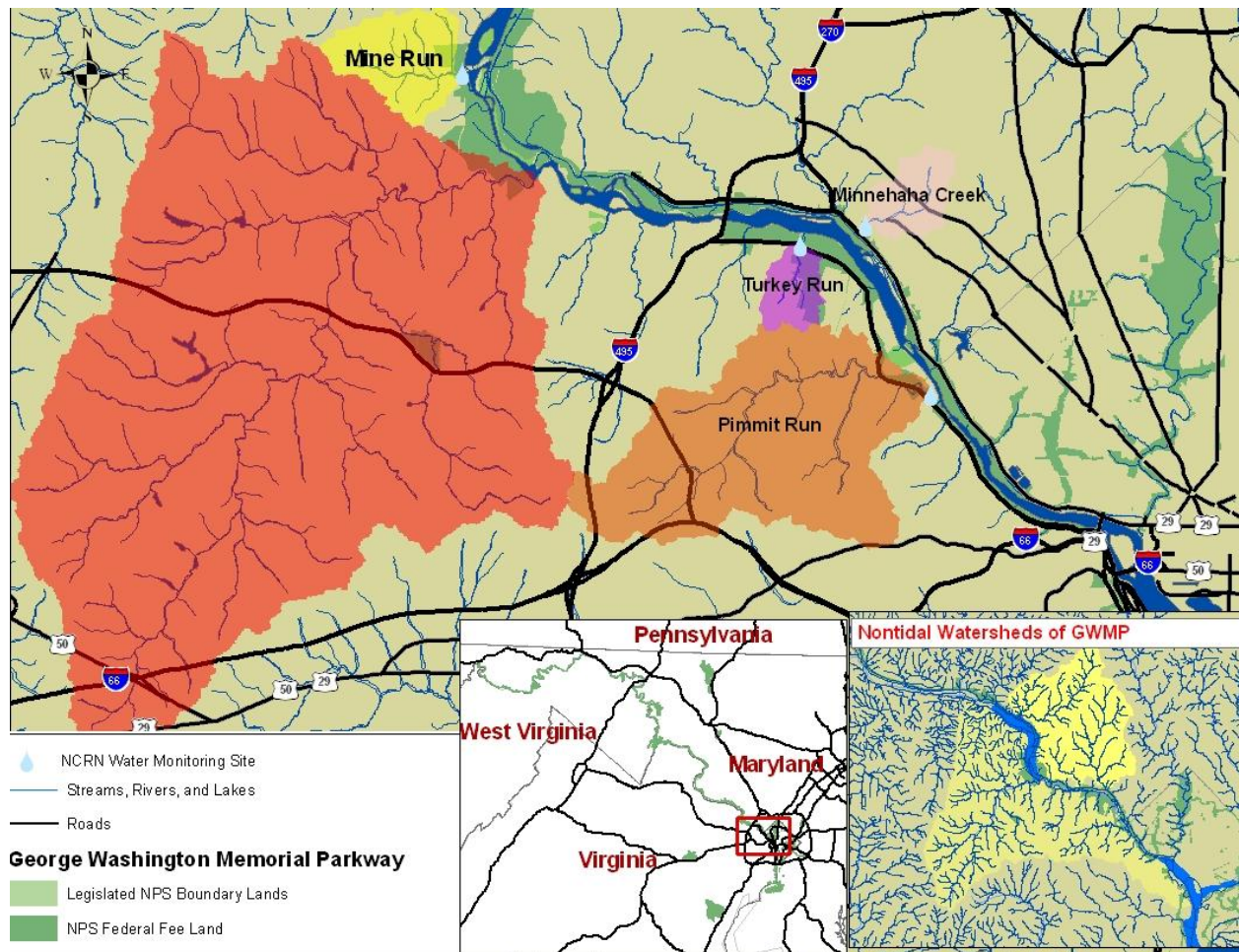


Figure 22: Perennial nontidal sampling sites and watersheds in GWMP

Five sites were monitored in the park on a monthly basis for dissolved oxygen, ph, specific conductance, temperature, acid neutralizing capacity, nitrate, ammonia, and total phosphorus. Summary statistics for October 2006 through September 2008 are shown in Table 9.

Table 9: Date range, number of site visits (N), and data range for the information covered in this report for GWMP.

Local Name	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/19/2006 - 9/23/2008	84	-6	32	16	21	10
ANC	µeq/L	10/19/2006 - 9/23/2008	92	178	2272	1115	984	476
Discharge	cfs	10/19/2006 - 9/23/2008	48	0.16	102.90	6.80	1.62	16.99
DO	mg/l	10/19/2006 - 9/23/2008	93	4.81	14.77	8.54	8.09	2.08
Flow	ft/sec	10/19/2006 - 9/23/2008	51	0.005	1.470	0.358	0.275	0.315
Nitrate	mg/l	10/19/2006 - 9/23/2008	93	0.6	4.1	1.9	1.8	0.7
Ammonia	mg/l	10/19/2006 - 9/23/2008	58	0.031	0.150	0.063	0.063	0.025
pH	None	10/19/2006 - 9/23/2008	92	6.79	9.30	7.67	7.66	0.40
Phosphate	mg/l	10/19/2006 - 9/23/2008	93	0.05	5.75	0.45	0.24	0.81
Salinity	ppt	10/19/2006 - 9/23/2008	93	0.1	1.8	0.2	0.1	0.2
Specific conductance	µS/cm	10/19/2006 - 9/23/2008	93	121.9	3528.0	374.2	288.4	414.5
Water Depth	ft	10/19/2006 - 9/23/2008	54	0.10	2.05	0.71	0.63	0.41
Water Temperature	°C	10/19/2006 - 9/23/2008	93	1.38	22.20	13.65	15.70	6.42
Wetted Width	ft	10/19/2006 - 9/23/2008	65	1.5	100.0	18.4	11.0	17.5

Several readings of nitrate were above the desired level of 2.0 mg/L nitrate in 2007 and 2008 for all streams though none of the means were significantly greater than the threshold, in 2005-2006 and again in 2008 only Minnehaha Creek was significantly impaired for nitrate (Figure 24).

Phosphorus is consistently above the desired range of 0.1 mg/L at all sites (Figure 25).

Ammonia was barely detected and never exceeded threshold (Figure 26). Ammonia is a difficult parameter to measure. We frequently get readings below zero and the EDL of 0.032 with the very low readings we normally get means that much of the data is excluded from analysis (40 of 98 readings in the case of GWMP in FY2007-2008). While there were DO values below the desired level of 5mg/L in 2005-2006, there were no readings below the threshold in 2007 and only one instance each at Mine Run and Pimmit Run in 2008 (Figure 27).

Specific conductance is usually below the current threshold of 400 µS for all sites except Minnehaha Creek which is always high, and Pimmit and Turkey Run in late winter 2008 (figure 28). ANC is always above the desired level of 200 µS/cm, indicating that GWMP's streams are well buffered against acid inputs (Figure 29). The pH was within desired range except for individual readings on Pimmit Run and Turkey Run in late winter early spring 2006 and 2007 and Minnehaha Creek in 2008 of readings over 9 (figure 30). Water temperature was always within the desired range for aquatic life (0 to 25° C) (Figure 31).

The region experienced a drought in 2007. Several small streams in the region dried out, however GWMPs nontidal streams did not. Water depth was sufficient for discharge measurements throughout the year in Minnehaha Creek, Mine Run and Pimmit Run (Figure 32). Turkey Run water levels can be too low for discharge measurements in the spring and summer. We had only been able to take hydrology measurements in Difficult Run during periods of low flow and rarely managed a complete cross-section in order to calculate discharge (Table 9). The 2008 water quality report from the state of Virginia listed Difficult Run as a 5th order stream,

which is well outside of our sampling range (VA DEQ 2008). The site was dropped for 2009. Hydrology data is available from a USGS gage located just upstream of the park property.

Based on the data collected so far, normal water levels for Minnehaha Creek can be defined as discharge between 1.5 cfs and 5 cfs, with a flow of 0.08 f/s or higher (Table 10). Based on the data collected so far, normal water levels for Pimmit Run can be defined as discharge between 6 cfs and 13 cfs in a channel with a wetted width of 30 or more feet (Table 11). Based on the data collected so far, normal water levels for Turkey Run can be defined as discharge between 1 cfs and 5 cfs, with a flow of 0.1 f/s or higher in a channel with a wetted width of 15 or more feet (Table 12). Based on the data collected so far, normal water levels for Mine Run can be defined as discharge between 0.7 cfs and 4 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 5 or more feet (Table 13).

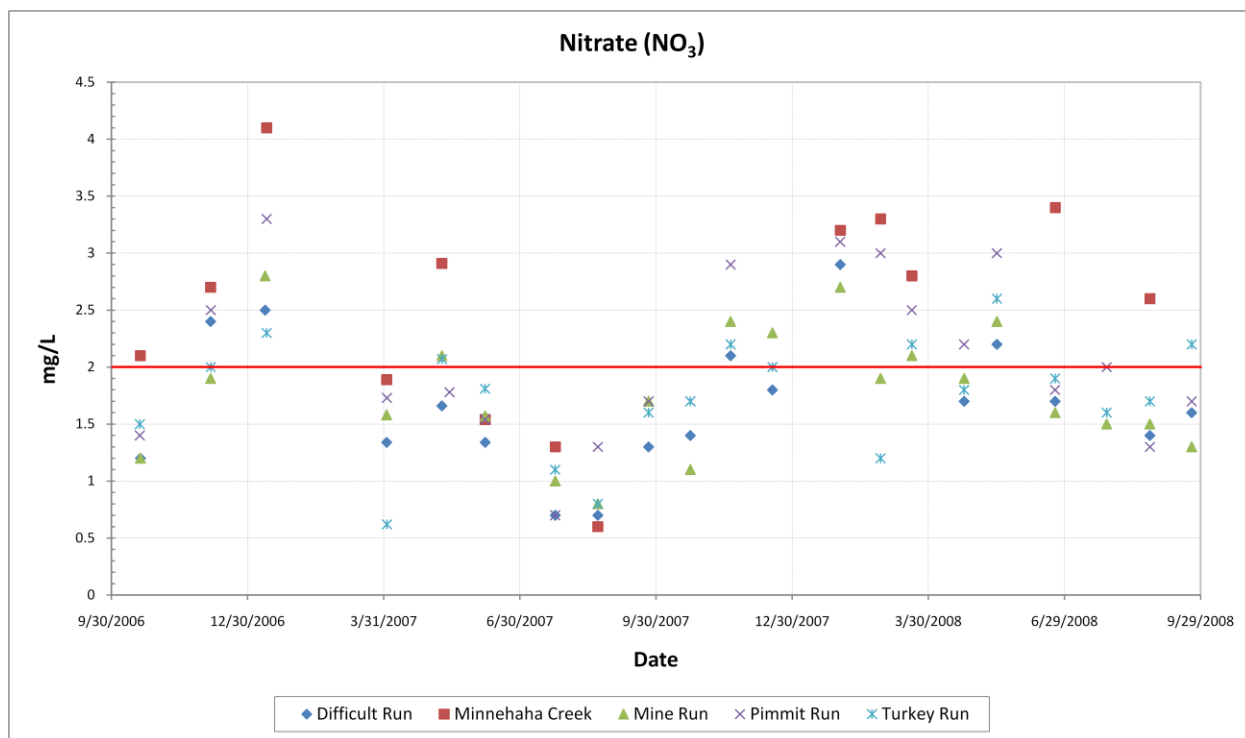


Figure 23: Nitrate in nontidal GWMP streams, FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

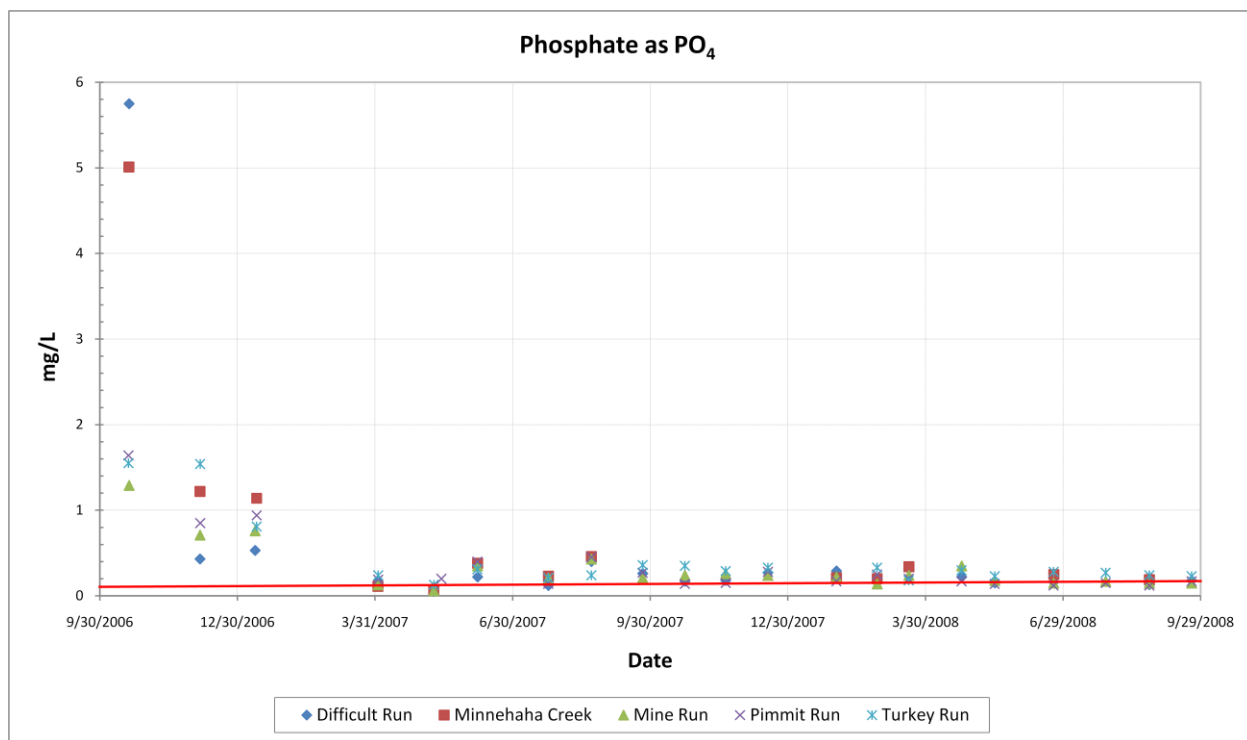


Figure 24: Phosphate in nontidal GWMP streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

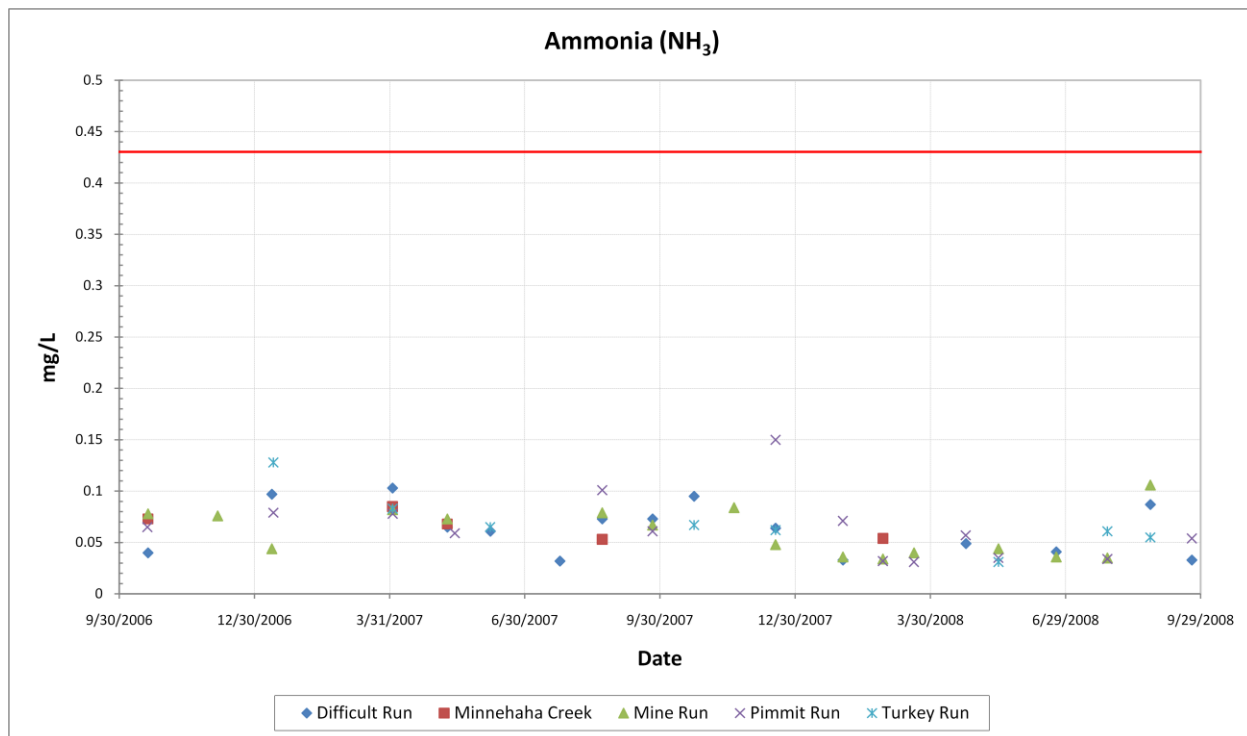


Figure 25: Ammonia in nontidal GWMP streams FY 2007- 2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

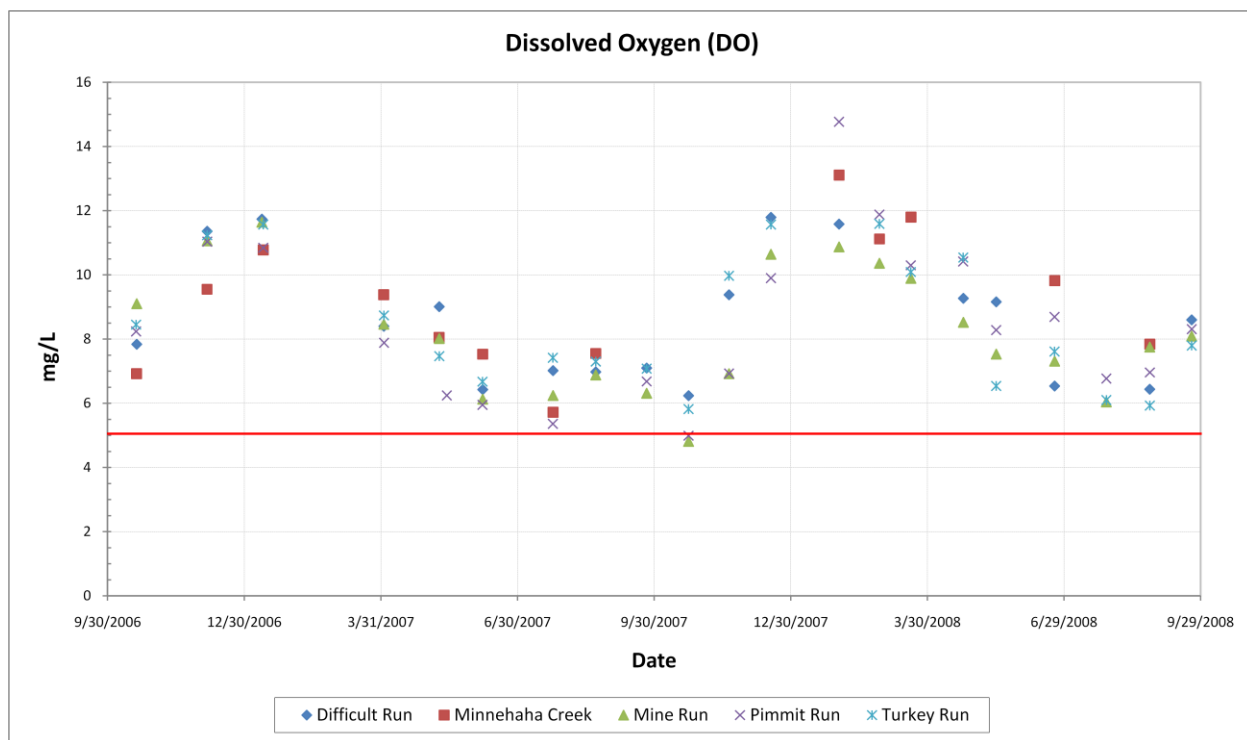


Figure 26: Dissolved oxygen in nontidal GWMP streams, FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

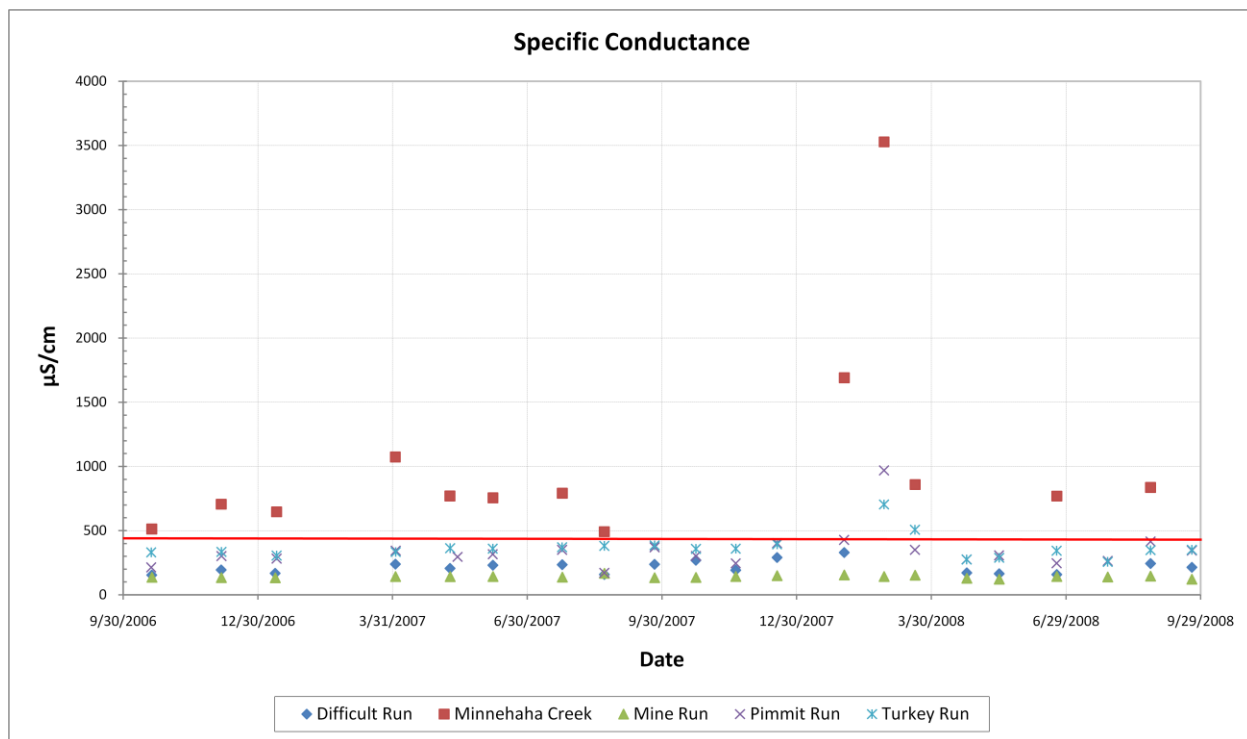


Figure 27: Specific Conductance in nontidal GWMP streams, FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

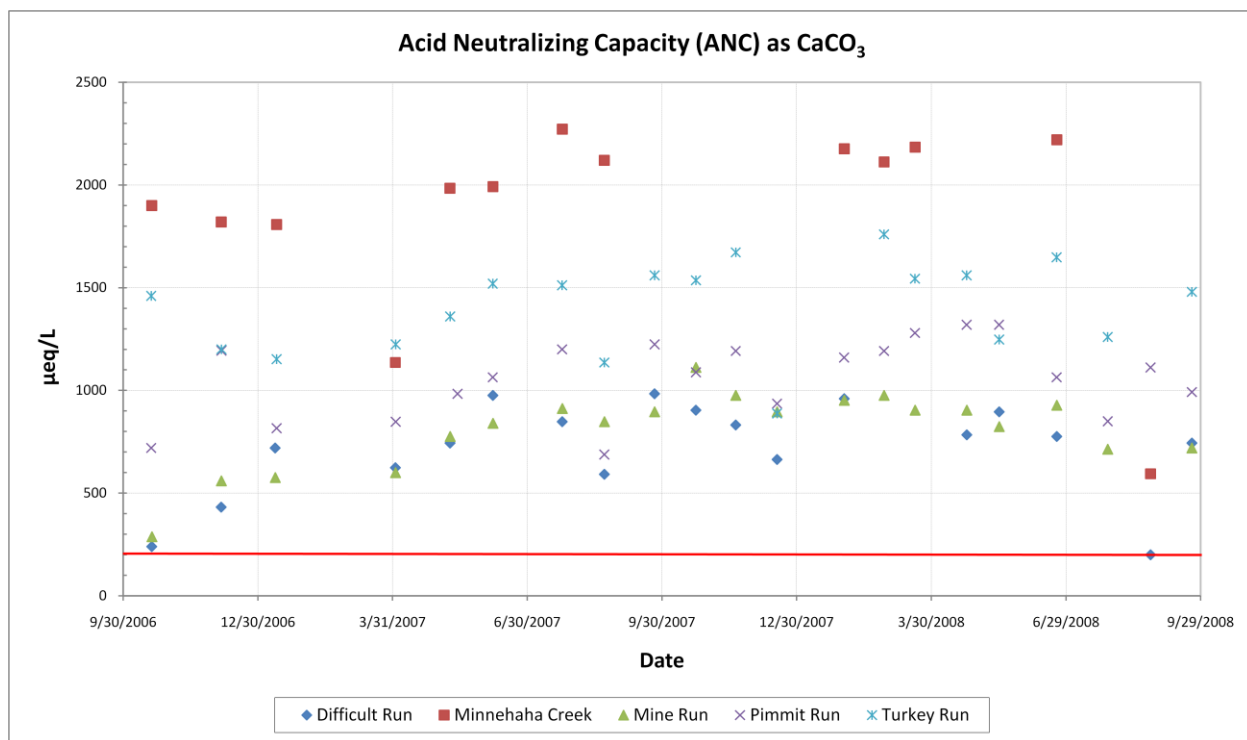


Figure 28: Acid Neutralizing Capacity in nontidal GWMP streams, FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq/L}$ (the red line on the graph).

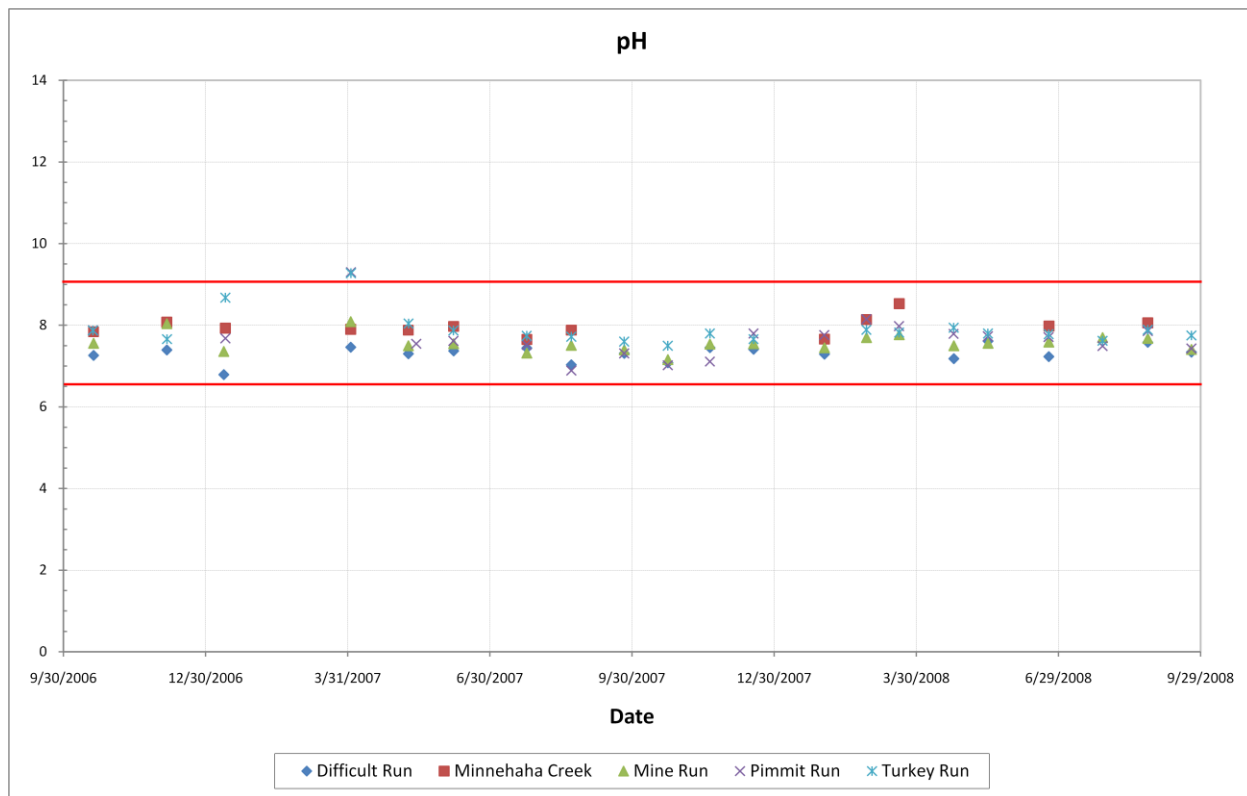


Figure 29: pH in nontidal GWMP streams, FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

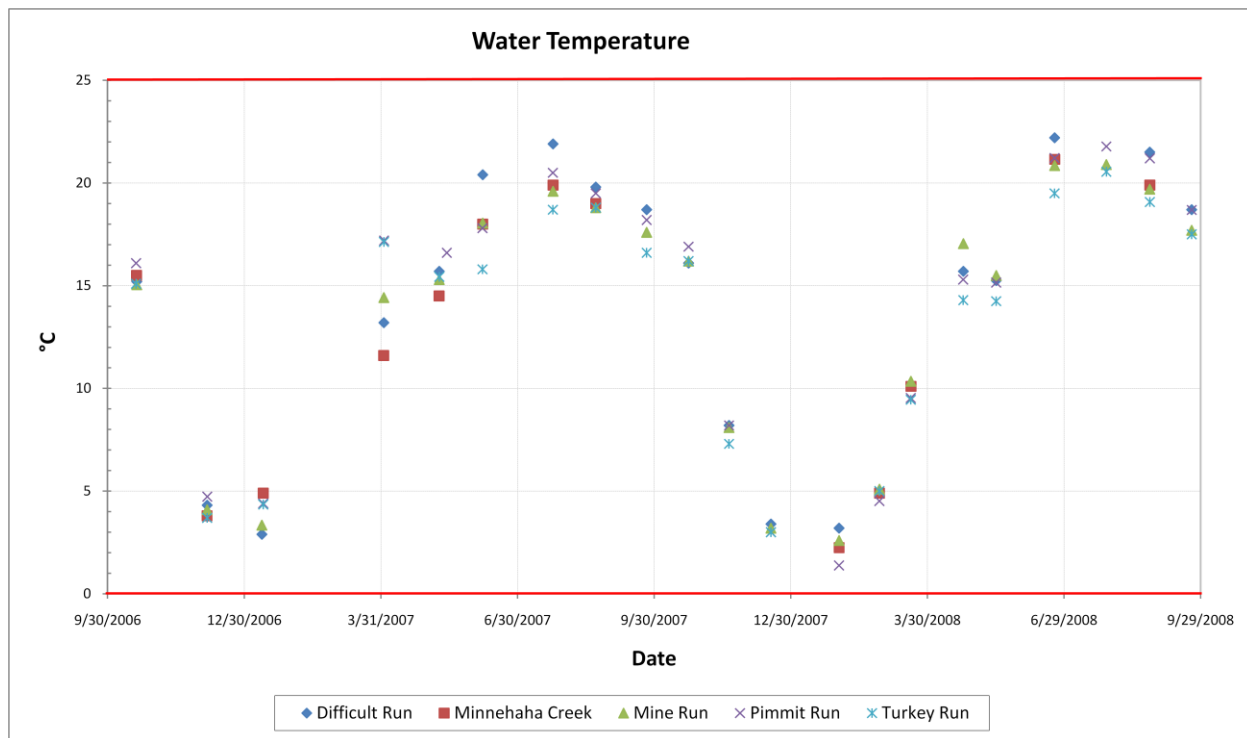


Figure 30: Water temperature in nontidal GWMP streams, FY 2007-2008. Temperatures between 0 and 25 °C are ideal for aquatic life.

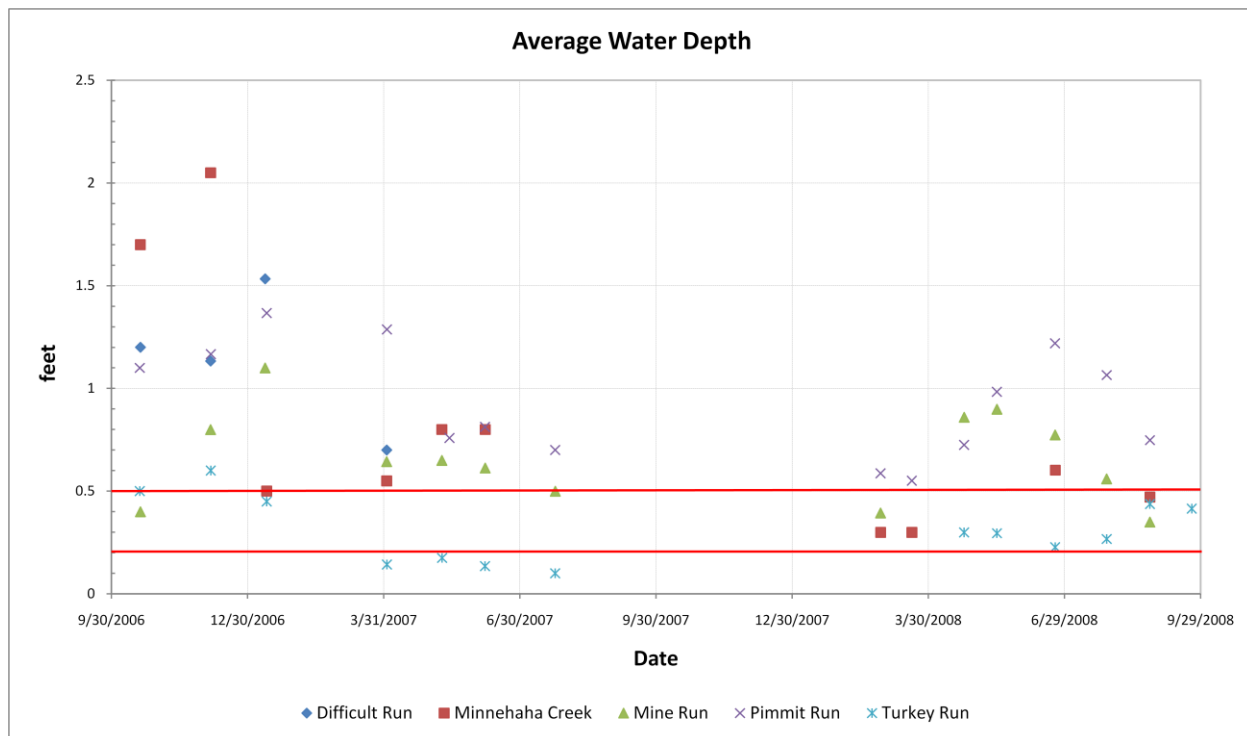


Figure 31: Water Depth (feet) in nontidal GWMP streams, FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 10: Hydrology data for Difficult Run, GWMP, November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	1.86	LOW	*Not Reported
12/5/2005	*Not Reported	0.53	LOW	*Not Reported
1/10/2006	*Not Reported	0.64	LOW	*Not Reported
2/16/2006	*Not Reported	1.26	LOW	*Not Reported
3/13/2006	*Not Reported	0.54	LOW	*Not Reported
4/6/2006	*Not Reported	1.23	LOW	*Not Reported
5/2/2006	*Not Reported	1.05	LOW	*Not Reported
6/15/2006	99.131	0.36	LOW	62.58
7/12/2006	117.795	1.4	LOW	60.66
8/7/2006	*Not Reported	1.05	LOW	*Not Reported
9/25/2006	*Not Reported	7.23	NORMAL	*Not Reported
10/19/2006	*Not Reported	0.32	LOW	63.5
12/5/2006	56.463	.79	LOW	65
1/11/2007	*Not Reported	.583	LOW	*Not Reported
2/15/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
3/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
4/2/2007	102.9	1.47	LOW	100
5/9/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
6/7/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
7/24/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
8/22/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/25/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/23/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
11/19/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
12/17/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/1/2008	*Not Reported	*Not Reported	LOW	*Not Reported
3/1/2008	*Not Reported	*Not Reported	LOW	*Not Reported
4/23/2008	*Not Reported	*Not Reported	NORMAL	*Not Reported
5/15/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
6/23/2008	*Not Reported	*Not Reported	NORMAL	*Not Reported
7/1/2008	*Not Reported	*Not Reported	LOW	*Not Reported
8/26/2008	*Not Reported	*Not Reported	LOW	*Not Reported
9/23/2008	*Not Reported	*Not Reported	LOW	*Not Reported

Table 11: Hydrology data for Mine Run, GWMP, November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	0.39	NORMAL	*Not Reported
12/5/2005	*Not Reported	0.27	LOW	*Not Reported
1/10/2006	3.963	0.46	NORMAL	7.83
2/16/2006	9.774	0.68	ABOVE NORMAL	9.6
3/13/2006	2.430	0.22	NORMAL	10.0
4/6/2006	*Not Reported	0.34	NORMAL	*Not Reported
5/2/2006	2.501	0.31	NORMAL	7.33
6/15/2006	3.640	0.30	NORMAL	7.58
7/12/2006	*Not Reported	0.35	NORMAL	*Not Reported
8/7/2006	0.700	0.06	LOW	11.71
9/25/2006	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/19/2006	3.526	0.86	NORMAL	10.25
11/1/2006	*Not Reported	*Not Reported	LOW	*Not Reported
12/5/2006	1.835	0.32	NORMAL	7.17
1/11/2007	3.861	0.36	NORMAL	9.75
2/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
3/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
4/2/2007	1.899	0.257	NORMAL	9.75
5/9/2007	1.582	0.275	NORMAL	8.00
6/7/2007	0.624	0.108	LOW	8.333
7/24/2007	*Not Reported	*Not Reported	NORMAL	7.333
8/22/2007	*Not Reported	*Not Reported	LOW	7.417
9/25/2007	*Not Reported	*Not Reported	LOW	6.500
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	9.2
2/27/2008	1.12	0.369	NORMAL	7.75
3/19/2008	*Not Reported	*Not Reported	LOW	4
4/23/2008	3.17	0.737	NORMAL	5.0
5/15/2008	3.36	0.746	NORMAL	6
6/23/2008	1.66	0.338	NORMAL	6.04
7/28/2008	0.77	0.275	NORMAL	5
8/26/2008	0.16	0.112	LOW	4
9/23/2008	*Not Reported	*Not Reported	LOW	*Not Reported

Table 12: Hydrology data for Minnehaha Creek, GWMP, November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	2.66	ABOVE NORMAL	*Not Reported
12/5/2005	*Not Reported	0.68	NORMAL	*Not Reported
1/5/2006	24.120	1.59	ABOVE NORMAL	7.6
2/16/2006	1.832	0.89	NORMAL	3.2
3/13/2006	2.356	0.435	NORMAL	5.4
4/6/2006	*Not Reported	0.87	NORMAL	*Not Reported
5/2/2006	*Not Reported	0.79	NORMAL	1.83
6/15/2006	1.531	0.08	NORMAL	13.67
7/12/2006	1.864	0.18	NORMAL	17.5
8/7/2006	4.686	0.05	NORMAL	28.75
9/25/2006	*Not Reported	*Not Reported	LOW	2
10/19/2006	0.356	0.01	LOW	23.75
12/5/2006	0.233	0.005	LOW	24.5
1/12/2007	2.848	1.34	NORMAL	4.25
4/2/2007	1.154	0.47	LOW	4.417
5/9/2007	1.752	0.613	NORMAL	3.167
6/7/2007	1.083	0.34	LOW	3.167
7/24/2007	*Not Reported	*Not Reported	LOW	*Not Reported
8/22/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/25/2007	*Not Reported	*Not Reported	LOW	*Not Reported
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	2
2/27/2008	0.33	0.733	LOW	1.5
3/19/2008	0.498	0.829	LOW	2
6/23/2008	0.6	0.429	LOW	2.11
8/26/2008	0.26	0.190	LOW	2.83

Table 13: Hydrology data for Pimmit Run, GWMP, November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	0.6	NORMAL	*Not Reported
12/5/2005	*Not Reported	0.16	LOW	*Not Reported
1/10/2006	9.280	0.19	NORMAL	36.58
2/16/2006	27.823	0.47	ABOVE NORMAL	36.4
3/13/2006	6.400	0.48	NORMAL	36.0
4/6/2006	12.299	0.28	NORMAL	36.75
5/2/2006	*Not Reported	0.28	NORMAL	*Not Reported
6/15/2006	72.193	1.31	FLOOD	32.42
7/12/2006	3.706	0.11	LOW	32.08
8/7/2006	26.628	0.45	ABOVE NORMAL	32.83
9/25/2006	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/19/2006	6.831	0.22	NORMAL	35.33
12/5/2006	29.005	0.17	ABOVE NORMAL	36.5
1/12/2007	18.198	0.383	ABOVE NORMAL	34.25
4/2/2007	9.130	0.241	NORMAL	30
5/14/2007	3.358	0.081	LOW	33.167
6/7/2007	2.026	0.059	LOW	30.750
7/24/2007	*Not Reported	*Not Reported	LOW	29.750
8/22/2007	*Not Reported	*Not Reported	LOW	30.750
9/25/2007	*Not Reported	*Not Reported	LOW	28.5
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	24.5
2/27/2008	4.18	0.300	LOW	23.75
3/19/2008	4.41	0.291	LOW	27.5
4/23/2008	9.45	0.418	NORMAL	30.5
5/15/2008	18.48	0.536	ABOVE NORMAL	35.07
6/23/2008	8.73	0.203	NORMAL	35.03
7/28/2008	4.57	0.126	LOW	35.06
8/26/2008	1.3	0.058	LOW	30
9/23/2008	*Not Reported	*Not Reported	LOW	33.5

Table 14: Hydrology data for Turkey Run, GWMP, November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	0.22	LOW	*Not Reported
12/5/2005	2.500	0.53	NORMAL	*Not Reported
1/10/2006	0.652	0.06	LOW	20.58
2/16/2006	*Not Reported	0.24	NORMAL	20.8
3/13/2006	0.586	0.18	LOW	20.6
4/6/2006	1.276	0.12	NORMAL	20.33
5/2/2006	*Not Reported	0.18	LOW	*Not Reported
6/15/2006	2.419	0.19	NORMAL	19.583
7/12/2006	4.479	0.39	NORMAL	17.66
8/7/2006	0.557	0.1	LOW	18.58
9/25/2006	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/19/2006	*Not Reported	0.04	LOW	*Not Reported
11/1/2006	*Not Reported	*Not Reported	LOW	*Not Reported
12/5/2006	6.489	0.63	ABOVE NORMAL	17.17
1/12/2007	1.552	0.14	NORMAL	18.33
2/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
3/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
4/2/2007	1.091	0.188	NORMAL	20.417
5/9/2007	0.360	0.05	LOW	21.083
6/7/2007	1.287	0.326	NORMAL	20.083
7/24/2007	*Not Reported	*Not Reported	LOW	4.833
8/22/2007	*Not Reported	*Not Reported	LOW	5.083
9/25/2007	*Not Reported	*Not Reported	LOW	3.333
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/1/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/27/2008	*Not Reported	*Not Reported	LOW	4.9
3/19/2008	*Not Reported	*Not Reported	LOW	7
4/23/2008	1.24	0.275	NORMAL	15
5/15/2008	1.23	0.244	NORMAL	17
6/23/2008	0.52	0.208	LOW	11
7/28/2008	0.4	0.114	LOW	13.03
8/26/2008	0.24	0.050	LOW	10.92
9/23/2008	0.22	0.033	LOW	15.75

Harpers Ferry National Historical Site (HAFE)

The rivers and streams greatly define the landscape at Harpers Ferry National Historical Park. The Potomac and Shenandoah watersheds cover enormous areas. The Potomac and Shenandoah Rivers are not in the park but there are some small tributaries that cross the park. The only stream with any appreciable length on park property that would be affected by park management is Flowing Springs, which winds for about one mile along the park before it enters the Shenandoah (Figure 32). Flowing Springs occurs in the portion of the park underlain by karst. Karst is a three dimensional landscape developed on and in soluble rock units such as dolomite (calcium and magnesium carbonate) or limestone (calcium carbonate). Through time, precipitation and groundwater drain through cracks and crevices in the carbonate bedrock, slowly dissolving the rock to form an underground network of conduits that often produce karstic features such as sinkholes, caves, and springs. In such places there may be little or no surface runoff making these areas very susceptible to water pollution, since it passes almost directly into the groundwater reservoir. Acidic precipitation increases the dissolution, which increases the speed of flow from surface to ground, and increases the spread of the pollution. Karst-geology occurs in the western section of HAFE. The limestone/dolomite bedrock of western HAFE runs throughout Washington County and is contiguous with areas under Antietam National Battlefield and Chesapeake and Ohio Canal National Historic Site (Woods et al. 1999).

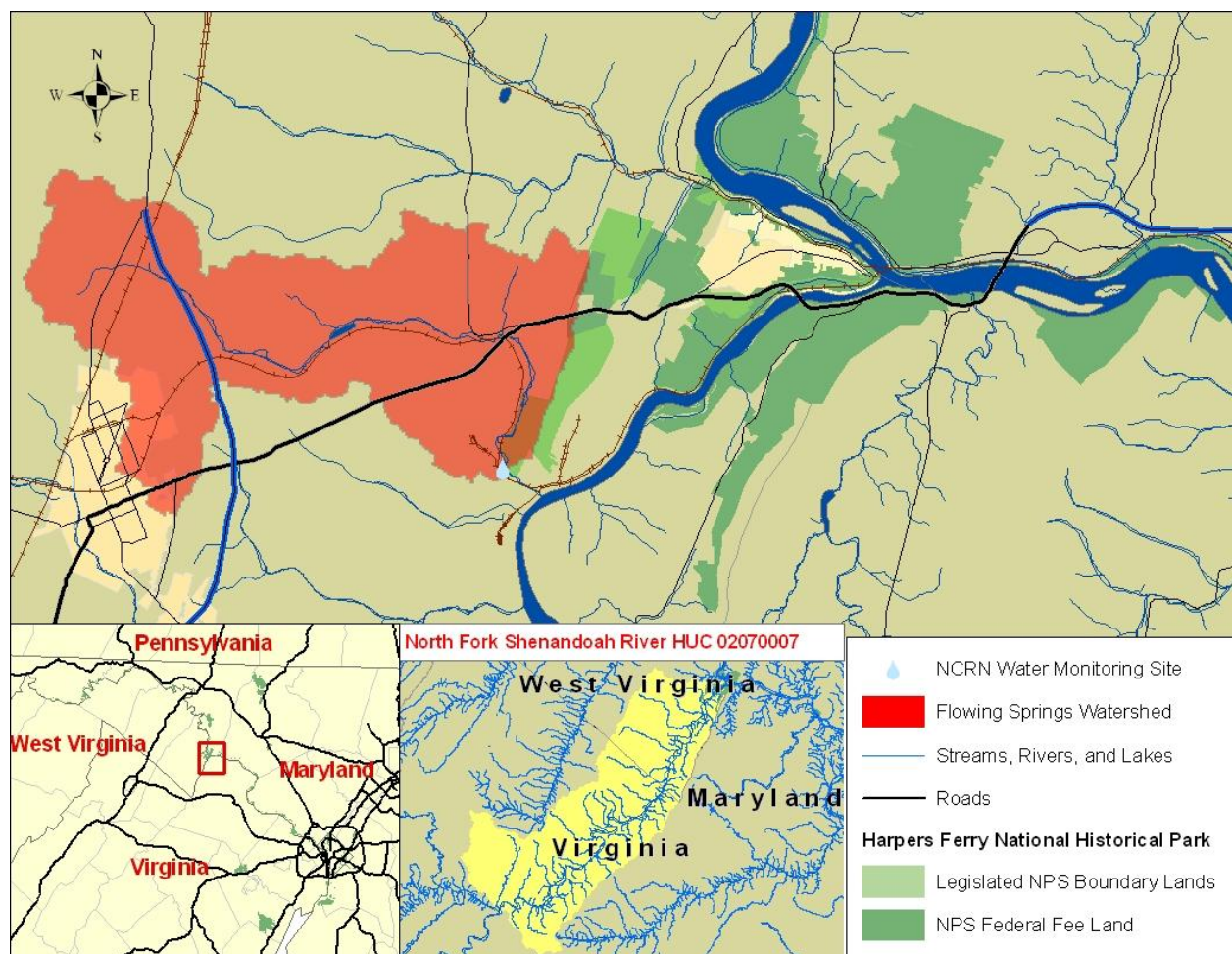


Figure 32: Relationship of the Flowing Springs monitoring site to the watershed and the park boundary

One site was monitored in the park on a monthly basis for dissolved oxygen, ph, specific conductance, temperature, acid neutralizing capacity, nitrate, ammonia, and total phosphorus. This report discusses data collected October 2006 through September 2008 in Flowing Springs. Summary Statistics for the time period are shown in Table 15.

Table 15: Date range, number of site visits (N), and data range for the information covered in this report for HAFE

Local Name	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/12/2006 - 9/18/2008	16	0	34	16	16	10
ANC	µeq/L	10/12/2006 - 9/18/2008	22	3200	5280	4772	4850	507
Discharge	cfs	10/12/2006 - 9/18/2008	15	0.00	21.12	8.17	6.99	6.04
DO	mg/l	10/12/2006 - 9/18/2008	22	5.82	14.42	9.08	8.97	2.09
Flow	ft/sec	10/12/2006 - 9/18/2008	14	0.42	2.24	1.15	1.10	0.48
Nitrate	mg/l	10/12/2006 - 9/18/2008	22	1.5	8.0	4.9	4.4	1.8
Ammonia	mg/l	10/12/2006 - 9/18/2008	19	0.031	1.314	0.127	0.058	0.289
pH	None	10/12/2006 - 9/18/2008	22	6.967	8.587	8.210	8.250	0.314
Phosphate	mg/l	10/12/2006 - 9/18/2008	22	0.17	1.31	0.44	0.30	0.33
Salinity	ppt	10/12/2006 - 9/18/2008	22	0.3	0.4	0.3	0.3	0.0
Specific conductance	µS/cm	10/12/2006 - 9/18/2008	22	461.6	837.3	651.8	640.8	73.8
Water Depth	ft	10/12/2006 - 9/18/2008	15	0.171	0.750	0.433	0.400	0.153
Water Temperature	°C	10/12/2006 - 9/18/2008	22	4.117	24.500	14.250	15.150	6.163
Wetted Width	ft	10/12/2006 - 9/18/2008	21	0	22.1	13.1	14.5	6.3

Nitrate exceeded the desired level of 2.0 mg/L every month except January 2007 (Figure 34). Phosphorus always exceeded threshold (Figure 35). Ammonia only exceeded the in January 2007 (Figure 36). There were no readings of DO below the threshold in 2007 or 2008 (Figure 37). Specific conductance always exceeded the desired threshold of 400 µS (Figure 38). The pH never exceeds 9 (Figure 40). ANC ranges from 3200-5280 (Figure 39), among the highest in the region along with Sharpsburg Creek in Antietam. The higher pH and acid neutralizing capacity of Flowing Spring Run are due to dissolution of the limestone and dolomite bedrock. This may also contribute to the higher specific conductance, though fertilizers, pesticides, and livestock runoff may also contribute. Water temperature follows expected seasonal trends and stays within the comfort zone of desired organisms (Figure 41).

The region experienced a drought in 2007. Several small streams in the region dried out, including Flowing Springs. The stream had no or interstitial flow October 2007 through January 2008 (Figure 42, Table 16). The stream hosts a very active beaver population and despite the steady groundwater flow through the karst, the combination of damming and siltation from their activity has at times buried base flow. Based on the data collected so far, normal water levels for Flowing Springs can be defined as discharge between 5 cfs and 18 cfs, with a flow of 0.7 f/s or higher in a channel with a wetted width of 14 or more feet.

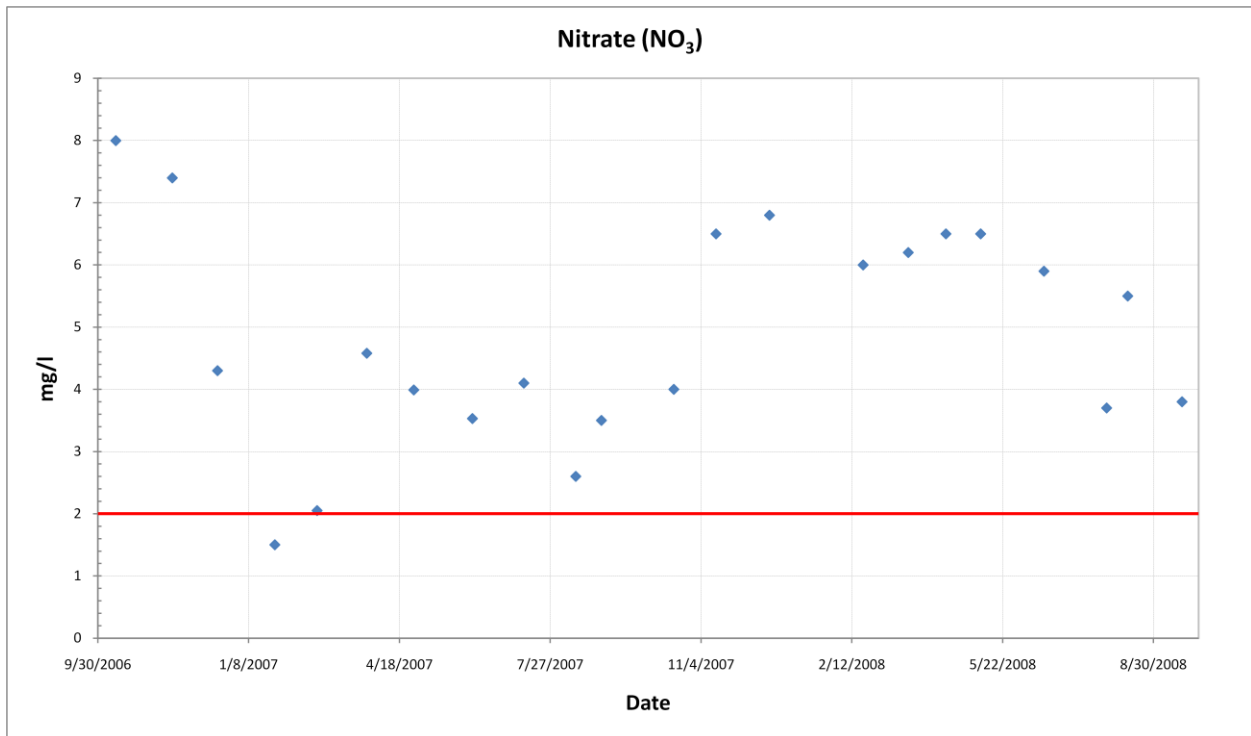


Figure 33: Nitrate in Flowing Springs, HAFE, FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

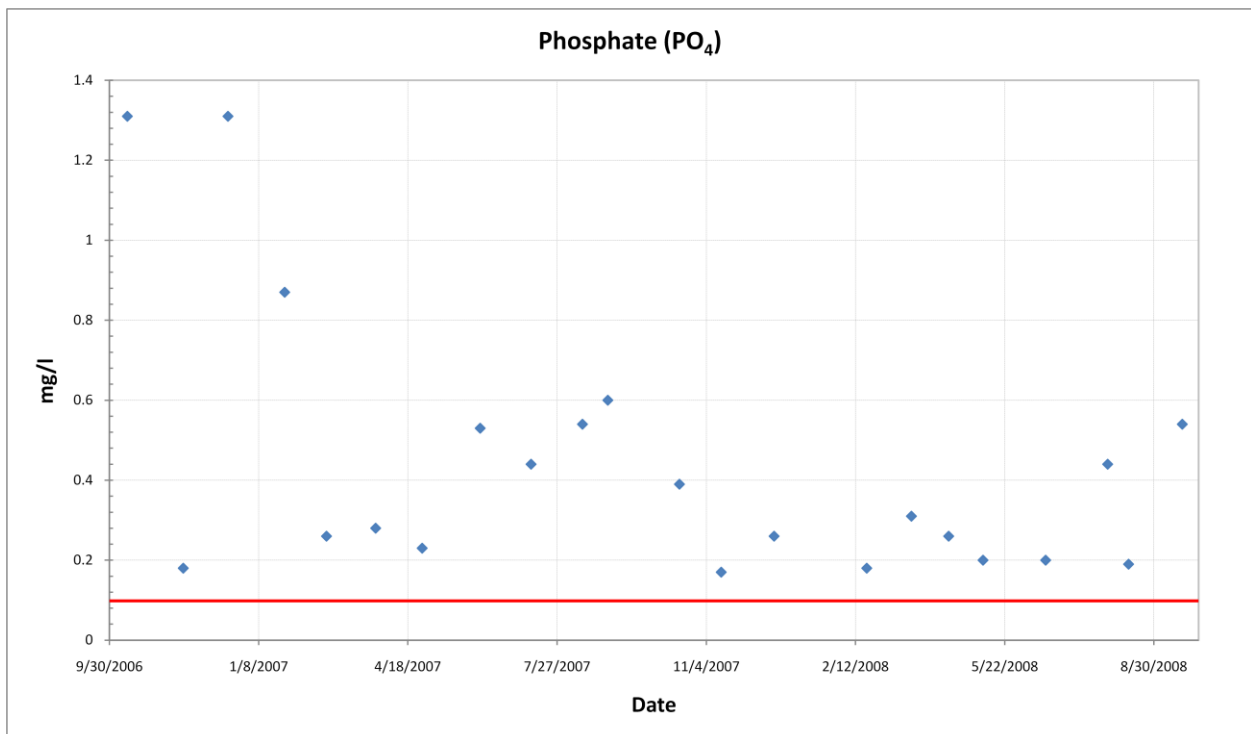


Figure 34: Phosphate in Flowing Springs, HAFE, FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

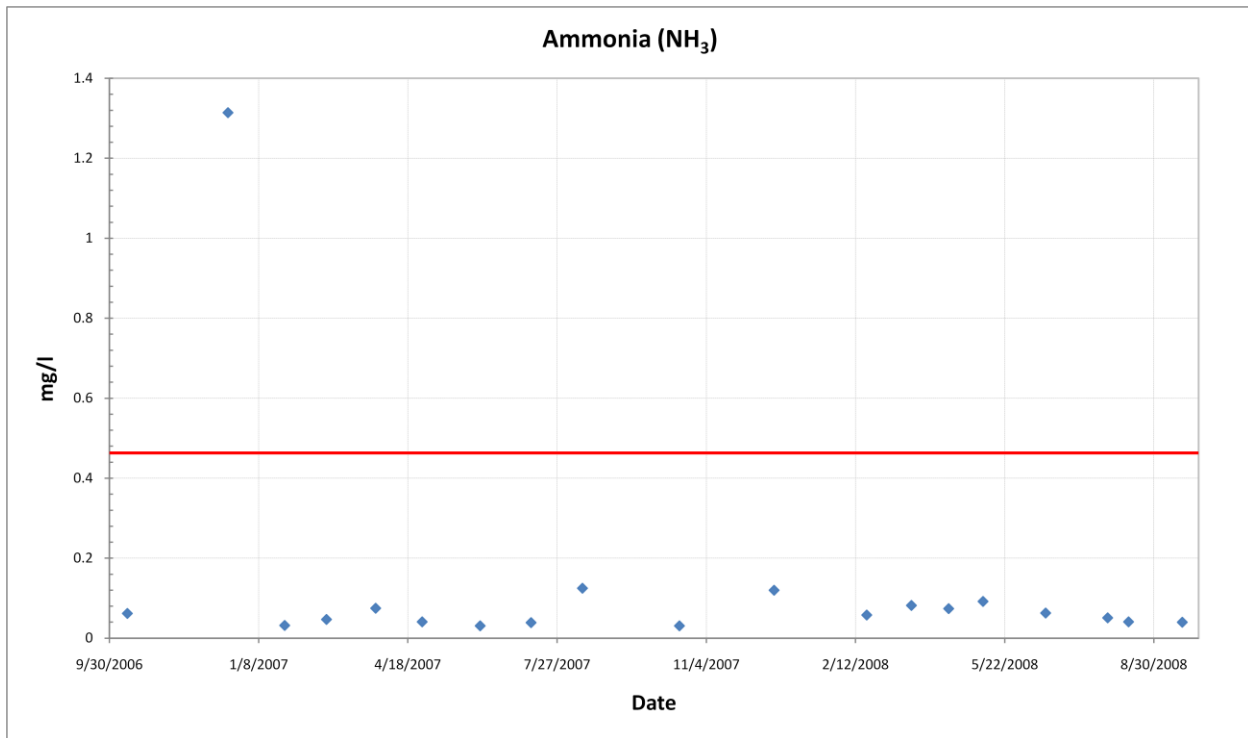


Figure 35: Ammonia in Flowing Springs, HAFE, FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

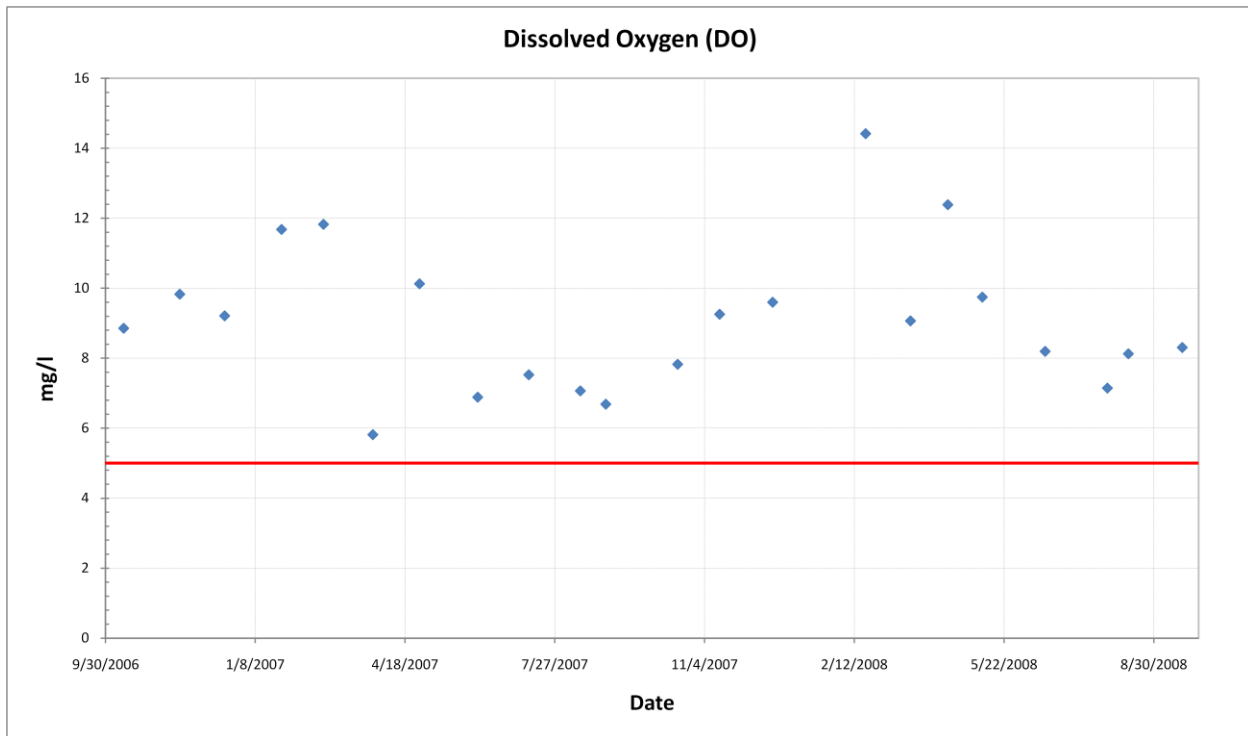


Figure 36: Dissolved oxygen in Flowing Springs, HAFE, FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

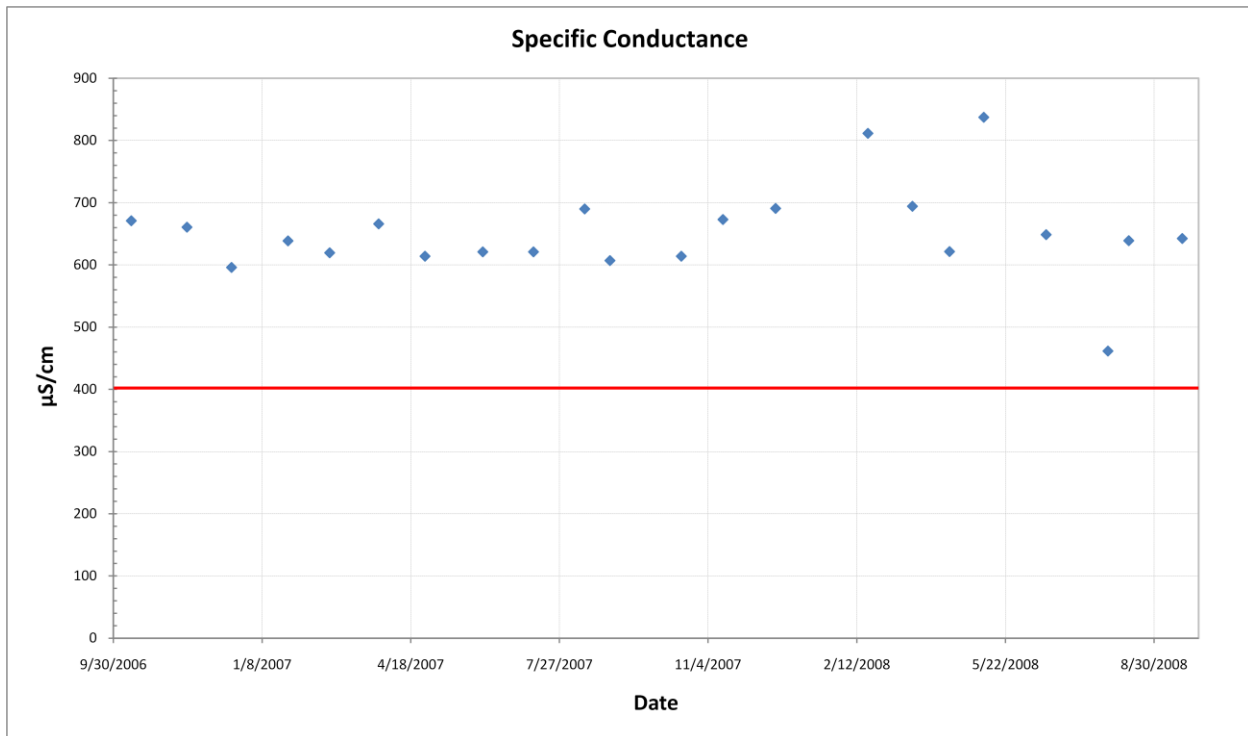


Figure 37: Specific Conductance in Flowing Springs, HAFE, FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

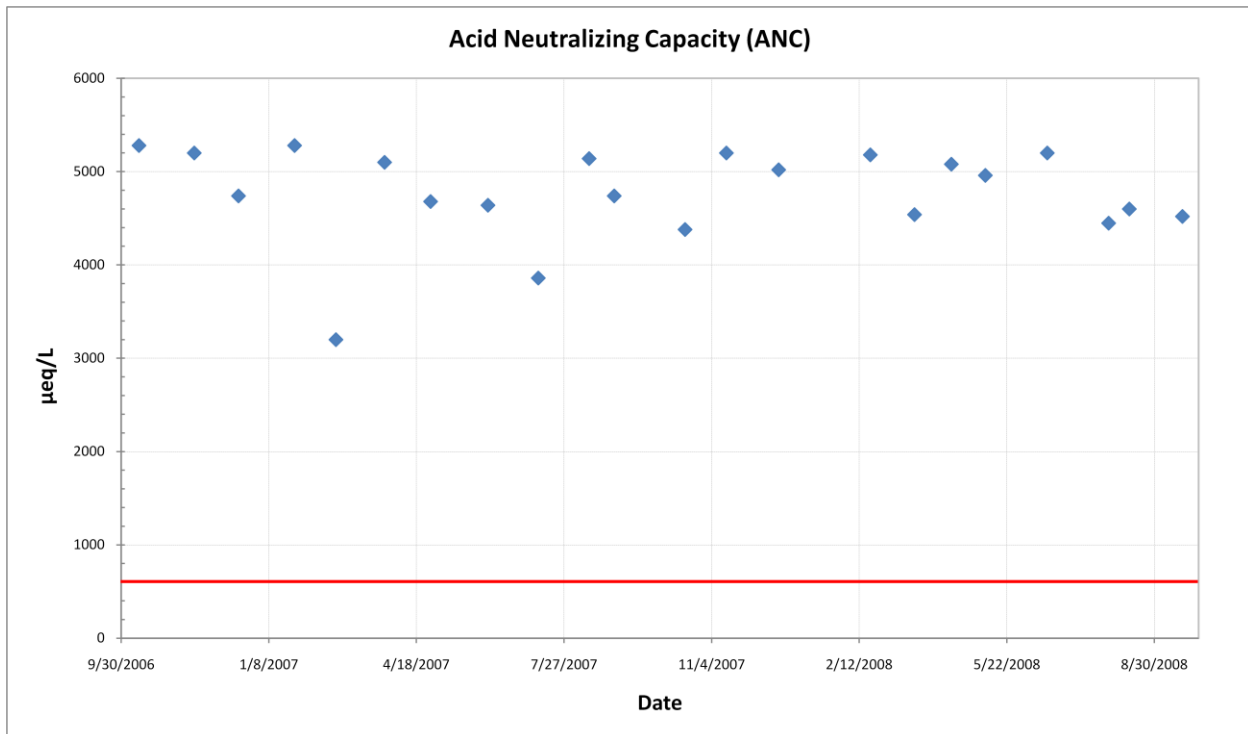


Figure 38: Acid Neutralizing Capacity in Flowing Springs, HAFE, FY 2007-2008. Karst waters should have ANC above 600 µeq/L (the red line on the graph).

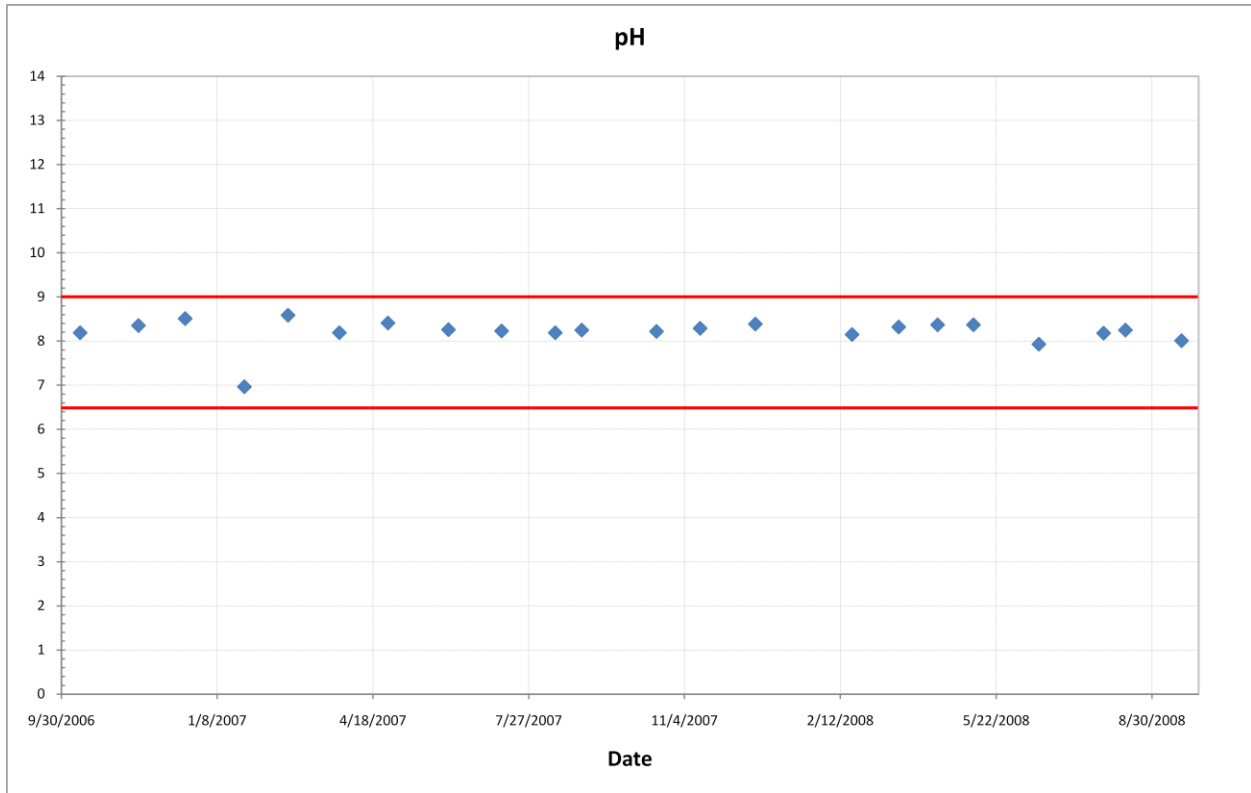


Figure 39: pH in Flowing Springs, HAFE, FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

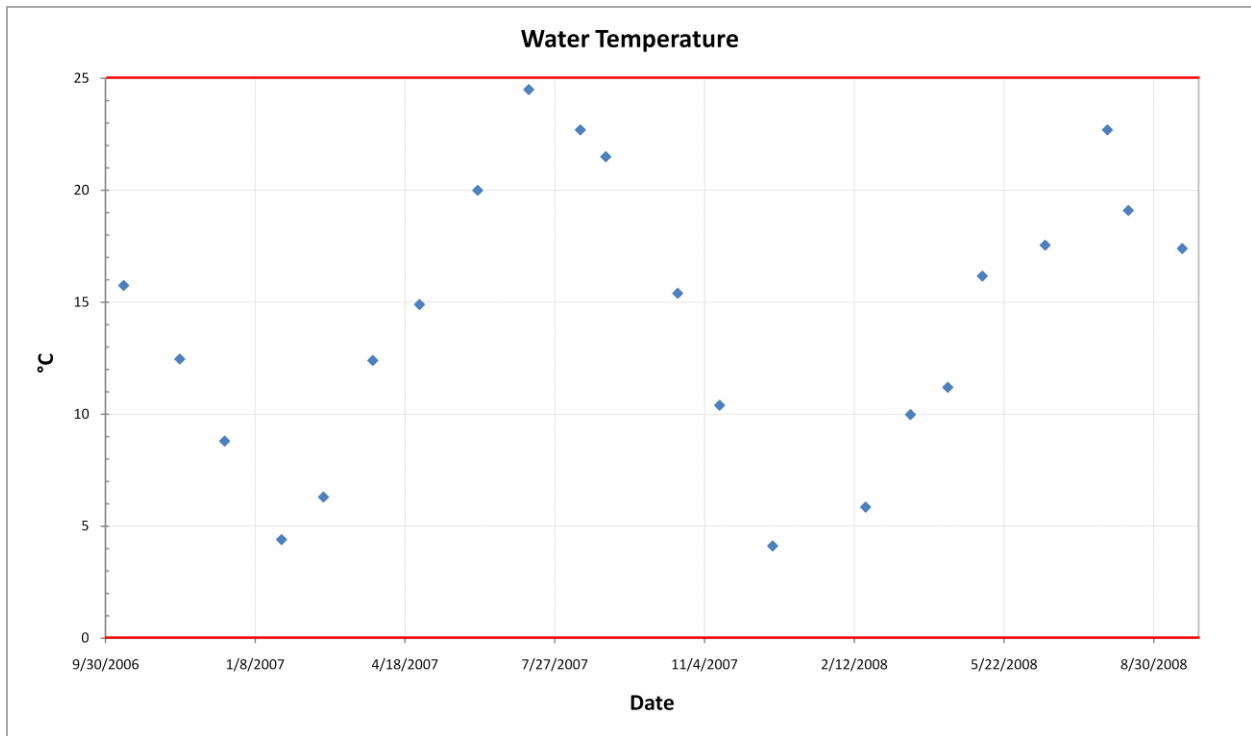


Figure 40: Water temperature in Flowing Springs, HAFE, FY 2007-2008. Temperatures between 0 and 25° C are ideal for aquatic life.

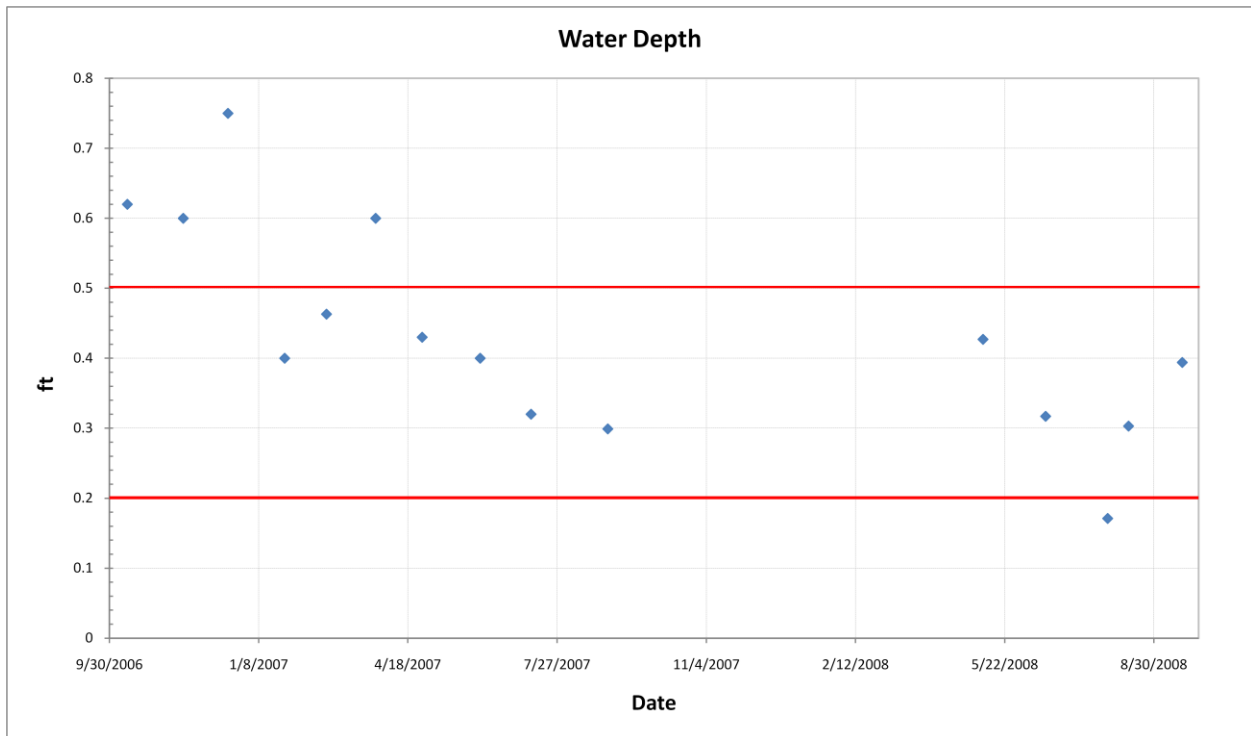


Figure 41: Water Depth (feet) in Flowing Springs, HAFE, FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 16: Hydrology data for Flowing Springs, HAFE June 2005 to September 2008

DATE	Discharge	Flow	Flow, below freezing	Wetted Width
6/2/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
6/30/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
10/11/2005	*Not Reported	0.30	LOW	*Not Reported
11/17/2005	*Not Reported	0.06	LOW	*Not Reported
12/14/2005	*Not Reported	*Not Reported	*Not Reported	*Not Reported
1/26/2006	15.442	1.87	NORMAL	14
2/28/2006	3.071	0.325	LOW	19.5
3/23/2006	11.254	1.66	NORMAL	14.83
4/12/2006	2.843	0.67	LOW	14.5
5/18/2006	1.268	0.26	LOW	14.0
6/28/2006	*Not Reported	2.61	NORMAL	*Not Reported
7/26/2006	11.926	1.14	NORMAL	14.5
8/14/2006	8.646	0.81	NORMAL	13.83
10/12/2006	21.123	2.24	ABOVE NORMAL	15.7
11/18/2006	17.381	1.983	NORMAL	14.5
12/18/2006	14.642	1.355	NORMAL	14.25
1/25/2007	7.960	1.086	NORMAL	18.667
2/22/2007	5.875	0.705	NORMAL	19.083
3/27/2007	11.609	1.11	NORMAL	18.9
4/27/2007	7.236	0.8	NORMAL	18.0
6/5/2007	6.760	0.91	NORMAL	14.5
7/9/2007	*Not Reported	*Not Reported	*Not Reported	9.333
8/13/2007	*Not Reported	*Not Reported	LOW	8.25
8/30/2007	3.779	1.26	LOW	10.000
10/17/2007	*Not Reported	*Not Reported	*Not Reported	*Not Reported
11/14/2007	*Not Reported	*Not Reported	*Not Reported	*Not Reported
12/19/2007	0.00	0	dry	0
1/22/2008	0	0	dry	0
2/19/2008	*Not Reported	*Not Reported	LOW	14.33
3/20/2008	*Not Reported	*Not Reported	NORMAL	16.333
4/14/2008	*Not Reported	*Not Reported	LOW	11.583
5/7/2008	11.14	1.172	LOW	22.1
6/18/2008	6.99	1.038	NORMAL	21.04
7/30/2008	2.304	.839	LOW	16.08
8/13/2008	0.75	.420	LOW	5.92
9/18/2008	5.05	1.240	LOW	6.25

Manassas National Battlefield Park (MANA)

The 2,064 ha park is located approximately 72 km southwest of Washington, D.C. in Prince William County, Virginia within the Piedmont physiographic region. MANA's streams are lined with dark red siltstone (Fenneman 1938, Thornbury 1968, Blomquist et al. 1996, Roth et al. 1999, William & Mary 2000). The park contains about 16 miles of named streams and several unnamed watercourses.

The eastern boundary of the park is Bull Run. Program staff identified 4 perennial streams within the park (Figure 43): Young's Branch, its tributaries Chinn's Branch and Dogans Branch, and Holkums Branch. Young's Branch and Holkum's Branch are tributaries of Bull Run. Most of Young's Branch Watershed is contained within the battlefield. Chinn's Branch and several smaller intermittent tributaries are entirely on park property. Holkum's Branch begins on the Northern Virginia Community College Manassas Campus.

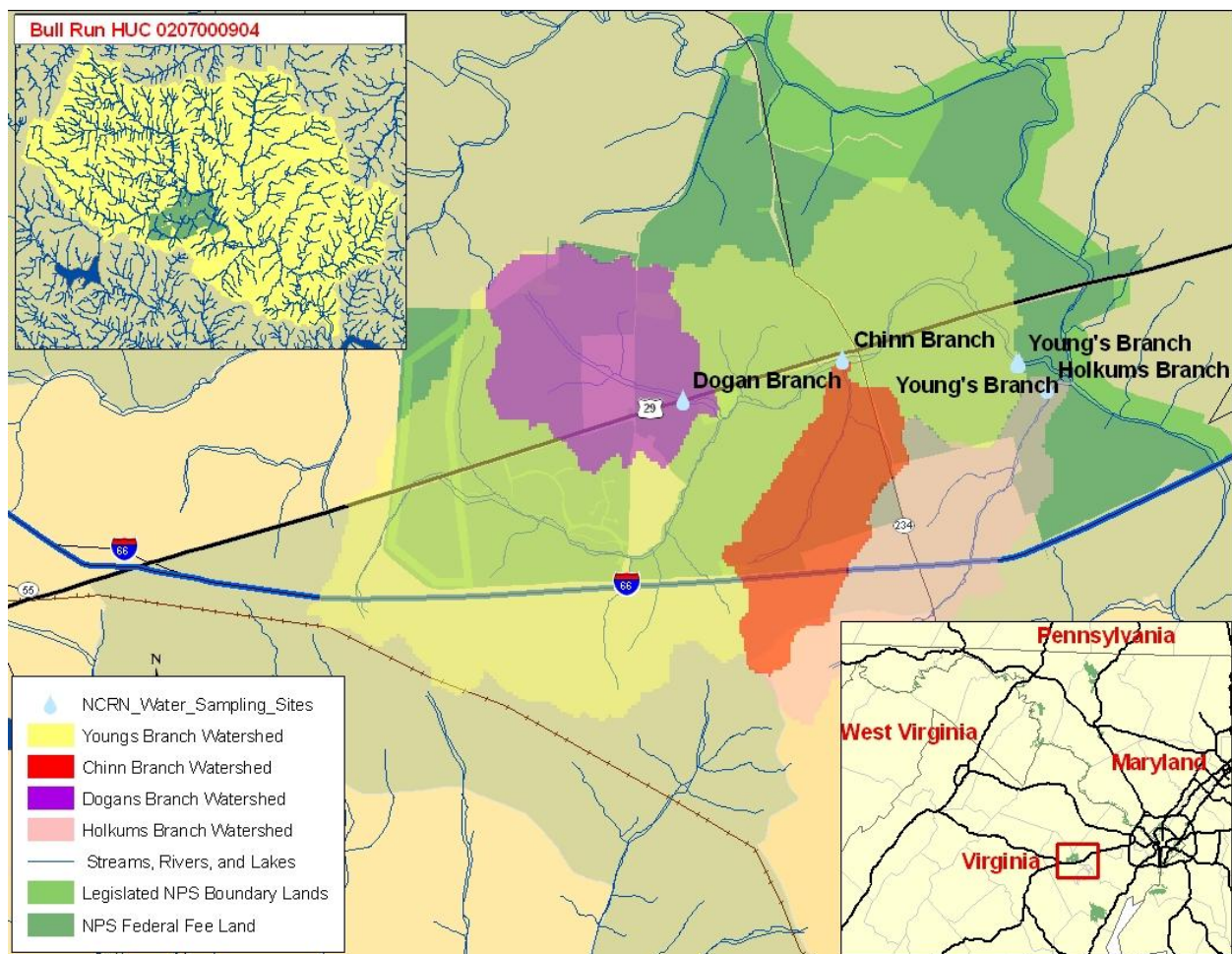


Figure 42: Relationship of MANA stream monitoring sites to their watersheds and the park boundary

This report discusses data collected October 2006 through September 2008 for Chinn's Branch (CHBR), Dogan's Branch (DOBR), Holkum's Branch (HOBR), and Young's Branch (YOBR). Summary statistics for the time period are shown in Table 17.

Table 17: Date range, number of site visits (N), and data range for the information covered in this report in MANA.

<i>Parameter</i>	<i>Units</i>	<i>Period of Record</i>	<i>N</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Mean</i>	<i>Median</i>	<i>Standard Deviation</i>
Air Temperature	°C	11/2/2006 - 9/3/2008	64	-2	31	14	13	11
ANC	µeq/L	11/2/2006 - 9/3/2008	68	736	3912	1637	1466	675
Discharge	cfs	11/2/2006 - 9/3/2008	45	0.00	16.81	1.43	0.30	2.85
DO	mg/l	11/2/2006 - 9/3/2008	68	1.7	20.0	8.9	9.5	3.2
Flow	ft/sec	11/2/2006 - 9/3/2008	46	0.000	1.656	0.331	0.118	0.416
Nitrate	mg/l	11/2/2006 - 9/3/2008	68	0.08	2.30	0.85	0.70	0.59
Ammonia	mg/l	11/2/2006 - 9/3/2008	36	0.001	0.249	0.054	0.049	0.038
pH	None	11/2/2006 - 9/3/2008	65	4.64	9.61	7.59	7.59	0.50
Phosphate	mg/l	11/2/2006 - 9/3/2008	68	0.07	1.25	0.26	0.20	0.20
Salinity	ppt	11/2/2006 - 9/3/2008	71	0.0	0.8	0.2	0.2	0.2
Specific conductance	µS/cm	11/2/2006 - 9/3/2008	71	0	2039	497	406	350
Water Depth	ft	11/2/2006 - 9/3/2008	47	0.0	1.4	0.3	0.2	0.3
Water Temperature	°C	11/2/2006 - 9/3/2008	68	1.15	24.35	11.72	11.65	7.22
Wetted Width	ft	11/2/2006 - 9/3/2008	75	0.00	32.58	9.14	6.83	8.56

Much of the park is maintained as agriculture to replicate the historical Civil War viewshed. The agriculture lease agreements allow for fertilizer and pesticide applications. These are probably among the sources of the nitrate and phosphate. Other sources include acid rain and atmospheric deposition as well as background levels in groundwater. As expected in an agricultural area nitrate, phosphorus and specific conductance continue to exceed thresholds for stream health.

Nitrate only exceeded the threshold December 2007 at Chinns Branch and January 2008 at all sites (Figure 44). Phosphate exceeded threshold at all sites with water January– November 2007 (Figure 45). Chinns Branch also exceeded phosphate threshold October 2006, December 2007, and March and April 2008. Dogans Branch and Holkums Branch also exceeded phosphate threshold October 2006 and March through May 2008. Youngs Branch also exceeded threshold May 2008. Possible PO₄ sources in the watersheds should be investigated, including orthophosphate additions to tap water. Particularly since nitrate and ammonia are not usually a problem. Ammonia was always well below threshold (Figure 46). DO appears to follow seasonal patterns with periods of failing to meet threshold during the summer, particularly in Youngs Branch (Figure 47).

All streams sampled in MANA exceed the specific conductance threshold for most of the year (Figure 48). ANC was always well above 200 µeq/L indicating good buffering (Figure 49). The pH was almost always within the ideal range to support aquatic life, except Dogans Branch (>9) in April 2007 and Youngs Branch (<5) in July 2007 (Figure 50). Water temperature follows expected seasonal trends and stays within the comfort zone of desired organisms (Figure 51)

The region experienced a drought in 2007. Several small streams in the region dried out, including all MANA streams. Chinn's Branch dried before 2007 and lacked flow or was dry on 14 occasions: June 2005, June and July 2006, July through November 2007, January and July through September 2008 (Table 18). Dogan's Branch rarely had enough flow for a discharge

measurement (Figure 52). The stream functions more like a long pond that becomes a series of disconnected ponds during dry conditions. The stream dried before 2007 and has been without flow on 7 occasions since 2005: June and December 2005, August and September 2006, July and October 2007, and July through September 2008. Holkum's Branch dried before 2007 and has been without flow on 7 occasions: June 2005, March, June, and August 2006, July and October 2007, and July 2008. Since drying is an annual occurrence and can occur for months at a time, these streams are not perennial and do not fit into our sampling design. These three sites were dropped at the beginning of FY2009.

Young's Branch is the only stream that maintains sufficient depth for discharge measurements most of the year, the exception being May-November 2007 when the Region was in a drought (Figure 52). Based on the data collected so far, normal water levels for Young's Branch can be defined as discharge between 2.5 cfs and 16 cfs, with a flow of 0.1 f/s or higher in a channel with a wetted width of 13 or more feet. Flows have not been observed above normal during sampling visits. Young's Branch had standing pools without flow in summer 2006 and went dry in October 2007. It was observed dry again in fall 2009 (Norris and Pieper 2010). While Young's Branch does not experience annual seasonal drying, it does bear careful observation.

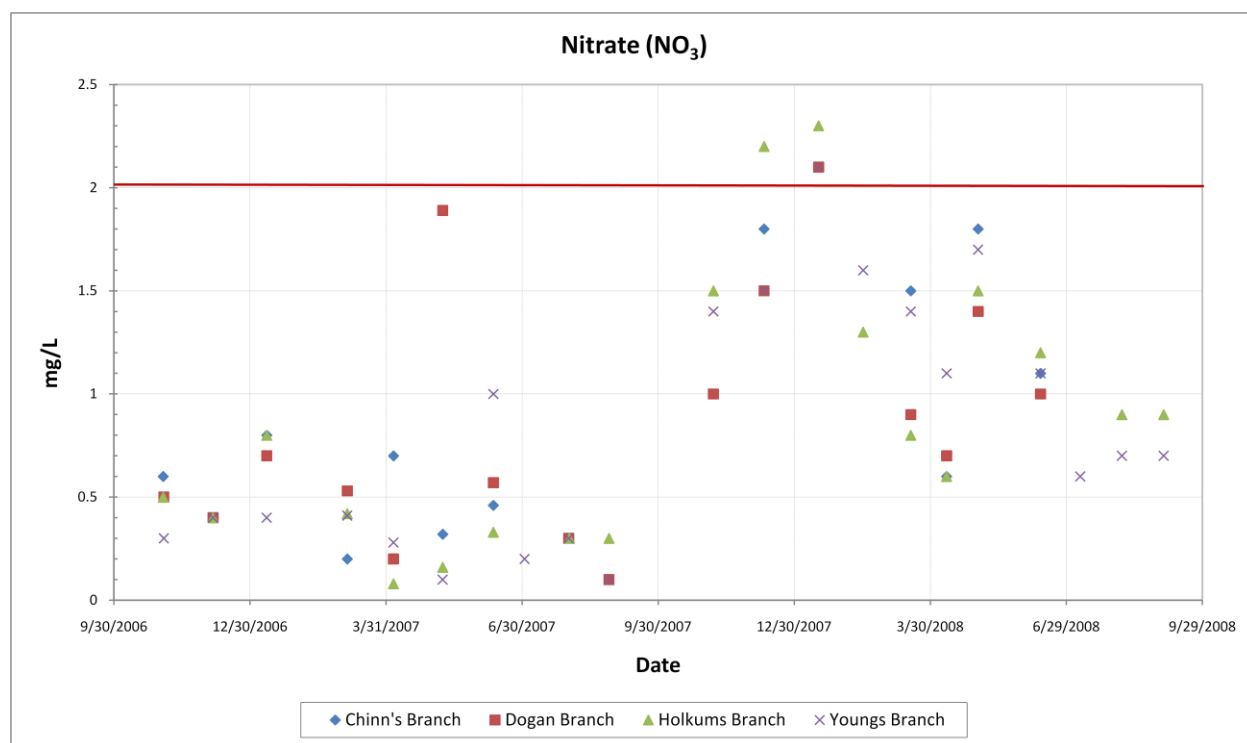


Figure 43: Nitrate in MANA streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

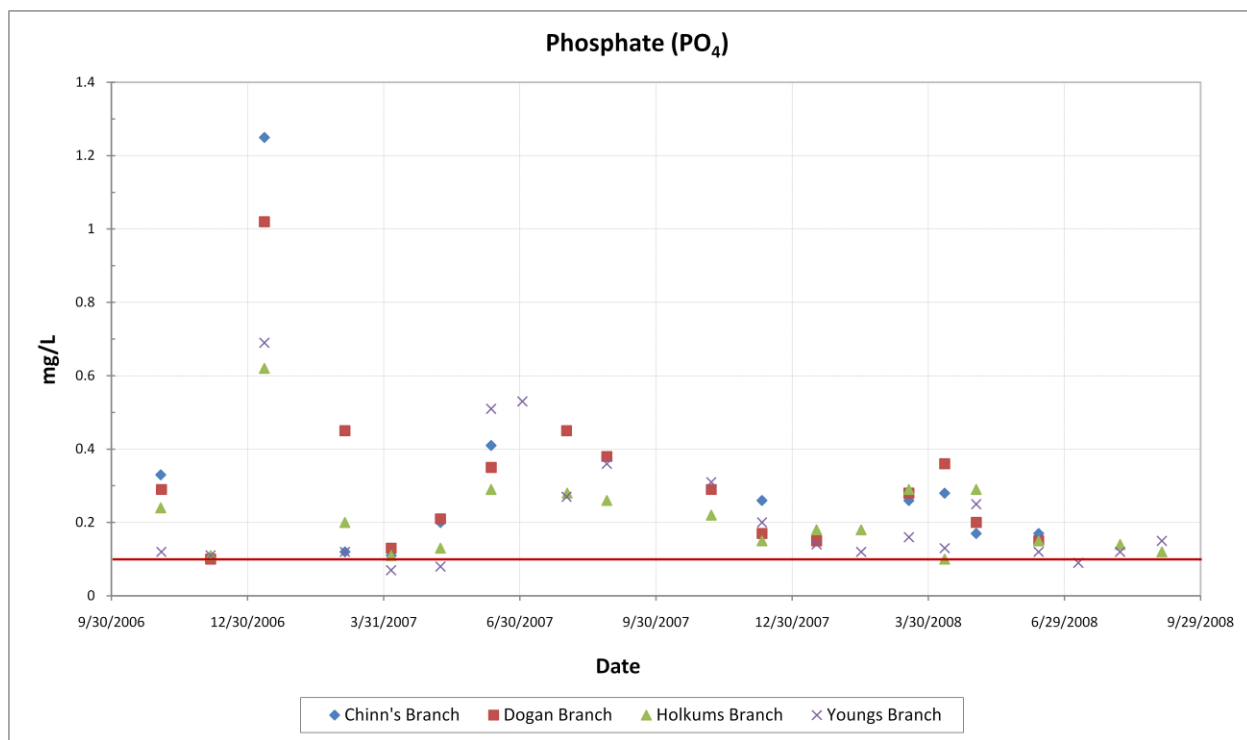


Figure 44: Phosphate in MANA streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO_4 (red line).

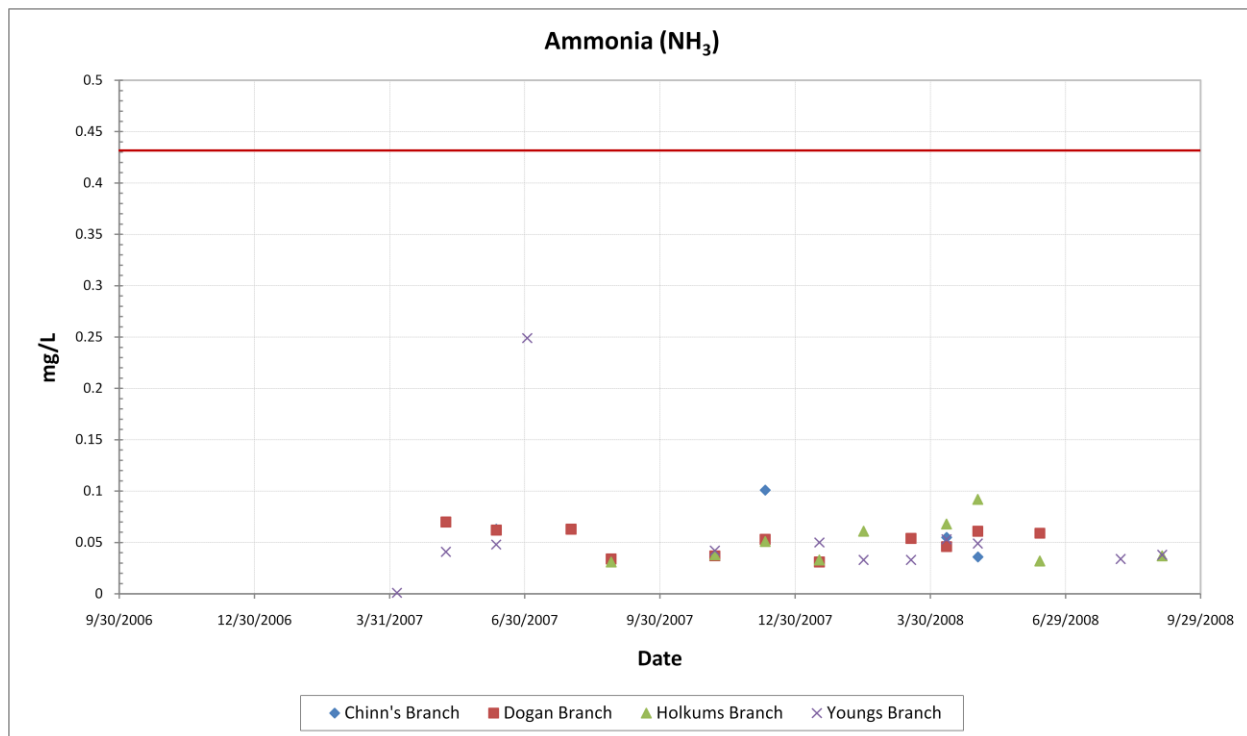


Figure 45: Ammonia in MANA streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH_3 (red line).

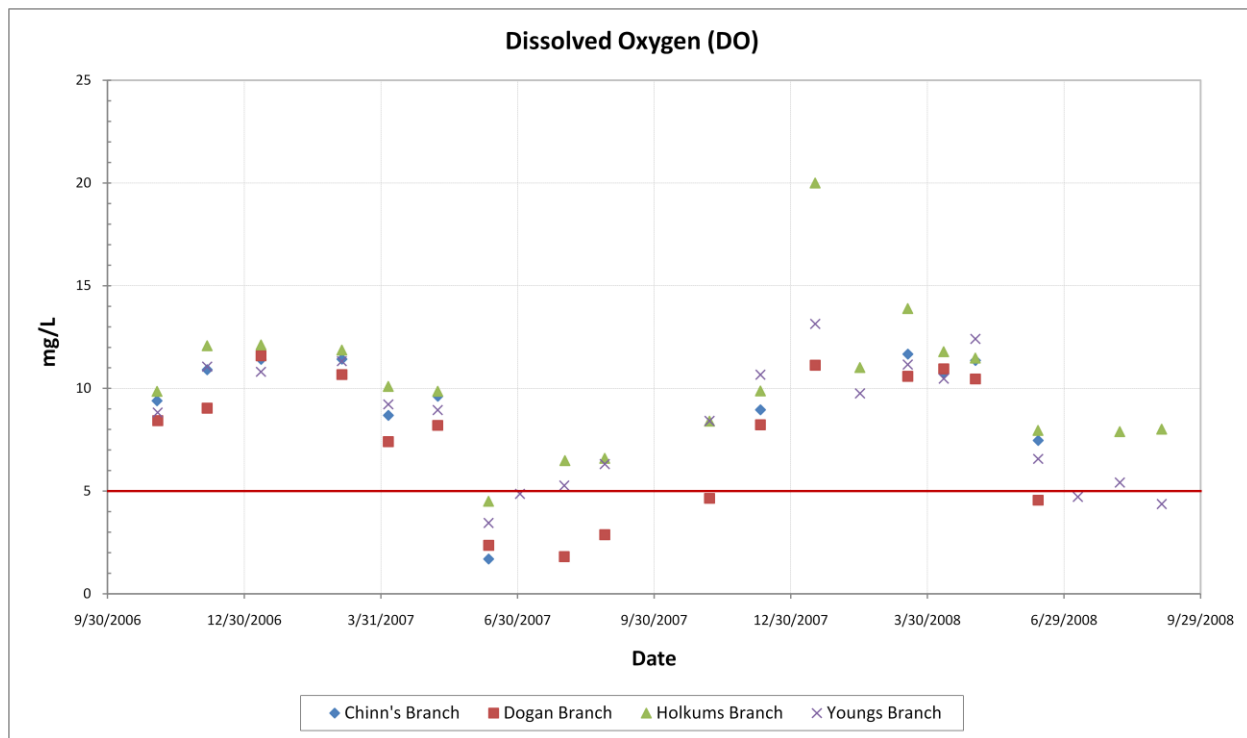


Figure 46: Dissolved oxygen in MANA streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

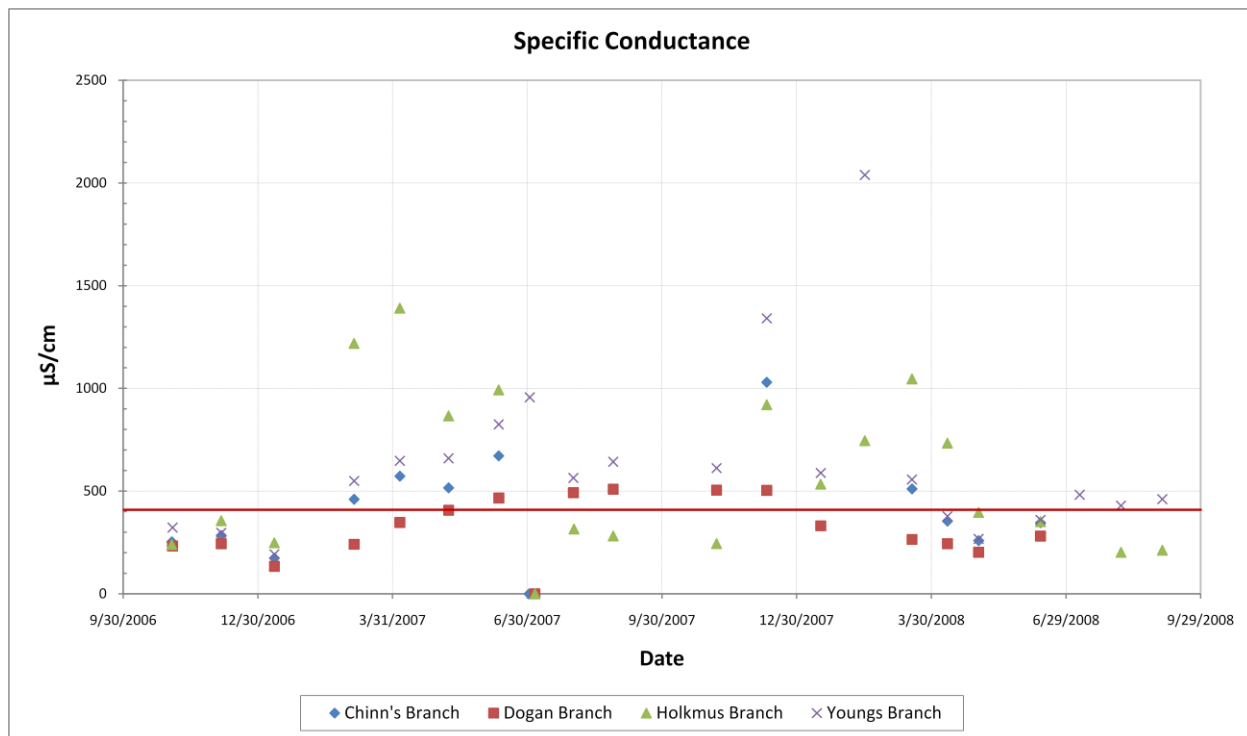


Figure 47: Specific Conductance in MANA streams FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

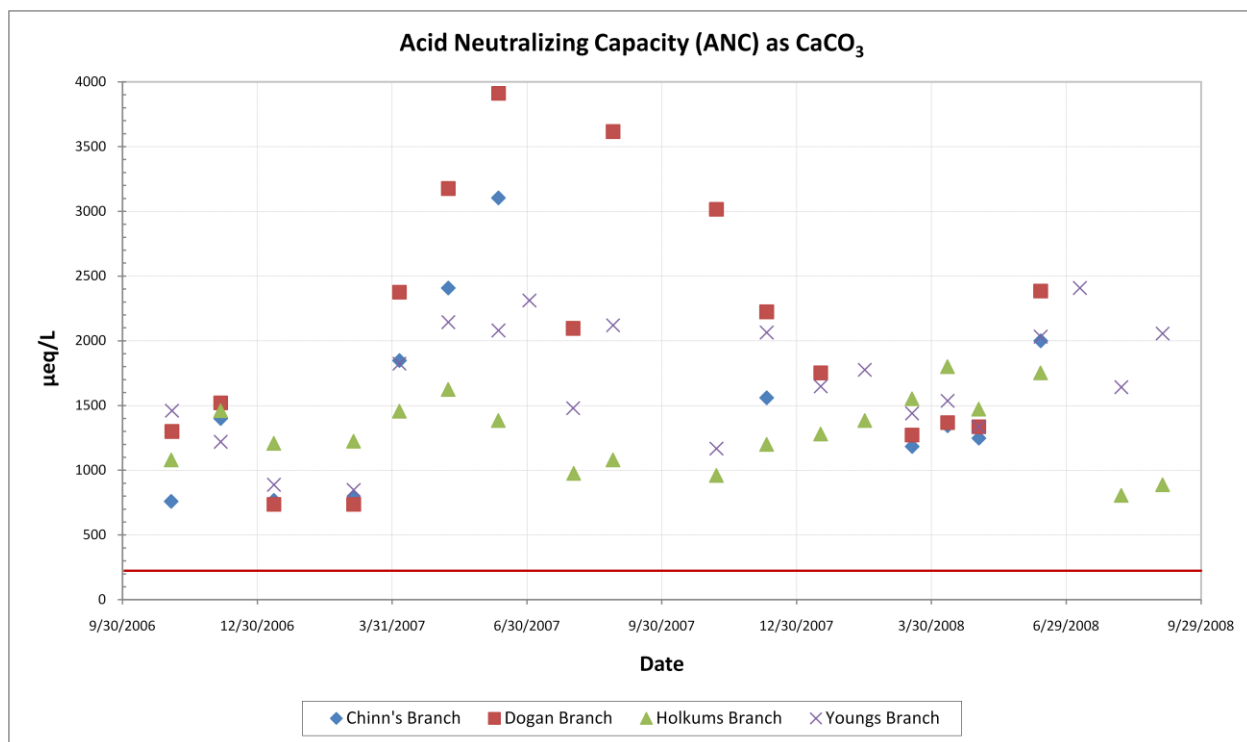


Figure 48: Acid Neutralizing Capacity in MANA streams FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq/L}$ (the red line on the graph).

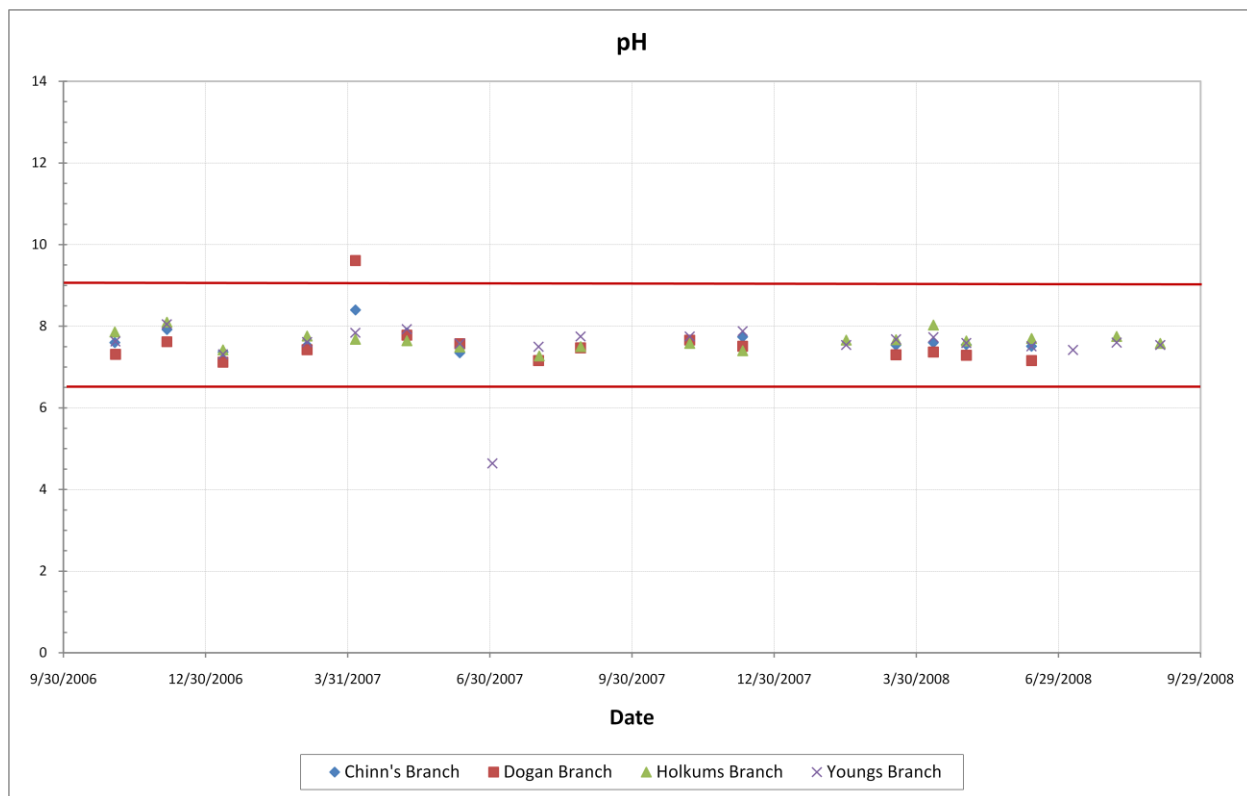


Figure 49: pH in MANA streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

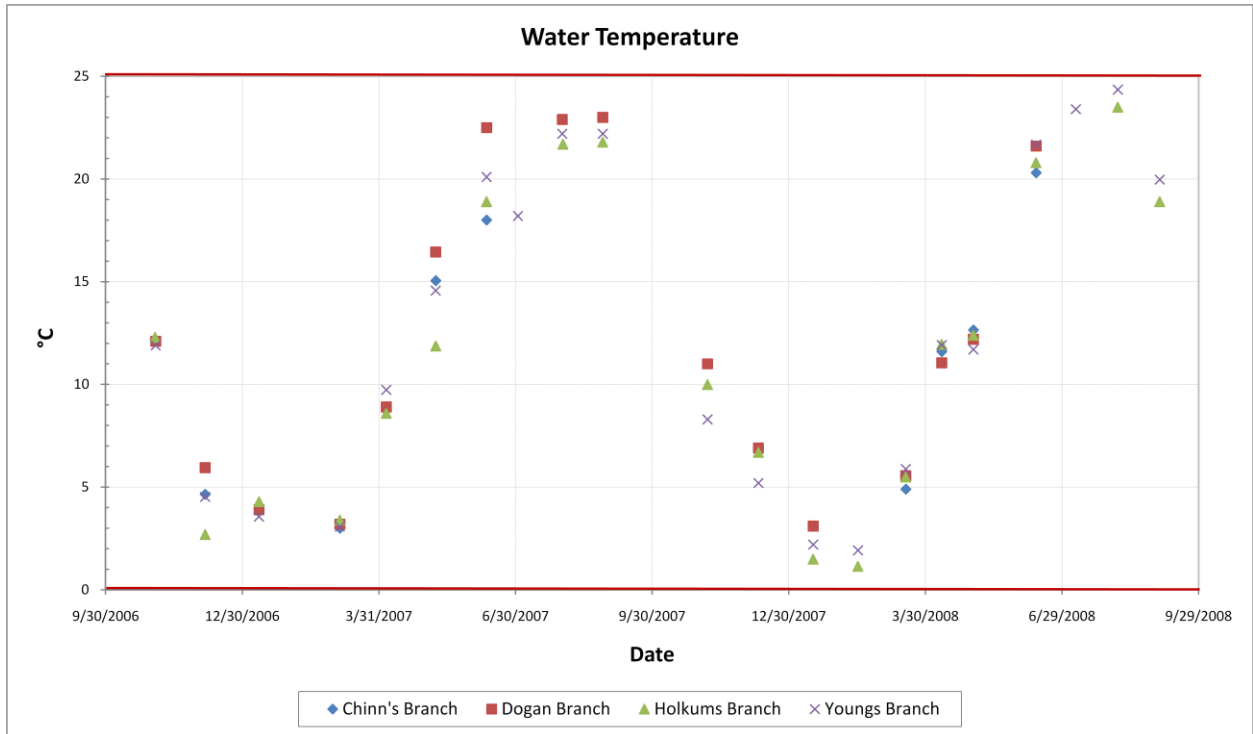


Figure 50: Water temperature in MANA streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

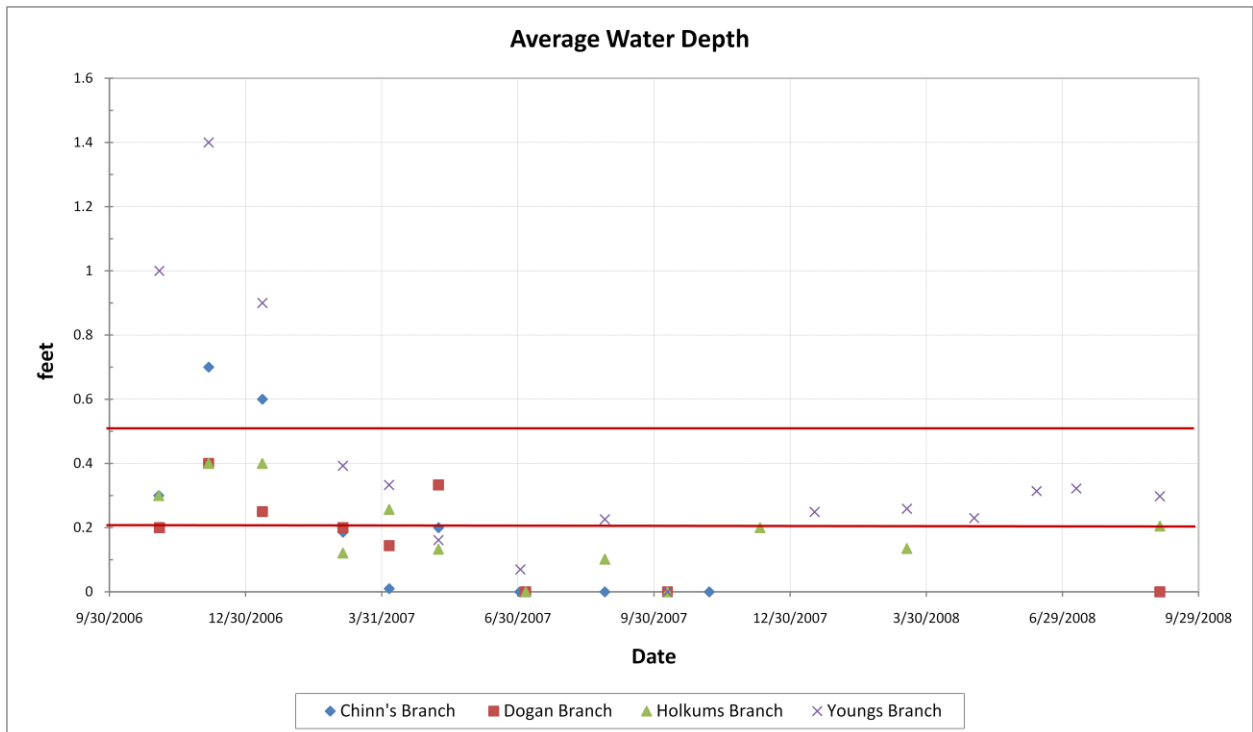


Figure 51: Water Depth (feet) in MANA streams FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet (red line).

Table 18: Hydrology data for Chinns Branch, MANA, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/22/2005	*Not Reported	*Not Reported	NO FLOW	*Not Reported
10/27/2005	*Not Reported	0.43	LOW	*Not Reported
12/1/2005	*Not Reported	1.14	LOW	*Not Reported
12/27/2005	*Not Reported	1.39	LOW	4.5
1/17/2006	1.230	1.2	LOW	3.5
2/21/2006	1.383	1.66	LOW	4.17
3/15/2006	0.728	0.56	LOW	2.17
4/18/2006	0.531	0.41	LOW	2.6
5/22/2006	0.074	0.13	LOW	2.83
6/19/2006	*Not Reported	0	NO FLOW	4.67
7/25/2006	*Not Reported	0	NO FLOW	7.16
8/17/2006	0.013	0.02	LOW	2.1
9/18/2006	0.048	0.03	LOW	3.58
11/2/2006	1.638	0.72	NORMAL	7.58
12/5/2006	0.191	0.04	LOW	6.83
1/10/2007	1.706	.365	NORMAL	7.42
2/7/2007	FROZEN	FROZEN	FROZEN	FROZEN
3/5/2007	2.202	1.067	NORMAL	7.5
4/5/2007	0.214	0.106	LOW	7.167
5/8/2007	0.296	0.74	LOW	2
6/11/2007	*Not Reported	*Not Reported	LOW	2.333
7/2/2007	0	0	DRY	0
8/1/2007	0	0	DRY	0
8/28/2007	0	0	DRY	0
10/9/2007	0	0	DRY	0
11/6/2007	0	0	DRY	0
12/10/2007	*Not Reported	*Not Reported	LOW	8.250
1/15/2008	0	0	DRY	0
2/14/2008	FROZEN	FROZEN	FROZEN	FROZEN
3/17/2008	*Not Reported	*Not Reported	LOW	1.75
4/10/2008	*Not Reported	*Not Reported	LOW	2.917
5/1/2008	*Not Reported	*Not Reported	LOW	3
6/12/2008	*Not Reported	*Not Reported	LOW	1.09
7/9/2008	0	0	DRY	0
8/6/2008	0	0	DRY	0
9/3/2008	0	0	DRY	0

Table 19: Hydrology data for Dogans Branch, MANA, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/22/2005	*Not Reported	*Not Reported	NO FLOW	*Not Reported
10/27/2005	*Not Reported	0.10	LOW	*Not Reported
12/1/2005	*Not Reported	0	NO FLOW	*Not Reported
12/27/2005	*Not Reported	0.16	LOW	12.25
1/17/2006	0.450	0.03	LOW	15
2/21/2006	0.257	0.03	LOW	12.25
3/15/2006	0.433	0.04	LOW	10.83
4/18/2006	0.307	0.03	LOW	11.6
5/22/2006	*Not Reported	0.0	LOW	10.17
6/19/2006	*Not Reported	0.0	LOW	9.75
7/25/2006	*Not Reported	0.0	LOW	11.66
8/11/2006	*Not Reported	0	NO FLOW	*Not Reported
9/18/2006	*Not Reported	0	NO FLOW	*Not Reported
11/2/2006	0.594	0.31	LOW	9.58
12/5/2006	0.465	.17	LOW	6.83
1/10/2007	2.080	0.695	LOW	11.917
2/7/2007	FROZEN	FROZEN	FROZEN	FROZEN
3/5/2007	0.288	0.171	LOW	8.167
4/5/2007	0.086	0.054	LOW	8.167
5/8/2007	0.015	0.003	LOW	6.25
6/11/2007	*Not Reported	*Not Reported	LOW	4.583
7/6/2007	0	0	DRY	0
8/1/2007	*Not Reported	*Not Reported	LOW	12.667
8/28/2007	*Not Reported	*Not Reported	LOW	11.333
10/9/2007	0	0	DRY	0
11/6/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/10/2007	*Not Reported	*Not Reported	LOW	12.417
1/15/2008	*Not Reported	*Not Reported	LOW	11.2
2/14/2008	FROZEN	FROZEN	FROZEN	FROZEN
3/17/2008	*Not Reported	*Not Reported	LOW	6.75
4/10/2008	*Not Reported	*Not Reported	LOW	6
5/1/2008	*Not Reported	*Not Reported	LOW	6.06
6/12/2008	*Not Reported	*Not Reported	LOW	5.06
7/9/2008	0	0	DRY	0
8/6/2008	0	0	DRY	0
9/3/2008	0	0	DRY	0

Table 20: Hydrology data for Holikum's Branch, MANA, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/22/2005	*Not Reported	*Not Reported	NO FLOW	*Not Reported
10/27/2005	*Not Reported	1.17	NORMAL	*Not Reported
12/1/2005	*Not Reported	1.02	NORMAL	*Not Reported
12/27/2005	2.010	1.54	NORMAL	15.42
1/17/2006	12.895	2.09	ABOVE NORMAL	15
2/21/2006	2.352	0.855	NORMAL	16.33
3/15/2006	*Not Reported	0	NO FLOW	4.25
4/18/2006	0.956	0.40	LOW	16.6
5/22/2006	*Not Reported	*Not Reported	LOW	15.25
6/19/2006	*Not Reported	0	NO FLOW	2.0
7/25/2006	*Not Reported	0.0	LOW	8.25
8/16/2006	0	0	DRY	0
9/18/2006	0.253	0.1	LOW	8.42
11/2/2006	5.844	1.25	NORMAL	15.58
12/5/2006	.147	0.08	LOW	4.58
1/10/2007	2.231	0.69	NORMAL	8.083
2/7/2007	FROZEN	FROZEN	FROZEN	FROZEN
3/5/2007	0.276	0.1	LOW	14.5
4/5/2007	0.202	0.104	LOW	6.667
5/8/2007	0.105	0.087	LOW	6.417
6/11/2007	*Not Reported	*Not Reported	LOW	4.583
7/6/2007	0	0	DRY	0
8/1/2007	*Not Reported	*Not Reported	LOW	4.083
8/28/2007	0.664	1.656	LOW	3.833
10/9/2007	0	0	DRY	0
11/6/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/10/2007	1.029	.858	LOW	3.0
1/15/2008	*Not Reported	*Not Reported	LOW	3.25
2/14/2008	*Not Reported	*Not Reported	NORMAL	2.5
3/17/2008	0.46	1.152	LOW	3
4/10/2008	*Not Reported	*Not Reported	LOW	5.083
5/1/2008	*Not Reported	*Not Reported	LOW	8.04
6/12/2008	*Not Reported	*Not Reported	LOW	6.07
7/9/2008	*Absent	*Not Reported	DRY	*Absent
8/6/2008	*Not Reported	*Not Reported	NORMAL	5.17
9/3/2008	0.39	.235	LOW	8.083

Table 21: Hydrology data for Young's Branch, MANA, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/22/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/27/2005	*Not Reported	0.89	LOW	*Not Reported
12/1/2005	*Not Reported	0.4	LOW	*Not Reported
12/27/2005	10.395	0.53	NORMAL	12.83
1/17/2006	7.204	0.38	NORMAL	15.17
2/21/2006	6.987	0.39	NORMAL	16.9
3/15/2006	5.900	0.33	NORMAL	14.75
4/18/2006	4.380	0.26	NORMAL	16.0
5/22/2006	0.010	.001	LOW	14.75
6/19/2006	*Not Reported	0	NO FLOW	13.42
7/25/2006	*Not Reported	0.06	LOW	12.5
8/16/2006	*Not Reported	0	NO FLOW	11.58
9/18/2006	1.053	0.03	LOW	19.5
11/2/2006	6.305	0.38	NORMAL	17.25
12/5/2006	4.292	.13	NORMAL	23.58
1/10/2007	16.814	.47	NORMAL	26.5
2/7/2007	FROZEN	FROZEN	FROZEN	FROZEN
3/5/2007	2.526	.193	NORMAL	32.583
4/5/2007	1.074	0.082	LOW	28.833
5/8/2007	1.118	0.154	LOW	27.5
6/11/2007	*Not Reported	*Not Reported	LOW	24.417
7/2/2007	*Not Reported	*Not Reported	LOW	18.417
8/1/2007	*Not Reported	*Not Reported	LOW	27.417
8/28/2007	0.162	.363	LOW	1.667
10/9/2007	0	0	DRY	0
11/6/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/10/2007	*Not Reported	*Not Reported	LOW	13.0
1/15/2008	1.85	.925	LOW	8
2/14/2008	*Not Reported	*Not Reported	NORMAL	12.25
3/17/2008	2.19	.855	LOW	9.833
4/10/2008	*Not Reported	*Not Reported	LOW	9.417
5/1/2008	5.97	.865	NORMAL	30.06
6/12/2008	0.68	.073	LOW	29.07
7/9/2008	0.11	.061	LOW	5.08
8/6/2008	*Not Reported	*Not Reported	LOW	18.17
9/3/2008	0.27	.037	LOW	25.42

Monocacy National Battlefield (MONO)

MONO is located along the eastern side of the Frederick Valley within the Northern Piedmont Ecoregion, which is characterized by a gently rolling topography of low rounded hills, irregular plains, and open valleys and is underlain by metamorphic, igneous, and sedimentary rocks. The Frederick Valley of Maryland's western Piedmont represents the state's second largest karst terrain. Although the largest is located in eastern Washington County and is known as the Hagerstown Valley or Great Valley, the Frederick Valley has had more incidences of catastrophic collapse and active subsidence than its larger neighbor. The Frederick Valley is a lowland region that stretches from the Potomac River northward to Woodsboro in northern Frederick County, an area of approximately 154 sq. miles.

MONO is predominantly underlain by limestone bedrock which has developed karst topography with some resistant ridges of sand and siltstone. The karst topography affects water quality in the park similarly to the effects on ANTI and HAFE detailed previously (Southworth and Denenny 2005). It is a high yielding aquifer riddled with solution channels that reduce water filtration; as a result, groundwater is sometimes contaminated (Woods et al. 1996)

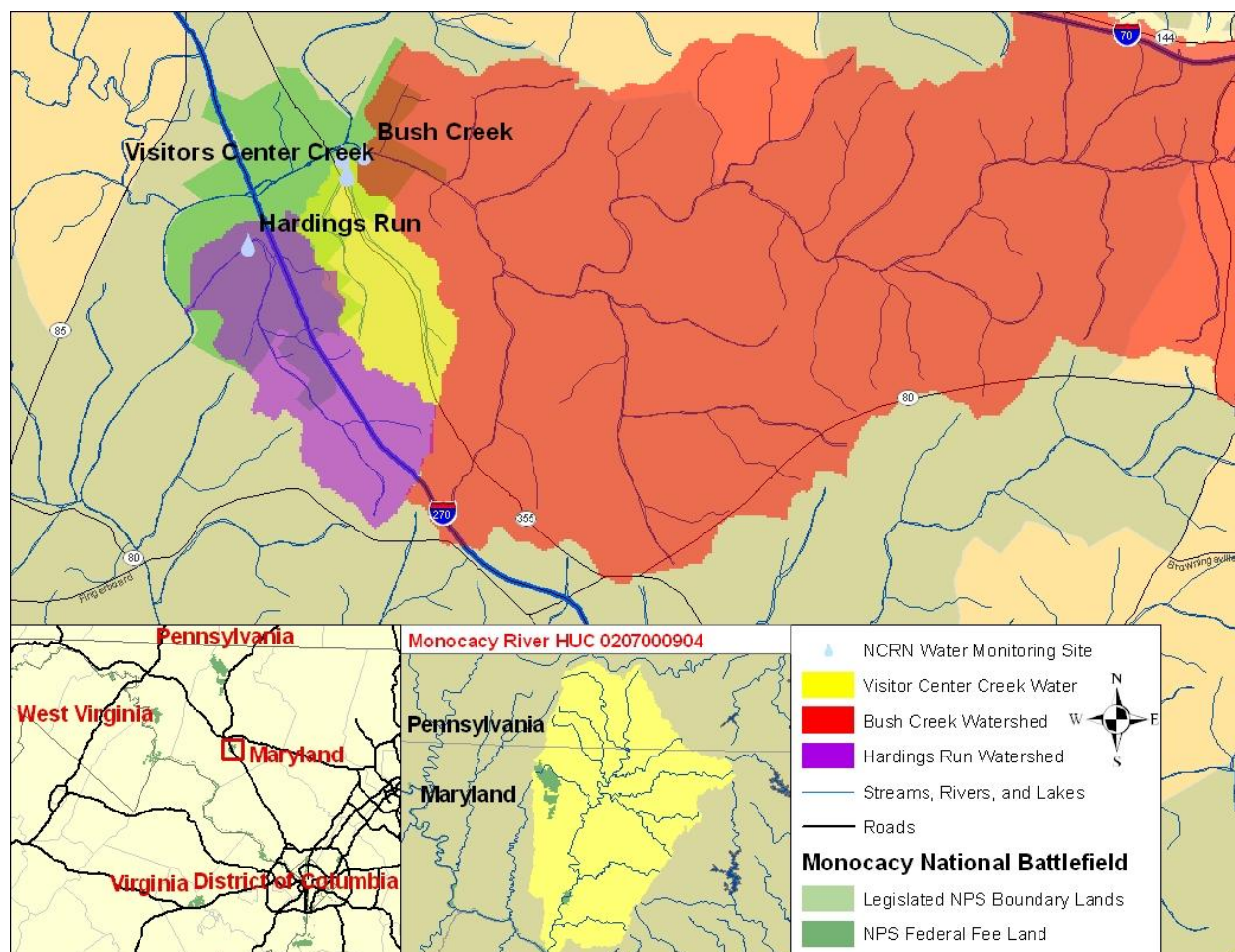


Figure 52: Relationship of the MONO stream monitoring sites to their watersheds and the park boundary

Streams in MONO are all part of the Lower Monocacy River drainage (USGS cataloging unit: 02070009) that drains 304 sq. miles before emptying into the Potomac River (Maryland Department of Natural Resources 2003) (Figure 52). The Monocacy River is the largest Maryland tributary of the Potomac River (Monocacy Scenic River Local Advisory Board 1990). The perennial streams in the park are Bush Creek and Thomas Farm Creek/Visitor Center Creek. Three ephemeral streams, Best Farm Creek, Harding's Run, and an unnamed drainage also feed into the river. The Monocacy River flows directly through and along the boundary of the national battlefield for approximately 2.5 miles. Approximately 0.8 miles of Bush Creek passes through the north central part of the national battlefield. Bush Creek is the largest Monocacy River tributary within the national battlefield, a moderately narrow, rapidly flowing creek with a cobble/gravel bottom with scoured sections of banks and cobble beds from periodic high flows (Motivans 1995). As the creek nears its confluence with the river, the stream channel becomes incised and much of the stream bank is undercut. Agriculture is the dominate land use within the Bush Creek watershed with approximately a third of the watershed still forested. Given the long history of human habitation and agricultural land use in the region, streams are far from pristine; however, much of lower Bush Creek and its tributaries appear to be in reasonably good condition at present.

This report discusses data collected October 2006 through September 2008 in Bush Creek, Harding's Run, and Visitor's Center (Gambrill Mill) Creek. Summary Statistics for the time period are shown in Table 22.

Table 22: Date range, number of site visits (N), and data range for the information covered in this report.

Parameter	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/16/2006 - 9/22/2008	52	0	35	18	20	10
ANC	µeq/L	10/16/2006 - 9/22/2008	59	576	4152	1696	1440	922
Discharge	cfs	10/16/2006 - 9/22/2008	38	0.0	123.2	10.1	1.2	24.2
DO	mg/l	10/16/2006 - 9/22/2008	59	3.41	15.90	9.70	9.39	2.85
Flow	ft/sec	10/16/2006 - 9/22/2008	41	0.00	2.07	0.54	0.47	0.52
Nitrate	mg/l	10/16/2006 - 9/22/2008	59	1.40	10.02	4.78	4.40	2.18
Ammonia	mg/l	10/16/2006 - 9/22/2008	33	0.031	0.316	0.070	0.050	0.055
pH	None	10/16/2006 - 9/22/2008	54	5.39	9.44	8.04	7.99	0.67
Phosphate	mg/l	10/16/2006 - 9/22/2008	59	0.07	4.66	0.54	0.27	0.79
Salinity	ppt	10/16/2006 - 9/22/2008	61	0.0	0.3	0.2	0.2	0.1
Specific conductance	µS/cm	10/16/2006 - 9/22/2008	61	0	633	366	357	136
Water Depth	ft	10/16/2006 - 9/22/2008	45	0.000	0.921	0.334	0.275	0.271
Water Temperature	°C	10/16/2006 - 9/22/2008	59	0.6	25.1	12.1	13.6	7.0
Wetted Width	ft	10/16/2006 - 9/22/2008	55	0.00	40.25	12.82	8.67	11.52

Nitrate and phosphate levels were consistently high in the park, though conditions were slightly better in 2007. Bush Creek only exceeded the nitrate threshold every month except July 2007

(Figure 53). Visitors Center Creek (Gambrill Mill) and Hardings Run always exceeded the ecological threshold and exceeded the human drinking water standard of 10 mg/L a few times in the summer. Visitor's Center Creek always exceeded the phosphate threshold except March 2007 (Figure 54). Bush Creek and Harding's Run always exceeded the phosphate threshold. There were no threshold exceedances for ammonia in 2007-2008 (Figure 55). Ammonia is a problematic parameter. We frequently get readings below zero and the EDL of 0.032 with the very low readings we normally get means that much of the data is excluded from analysis (34 of 67 readings in the case of MONO in FY2007-2008). DO met the threshold except for Visitors Center Creek in September and October 2007 (Figure 56).

Specific conductance is lower in Monocacy streams than it is in HAFE or ANTI. This may be due to differences in the chemistry and physical extent of the two areas of karst terrain. The threshold exceedances for Hardings Run and Visitor's Center Creek may be due to adjacent pollution sources (feedlot and retention pond for Harding's Run and former Visitor's Center septic field for Visitor's Center Creek (Figure 57). Specific Conductance should be closely monitored and sources determined. All sites exceeded the ANC exceeded minimum threshold, except Hardings Run in March 2007 (Figure 58). The pH in Bush Creek exceeded threshold (>9) December 2006, March 2007, and February and March 2008 (Figure 59). Visitors Center Creek exceeded threshold (<6) in June 2007. It is unclear how much of the watershed is on septic or sanitary sewer, which would also influence nutrients and specific conductance. Water temperature follows expected seasonal trends and stays within the comfort zone of desired organisms (Figure 60).

The region experienced a drought in 2007. Several small streams in the park dried out including Hardings Run and Visitor's Center Creek, however Bush Creek did not. Due to its location in a karst landscape, Bush Creek has consistent groundwater-based flow. Based on the data collected so far, normal water levels for Bush Creek can be defined as discharge between 40 cfs and 80 cfs, with a flow of 0.7 f/s or higher in a channel with a wetted width of 37 or more feet (Table 23). Based on the data collected so far, normal water levels for Visitors Center Creek can be defined as discharge between 1 cfs and 5 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 10 or more feet (Table 24). Visitors Center Creek experienced no flow on 5 occasions: January, July and August 2006; October 2007; and October 2008. In the 5 years of data collection, flow was never seen to be above normal. Harding's Run experienced no flow on 17 occasions: October and December 2005; January, July and September 2006; June 2007 through January 2008; and October through November 2008. Due to the frequency and extent of no flow in Harding's Run, it was dropped from the sampling design beginning with FY 2009 (Table 25).

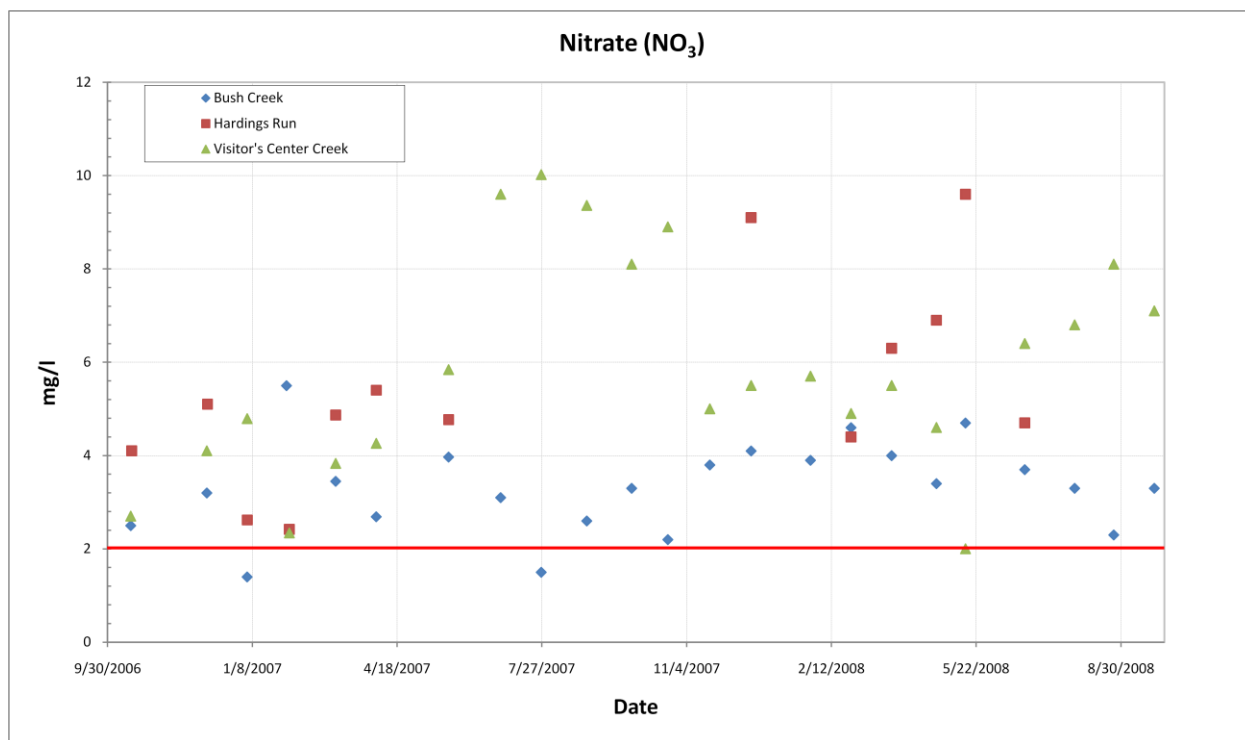


Figure 53: Nitrate in MONO streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

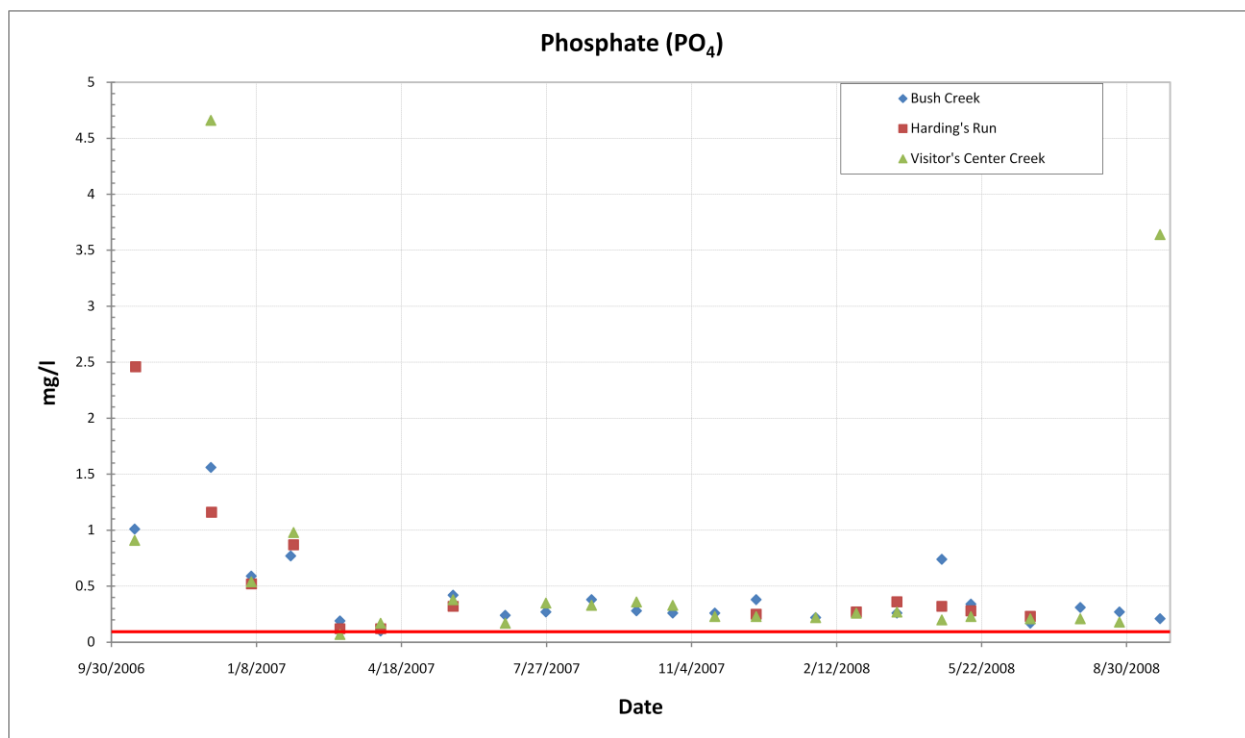


Figure 54: Phosphate in MONO streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

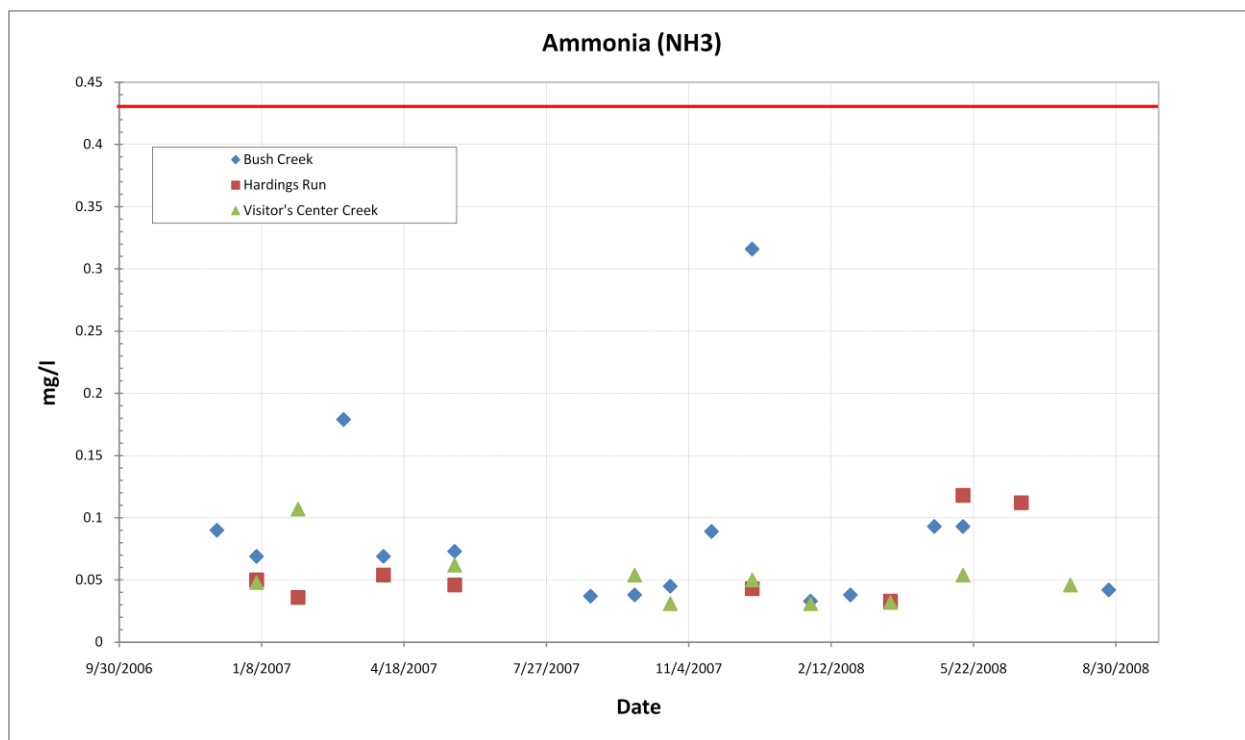


Figure 55: Ammonia in MONO streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

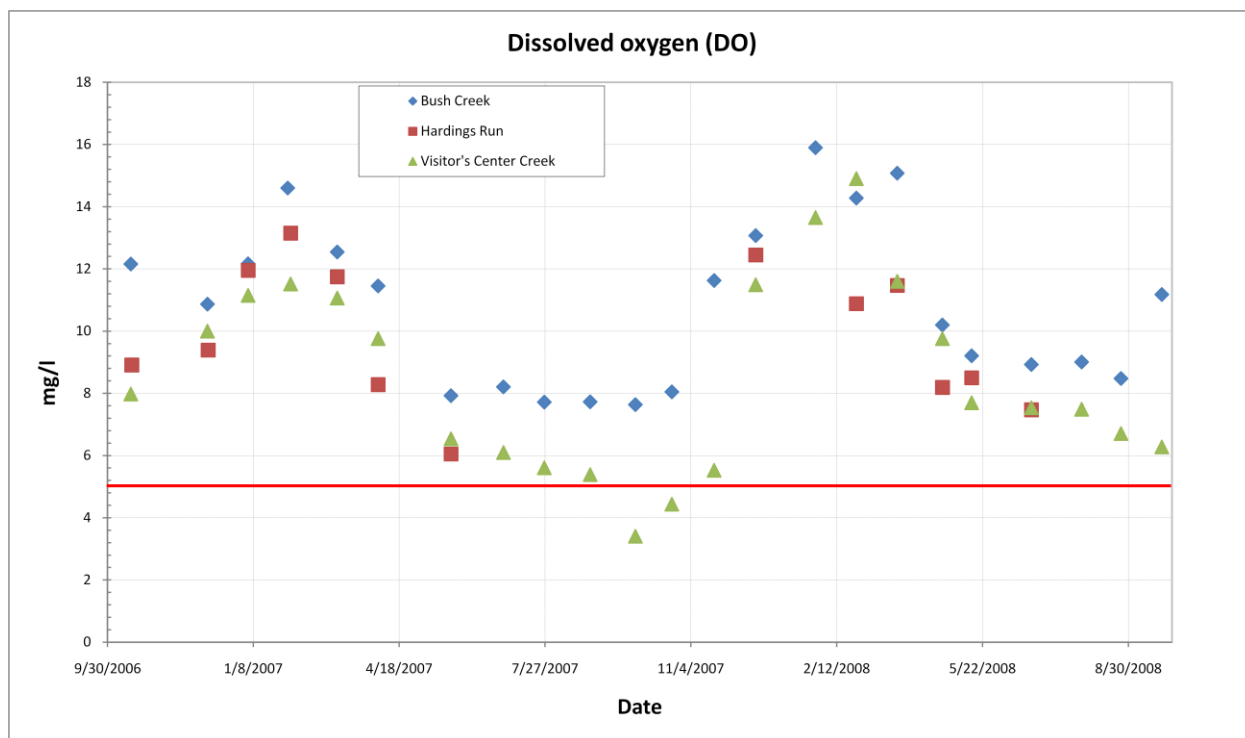


Figure 56: Dissolved oxygen in MONO streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (red line).

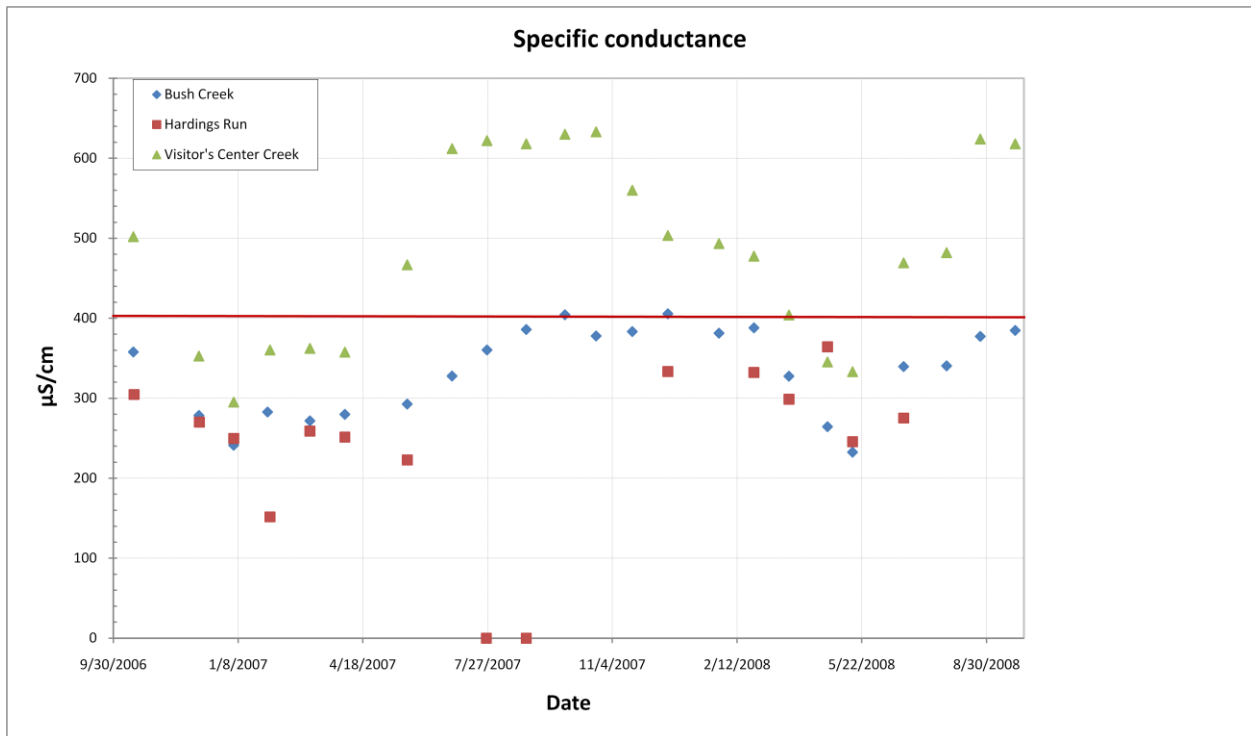


Figure 57: Specific Conductance in MONO streams FY 2007-2008. Ideally, healthy waters would have less than 400 $\mu\text{S}/\text{cm}$ (red line).

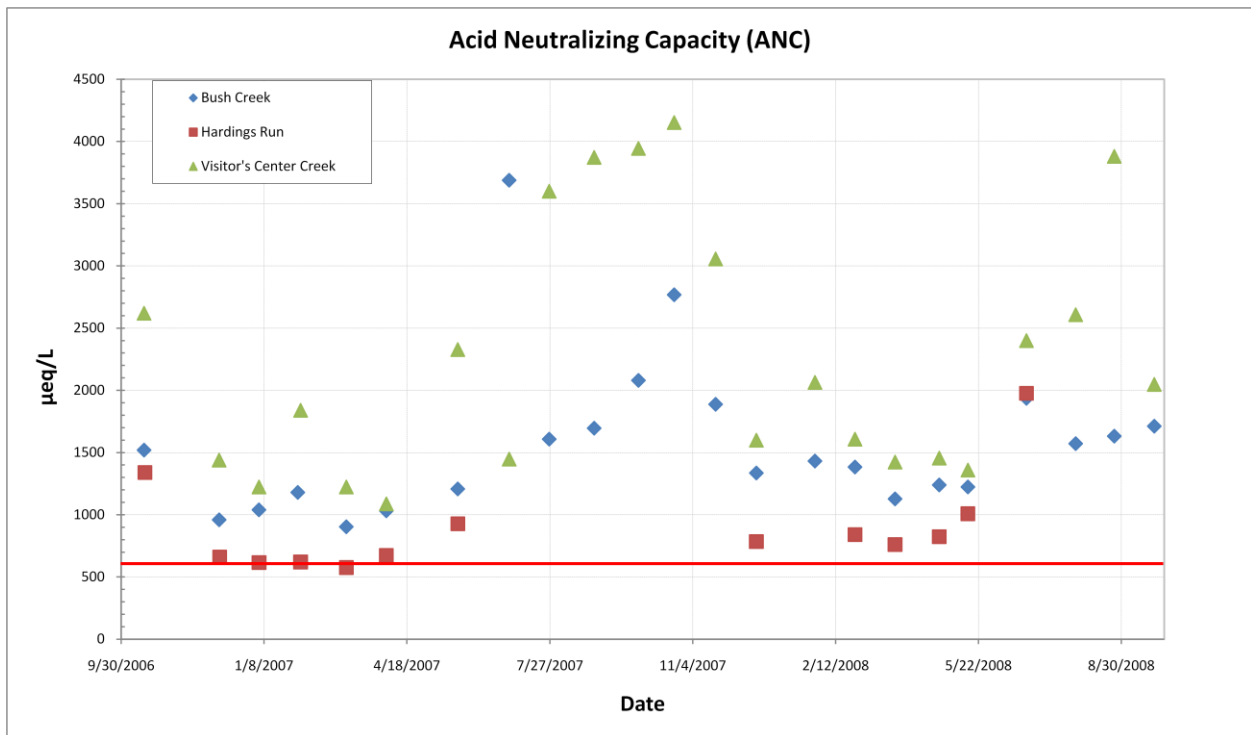


Figure 58: Acid Neutralizing Capacity in MONO streams FY 2007-2008. Karst waters should have ANC above 600 $\mu\text{eq}/\text{L}$ (the red line on the graph).

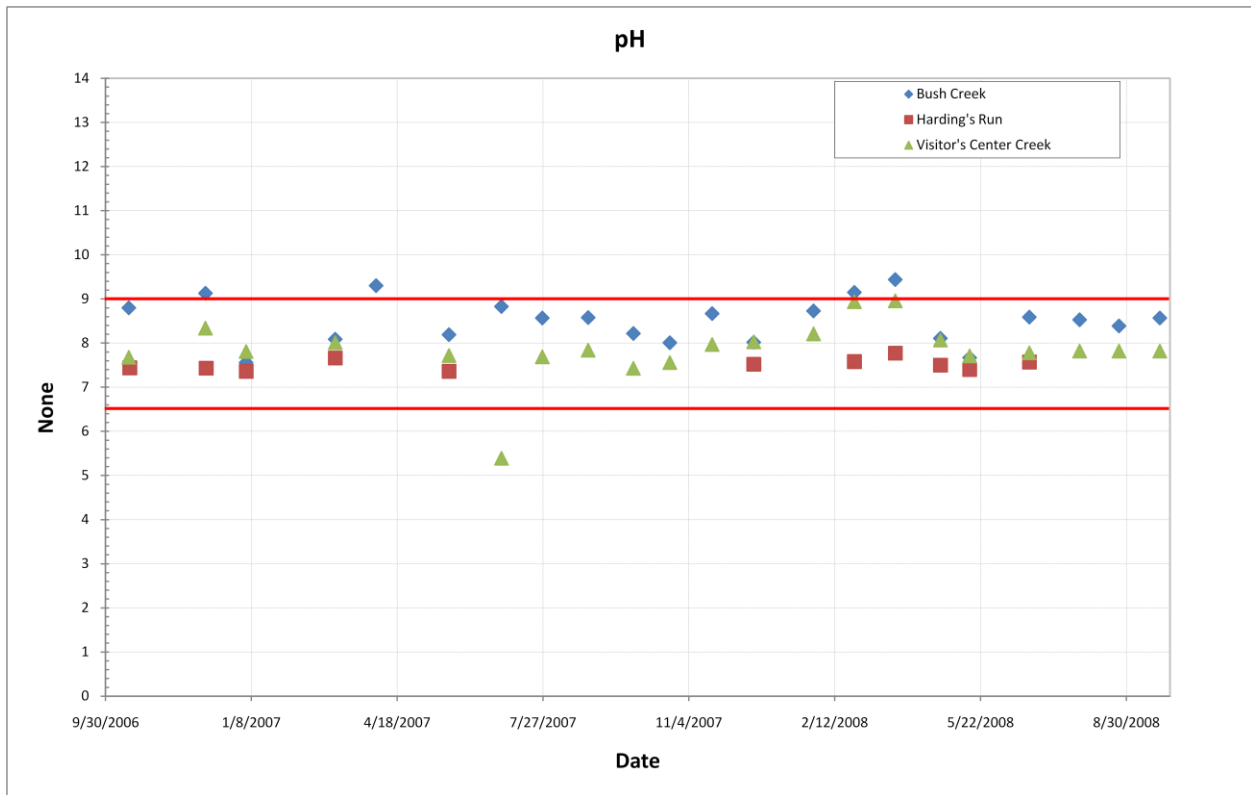


Figure 59: pH in MONO streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

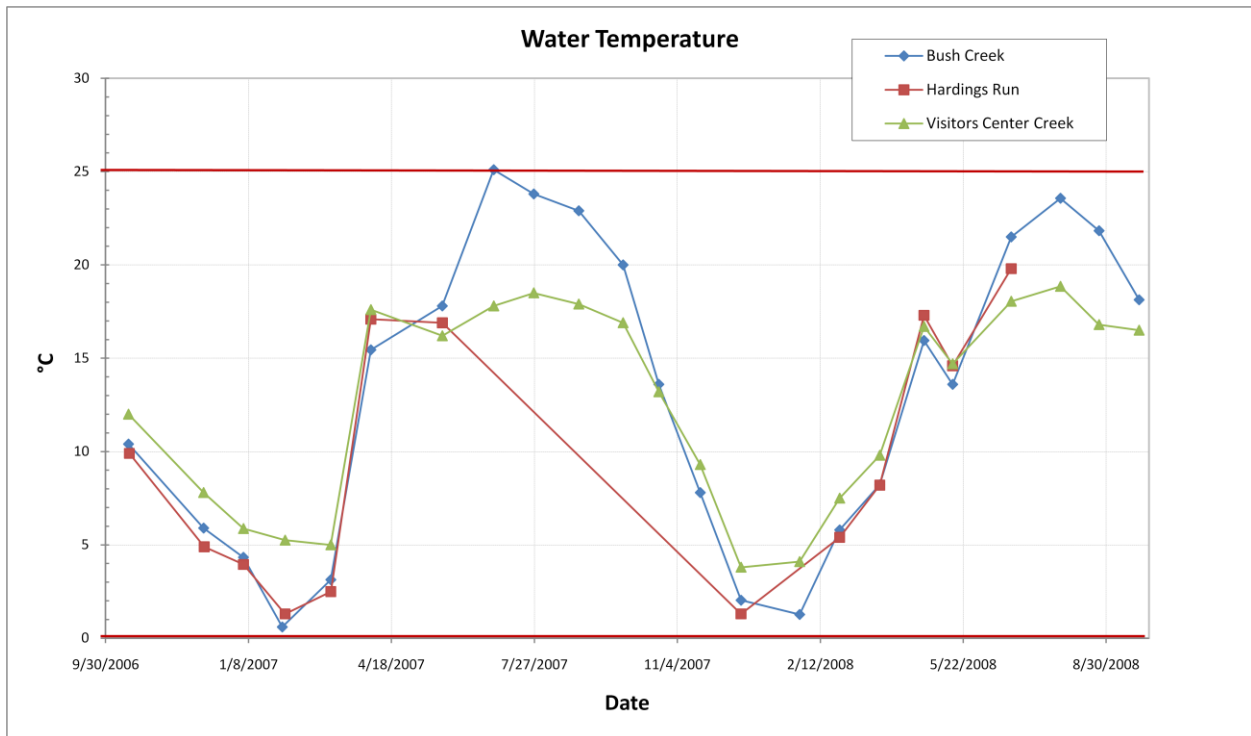


Figure 60: Water temperature in MONO streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

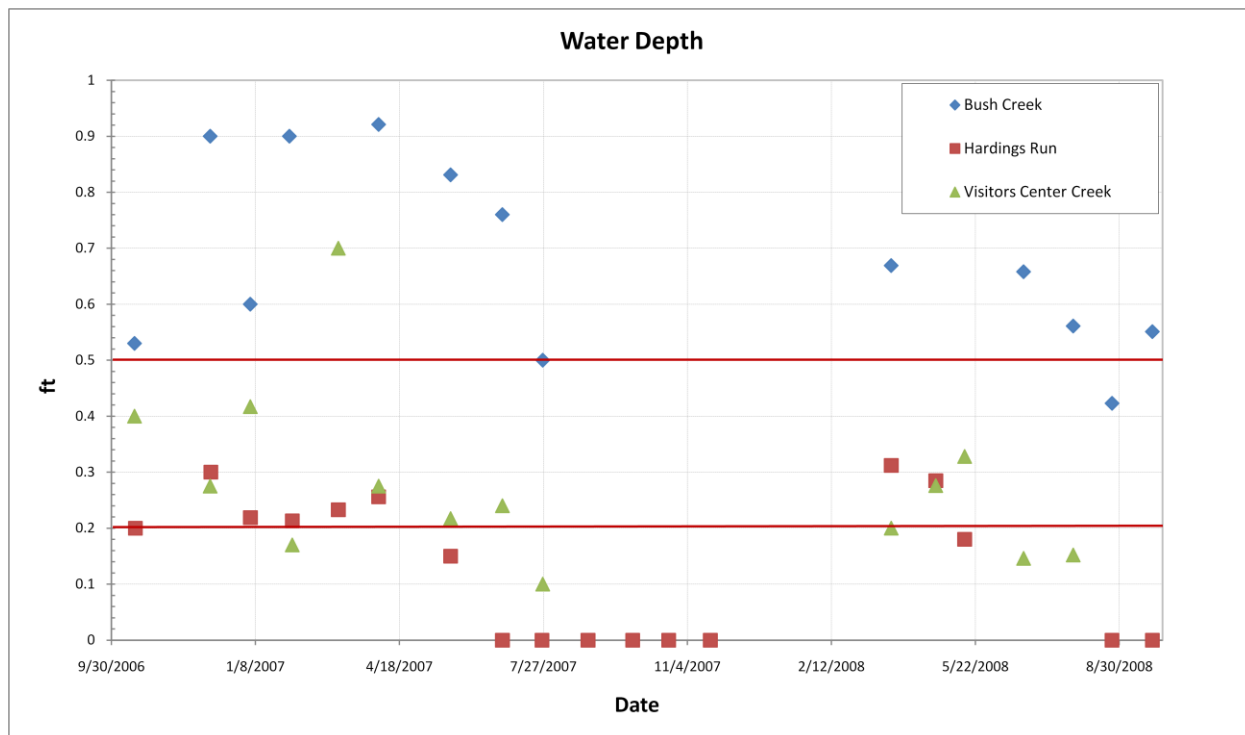


Figure 61: Water Depth (feet) in MONO streams FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 23: Hydrology data for Bush Creek, MONO May 2005 to September 2008

Date	Discharge	Flow	Flow, qualitative	Wetted Width
5/23/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
6/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
10/6/2005	*Not Reported	0.66	LOW	*Not Reported
11/8/2005	*Not Reported	0.98	LOW	*Not Reported
12/12/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/23/2006	87.804	1.81	ABOVE NORMAL	40.5
2/23/2006	*Not Reported	*Not Reported	NORMAL	40.9
3/21/2006	25.513	1.02	LOW	38.5
4/10/2006	33.493	1.39	LOW	37.5
5/16/2006	46.272	1.08	NORMAL	35.25
6/29/2006	168.751	2.27	ABOVE NORMAL	45.16
7/24/2006	17.942	1.44	LOW	20.83
8/15/2006	9.359	0.51	LOW	29.5
9/13/2006	9.554	0.38	LOW	35.9
10/16/2006	*Not Reported	0.77	LOW	*Not Reported
12/7/2006	*Not Reported	1.67	LOW	*Not Reported
1/4/2007	123.168	.52	ABOVE NORMAL	37.5
1/31/2007	78.041	0.657	NORMAL	40.25
3/6/2007	*Not Reported	*Not Reported	LOW	*Not Reported
4/3/2007	42.582	0.777	NORMAL	37.417
5/23/2007	21.450	0.846	LOW	26.25
6/28/2007	*Not Reported	*Not Reported	LOW	24.750
7/26/2007	*Not Reported	*Not Reported	LOW	23.583
8/27/2007	*Not Reported	*Not Reported	LOW	22.5
9/27/2007	*Not Reported	*Not Reported	LOW	22.083
10/22/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/20/2007	*Not Reported	*Not Reported	LOW	24.0
12/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/28/2008	*Not Reported	*Not Reported	LOW	26.5
2/25/2008	*Not Reported	*Not Reported	LOW	37.1
3/24/2008	36.16	1.422	LOW	38
4/24/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
5/14/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
6/24/2008	18.14	1.038	LOW	26.07
7/29/2008	12.82	.854	LOW	26.75
8/25/2008	5.16	.497	LOW	24.58
9/22/2008	9.4	.667	LOW	25.58

Table 24: Hydrology data for Visitor's Center Creek (Gambrill Mill Creek), MONO May 2005 to September 2008

Date	Discharge	Flow	Flow, qualitative	Wetted Width
5/23/2005	*Not Reported	*Not Reported	LOW	*Not Reported
6/20/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/6/2005	*Not Reported	0.02	LOW	*Not Reported
11/8/2005	*Not Reported	0.58	LOW	*Not Reported
12/5/2005	*Not Reported	*Not Reported	DRY	0
1/23/2006	*Not Reported	*Not Reported	DRY	0
2/23/2006	*Not Reported	*Not Reported	NORMAL	16.6
3/21/2006	3.275	0.57	NORMAL	16.4
4/10/2006	0.490	0.11	LOW	16.4
5/16/2006	0.440	0.18	LOW	6.92
6/29/2006	10.401	1.24	ABOVE NORMAL	15.25
7/24/2006	*Not Reported	0.0	DRY	0
8/15/2006	*Not Reported	0	DRY	0
9/13/2006	0.077	0.02	LOW	9.6
10/16/2006	0.337	0.1	LOW	8.38
12/7/2006	*Not Reported	.235	LOW	*Not Reported
1/4/2007	2.273	.732	NORMAL	6.75
2/2/2007	0.102	.051	LOW	10.833
3/6/2007	8.351	1.03	ABOVE NORMAL	11.583
4/3/2007	1.184	0.228	NORMAL	10.167
5/23/2007	0.328	0.22	LOW	5.833
6/28/2007	*Not Reported	*Not Reported	LOW	5.167
7/26/2007	*Not Reported	*Not Reported	LOW	5.00
8/27/2007	*Not Reported	*Not Reported	LOW	3.333
9/27/2007	*Not Reported	*Not Reported	LOW	4.167
10/22/2007	*Not Reported	*Not Reported	DRY	0
11/20/2007	*Not Reported	*Not Reported	LOW	4.333
12/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/28/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/25/2008	*Not Reported	*Not Reported	LOW	6.05
3/24/2008	0.87	.723	LOW	6
4/24/2008	2.35	.880	NORMAL	9.665
5/14/2008	4.48	1.244	NORMAL	14
6/24/2008	0.27	.180	LOW	10.03
7/29/2008	0.12	.135	LOW	5.1
8/25/2008	*Not Reported	*Not Reported	LOW	6
9/22/2008	*Not Reported	*Not Reported	LOW	5.33

Table 25: Hydrology data for Harding's Run, MONO May 2005 to September 2008

Date	Discharge	Flow	Flow, qualitative	Wetted Width
5/23/2005	*Not Reported	*Not Reported	LOW	*Not Reported
6/20/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/6/2005	*Not Reported	0	DRY	*Not Reported
11/8/2005	*Not Reported	0.01	LOW	*Not Reported
12/5/2005	*Not Reported	*Not Reported	DRY	*Not Reported
1/23/2006	*Not Reported	*Not Reported	DRY	*Not Reported
2/23/2006	*Not Reported	*Not Reported	NORMAL	9.17
3/21/2006	0.650	0.52	LOW	6.25
4/10/2006	0.230	0.026	LOW	10.33
5/18/2006	0.060	0.05	LOW	6.0
6/29/2006	6.076	0.49	NORMAL	15.5
7/24/2006	*Not Reported	0	INTERSTITIAL	8.83
8/15/2006	*Not Reported	0.5	LOW	10.0
9/13/2006	*Not Reported	0	NO FLOW	0
10/16/2006	0.210	0.2	LOW	5.25
12/8/2006	2.962	1.5	NORMAL	6.58
1/4/2007	1.809	.734	LOW	8.083
2/2/2007	0.221	.113	LOW	8.667
3/6/2007	1.306	0.346	LOW	12.167
4/3/2007	1.231	0.470	LOW	9.333
5/23/2007	0.127	0.064	LOW	7.917
6/28/2007	0	0	NO FLOW	0
7/26/2007	0	0	DRY	0
8/27/2007	0	0	NO FLOW	0
9/27/2007	0	0	DRY	0
10/22/2007	0	0	DRY	0
11/20/2007	0	0	DRY	0
12/18/2007	*Not Reported	*Not Reported	DRY	*Not Reported
1/28/2008	*Not Reported	*Not Reported	DRY	*Not Reported
2/25/2008	*Not Reported	*Not Reported	LOW	9.07
3/24/2008	0.87	.462	LOW	6.07
4/24/2008	3.14	.849	NORMAL	13
5/14/2008	5.28	2.070	NORMAL	14.33
6/24/2008	*Not Reported	*Not Reported	LOW	4
8/25/2008	0	0	DRY	0
9/22/2008	0	0	DRY	0

National Capital Parks – East (NACE)

The park units that comprise National Capital Parks - East are located in Washington, DC and Prince George's County, Maryland within the Coastal Plain physiographic region. Most of the park units are within the Potomac River Watershed, with the exception of parts of Suitland Parkway and Baltimore and Washington Parkway. Given the urban setting, park surface waters are likely exposed to a variety of air- and waterborne pollutants.

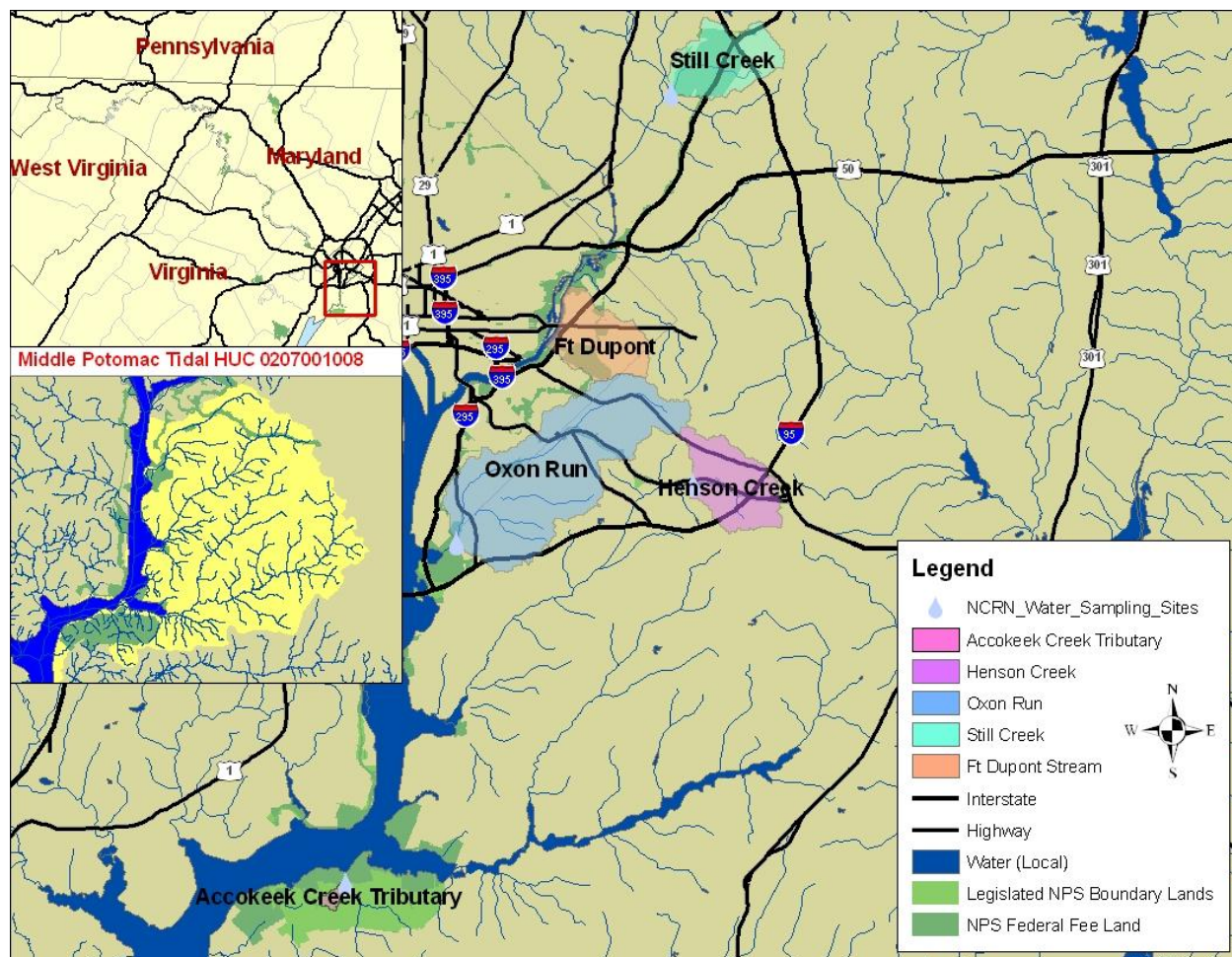


Figure 62: Relationship of the NACE Stream monitoring sites to their watersheds and the park subunit boundaries

Five sites were monitored in the park on a monthly basis in 2007 for dissolved oxygen, ph, specific conductance, temperature, acid neutralizing capacity, nitrate, ammonia, and total phosphorus. In 2008 Ft. Dupont was dropped due to a lack of adequate flow during most of the sampling season.

This report discusses data collected October 2006 through September 2008 for an Unnamed tributary of Accokeek Creek (ACCK), Ft. Dupont Stream (FTDU), Henson Creek (HECR), Oxon Run (OXRU), and Still Creek (STCK). Summary statistics for the time period are shown in Table 26.

Table 26: Date range, number of site visits (N), and data range for the information covered in this report.

Local Name	Units	Period of Record	N	Minimum	Maximum	Mean	Median
Air Temperature	°C	10/2/2006 - 9/2/2008	82	-2	34	18	19
ANC	µeq/L	10/2/2006 - 9/2/2008	89	278	2016	915	852
Discharge	cfs	10/2/2006 - 9/2/2008	56	0.00	34.65	4.16	1.82
DO	mg/l	10/2/2006 - 9/2/2008	89	3.573	15.000	8.451	8.290
Flow	ft/sec	10/2/2006 - 9/2/2008	59	0.000	1.933	0.490	0.457
Nitrate	mg/l	10/2/2006 - 9/2/2008	83	0.10	2.87	1.15	1
Ammonia	mg/l	10/2/2006 - 9/2/2008	59	0.031	1.033	0.147	0.089
pH	None	10/2/2006 - 9/2/2008	87	6.58	9.47	7.43	7.30
Phosphate	mg/l	10/2/2006 - 9/2/2008	84	0.06	8.80	0.58	0.26
Salinity	ppt	10/2/2006 - 9/2/2008	90	0.0	0.4	0.2	0.2
Specific conductance	µS/cm	10/2/2006 - 9/2/2008	90	0.0	753.5	357.1	370.2
Water Depth	ft	10/2/2006 - 9/2/2008	68	0.00	1.55	0.37	0.30
Water Temperature	°C	10/2/2006 - 9/2/2008	89	4.25	29.60	15.05	14.10
Wetted Width	ft	10/2/2006 - 9/2/2008	90	0	100	18	16

Several readings of nitrate were above the desired level of 2.0 mg/L nitrate in early spring 2007 for Still Creek, Oxon Run, and Ft Dupont creek, and fall 2007 through spring 2008 for Henson Creek, Still Creek, and Oxon Run (Figure 63). Phosphorus is consistently above the desired range of 0.1 mg/L at all sites, though the mean did not significantly exceed the threshold in 2007, except in Oxon Run. There were peaks at all sites in October 2006 (Figure 64). Ammonia is a problematic parameter. We frequently get readings below zero and the EDL of 0.032 with the very low readings we normally get means that much of the data is excluded from analysis (36 of 95 readings in the case of NACE in FY2007-2008). While there were ammonia values above desired condition (Ft. Dupont in early fall 2007, Oxon Run fall 2006 and spring and summer 2008), the mean met the threshold (Figure 65). There were only two occurrences of DO values below the desired level of 5mg/L: Still Creek 2007 and Accokeek Creek in 2008 (Figure 66).

Specific conductance is usually above the current threshold of 400 µS for Oxon Run and Henson Creek, Still Creek was above the threshold for most of 2007 and part of 2008, (Figure 67). ANC was well above the 200 µeq/L threshold, indicating good buffering (Figure 68). pH was in the desired range at all sites except for spikes in Henson Creek and Oxon Run in September 2007 and Oxon Run in April and September 2008 (Figure 69). Water temperature follows expected seasonal trends and stays within the comfort zone of desired organisms (Figure 70).

The region experienced a drought in 2007. Several streams in the region dried out, including Still Creek, Ft. Dupont Stream, Unnamed tributary of Accokeek Creek, and Oxon Run. Still Creek was dry January, February, and August 2007 (Table 27). Ft. Dupont stream also lacked flow in August 2006 and September 2007 (Table 28). There was not enough water for flow measurements June and December 2006, and June through November of 2007. We frequently had to dig a hole to be able to collect water samples and therefore dropped the site at the end of 2007. Oxon Run was dry in August 2007 (Table 30). Henson Creek did not dry out, though it did have very low flow (Table 29). None of the streams have maintained sufficient depth to support deployment of continuous data loggers (Figure 71).

Based on the data collected so far, normal water levels for Oxon Run can be defined as discharge between 9 cfs and 18 cfs, with a flow of 0.5 f/s or higher in a channel with a wetted width of 24 or more feet. Normal water levels for Unnamed tributary of Accokeek Creek can be defined as

discharge between 0.05 cfs and 0.5 cfs, with a flow of 0.01f/s or higher in a channel with a wetted width of 2 or more feet. UT Accokeek Creek is a small coastal Plain stream in a sandy plain. UT Accokeek Creek may experience annual late summer drying and therefore not be perennial. The 2010 data review will determine if the site should remain in our sampling pool. Normal water levels for Still Creek can be defined as discharge between 8 cfs and 10 cfs, with a flow of 0.8 f/s or higher in a channel with a wetted width of 14 or more feet. Normal water levels for Henson Creek can be defined as discharge between 1.6 cfs and 8 cfs, with a flow of 0.12 f/s or higher in a channel with a wetted width of 10 or more feet.

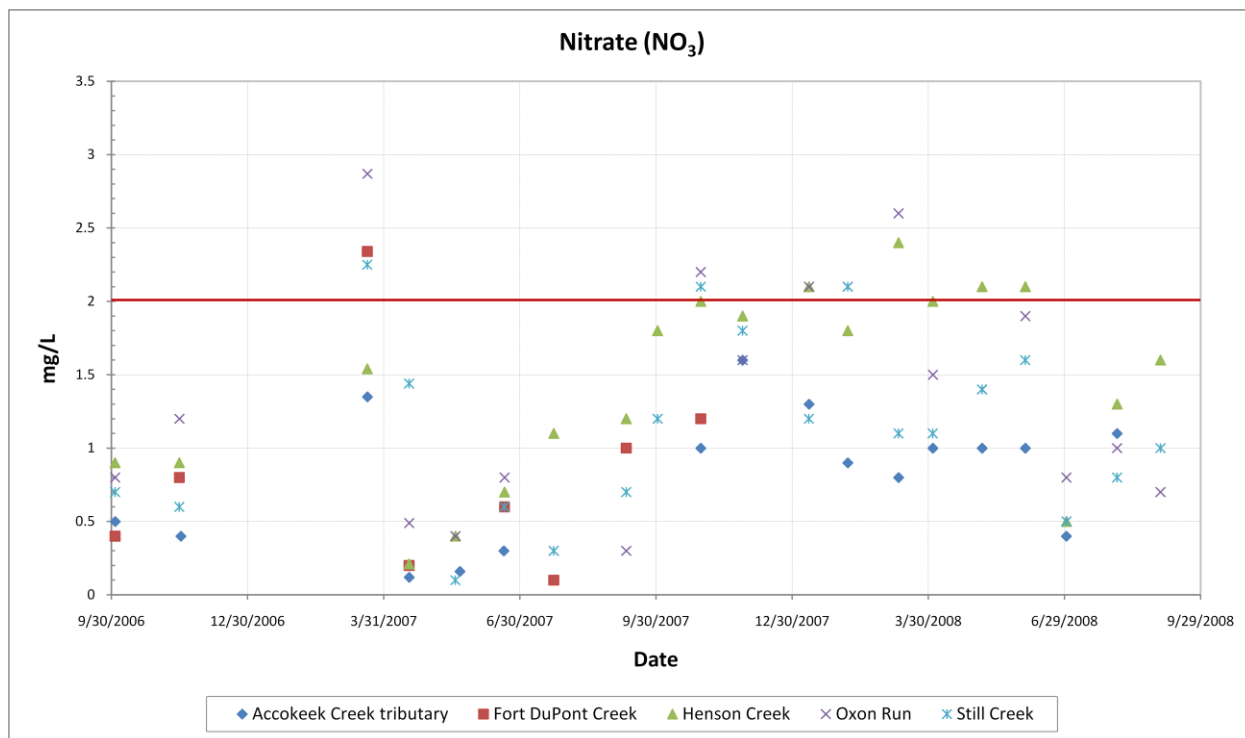


Figure 63: Nitrate in NACE streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

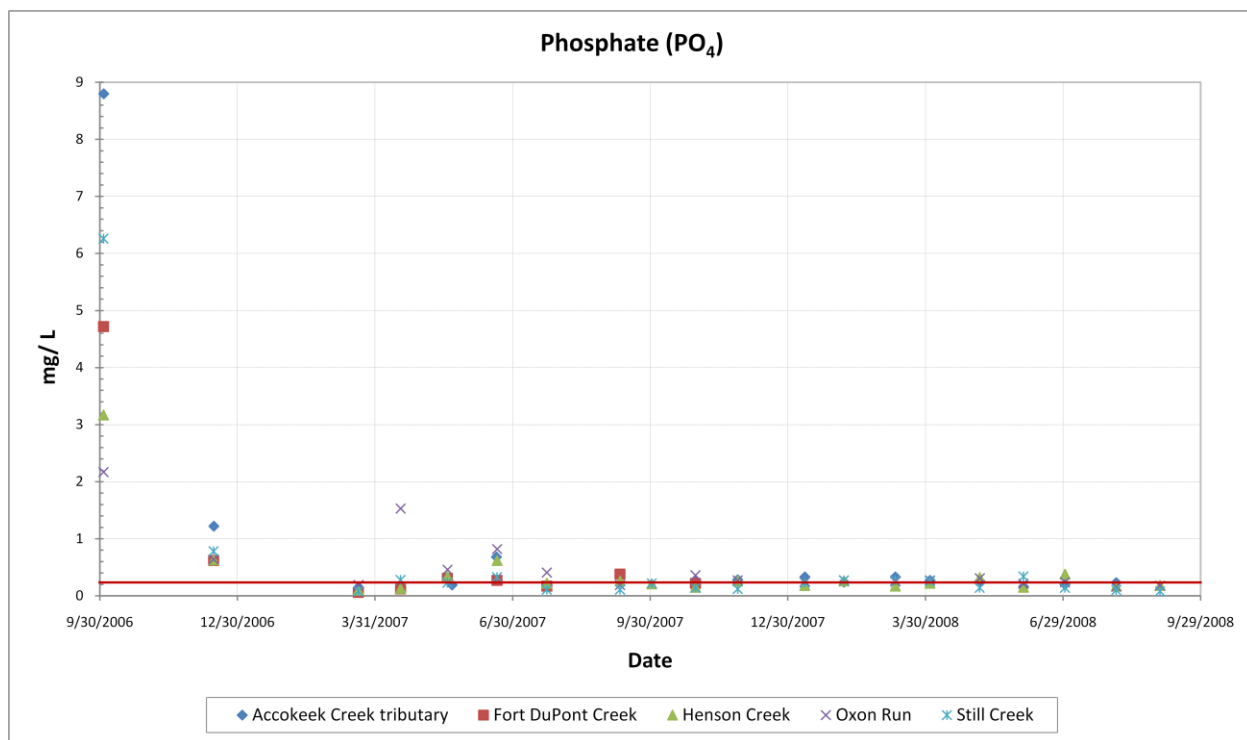


Figure 64: Phosphate in NACE streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO_4 (red line).

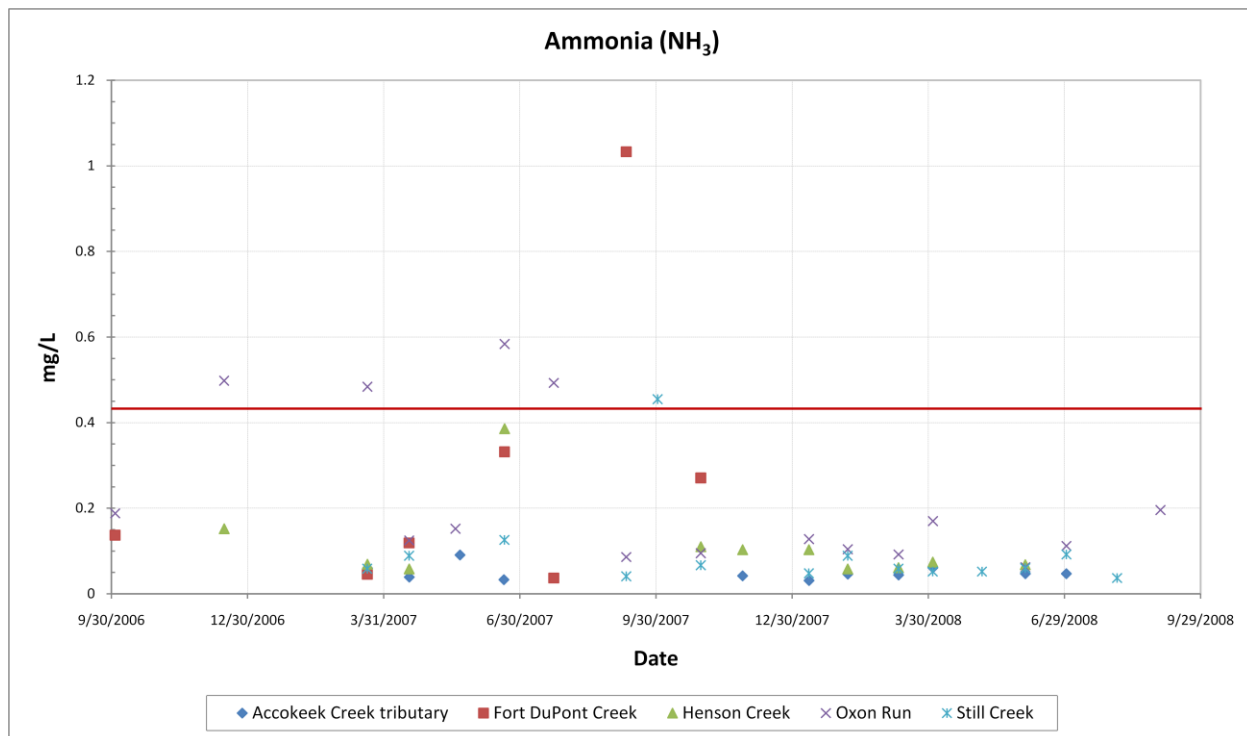


Figure 65: Ammonia in NACE streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH_3 (red line).

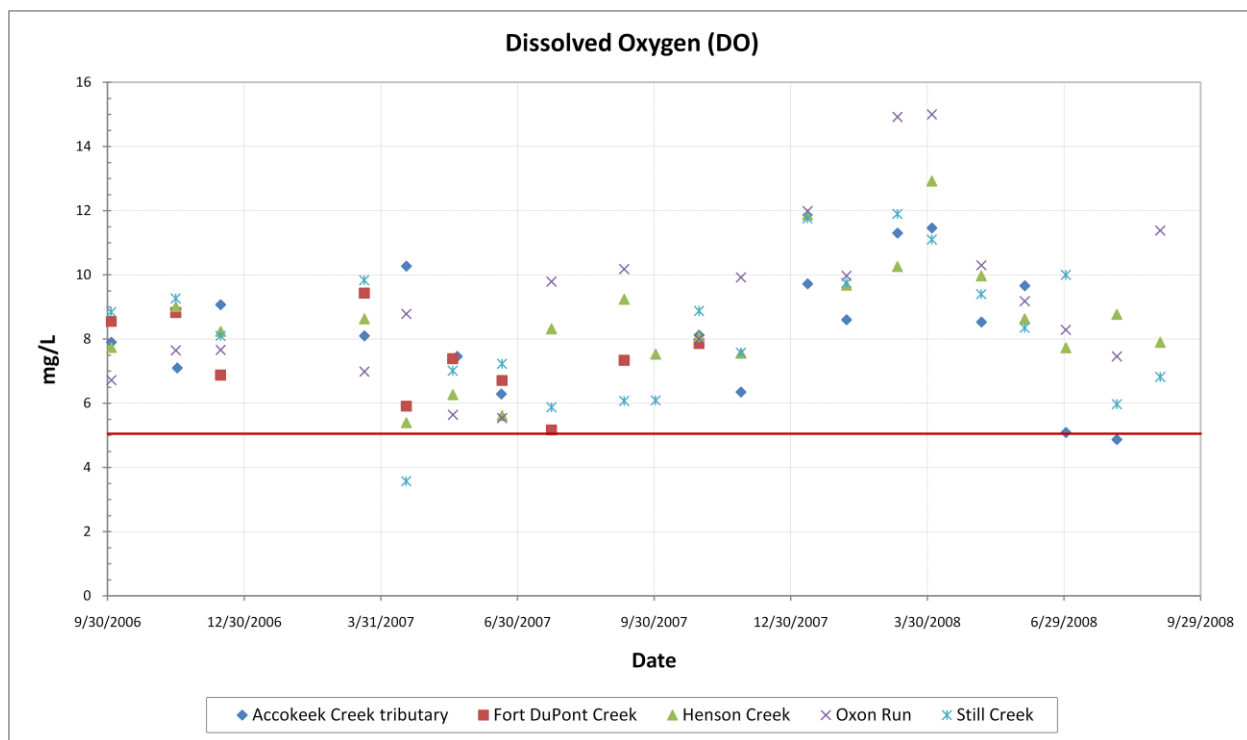


Figure 66: Dissolved oxygen in NACE streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

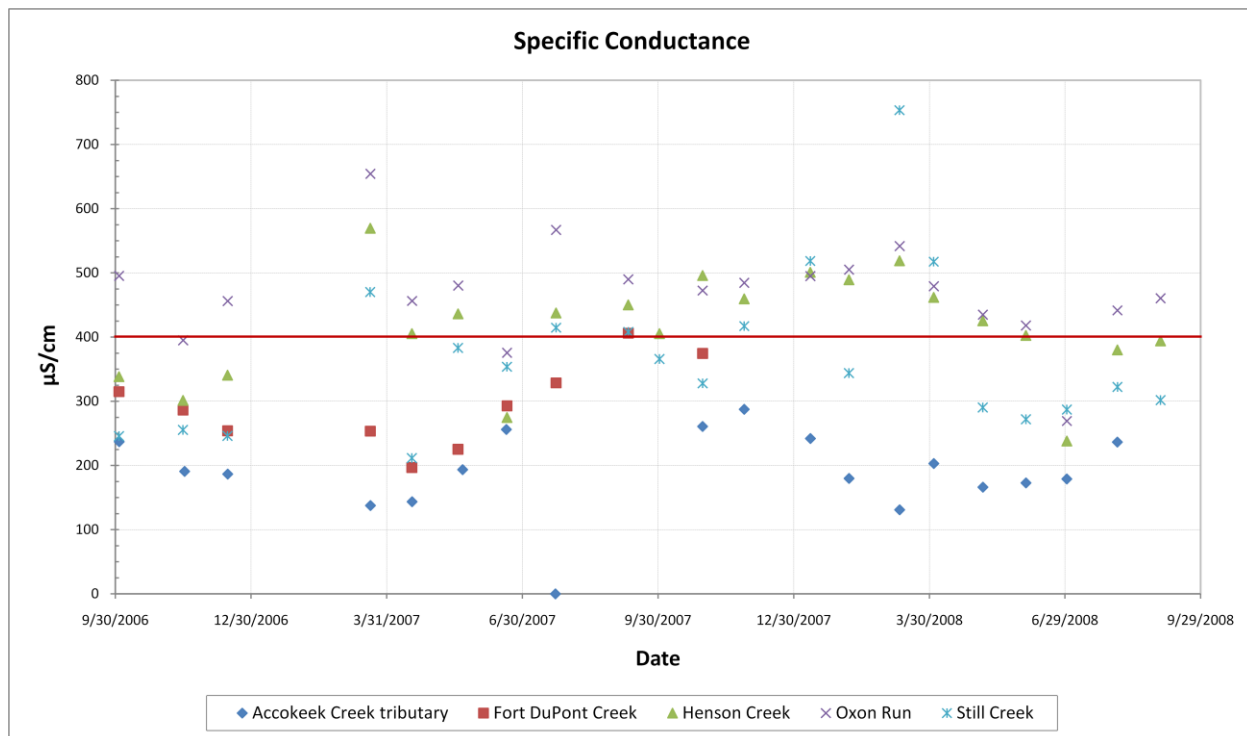


Figure 67: Specific Conductance in NACE streams FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

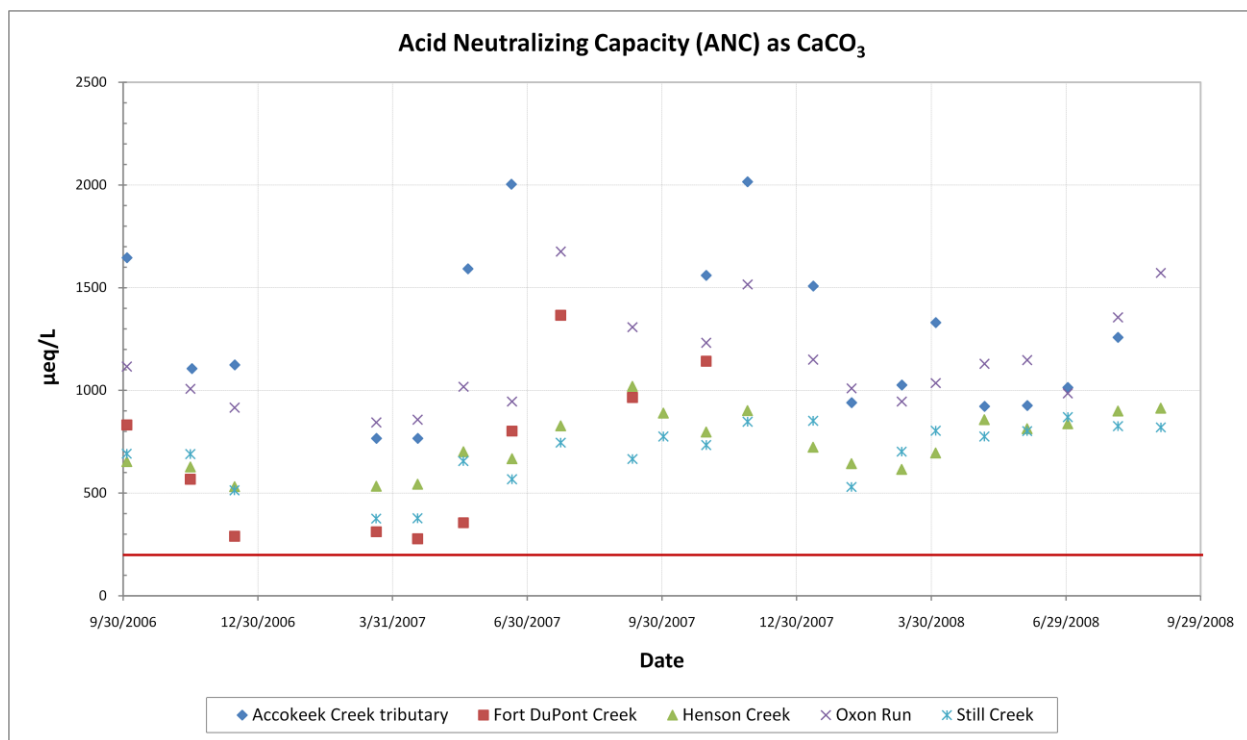


Figure 68: Acid Neutralizing Capacity in NACE streams FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq/L}$ (the red line on the graph).

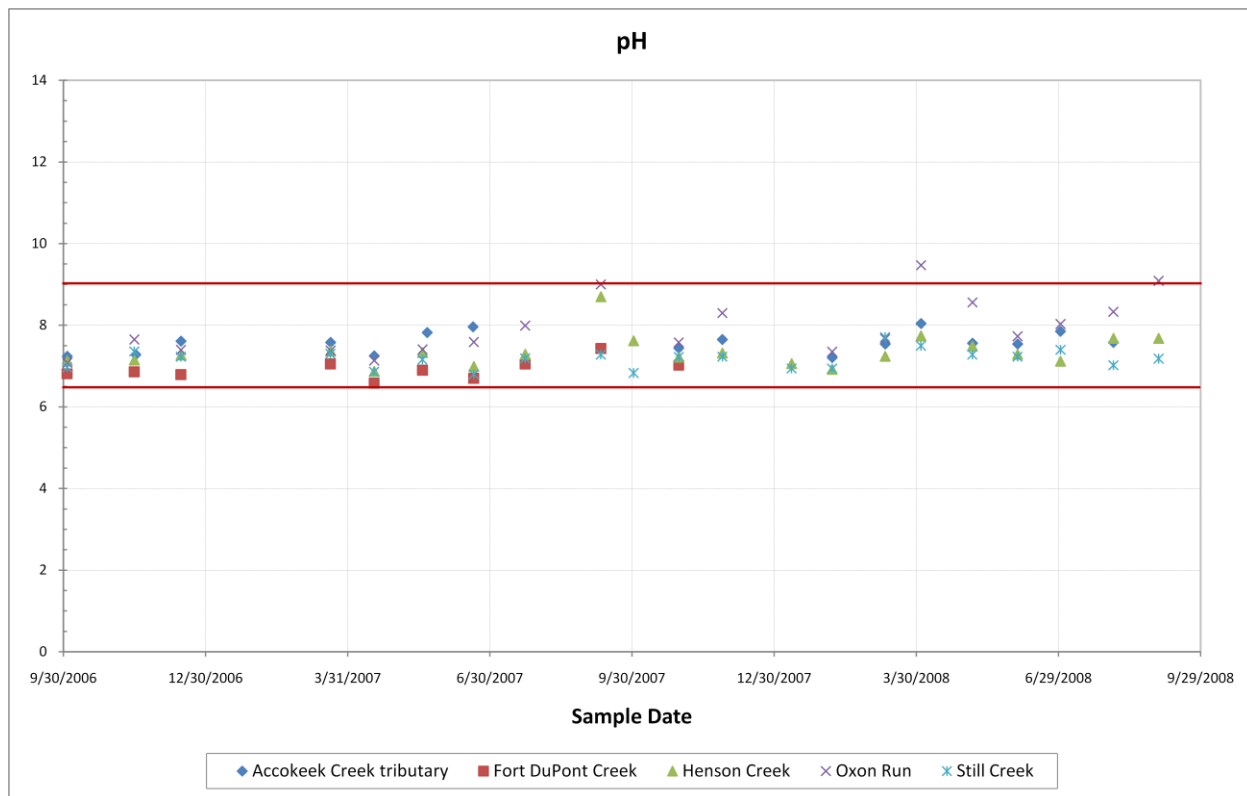


Figure 69: pH in NACE streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

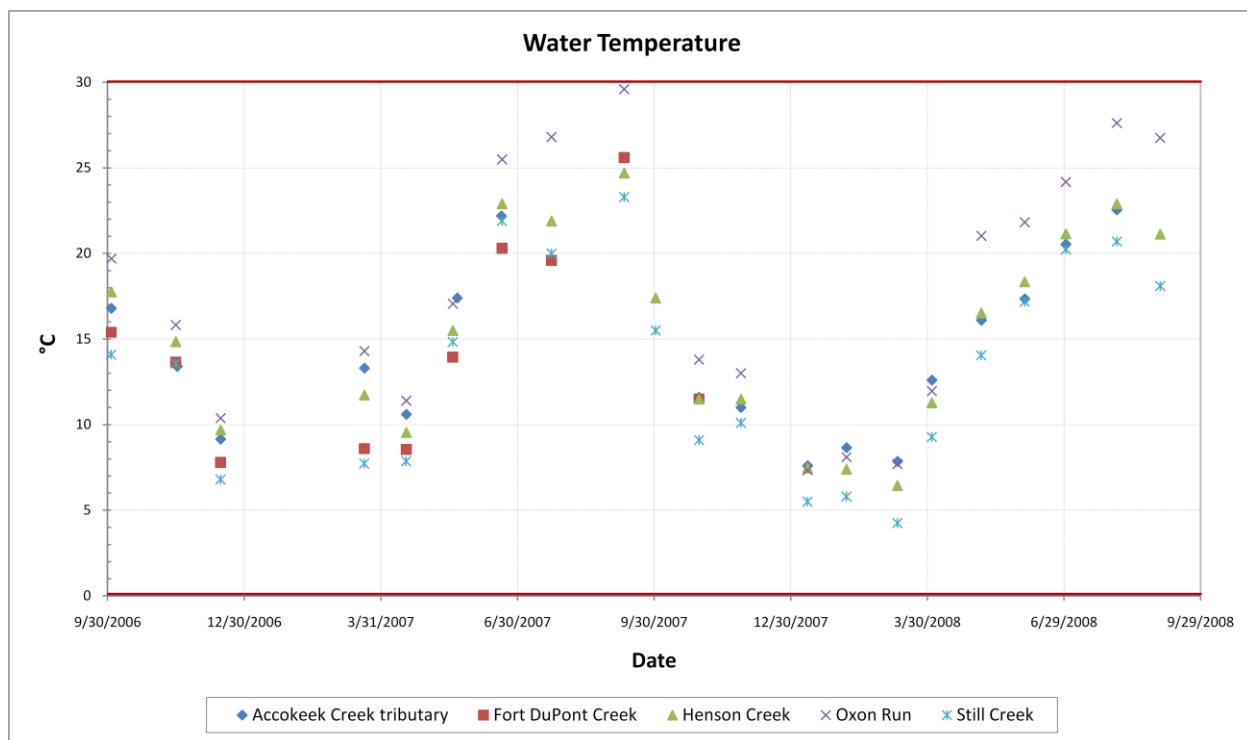


Figure 70: Water temperature in NACE streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

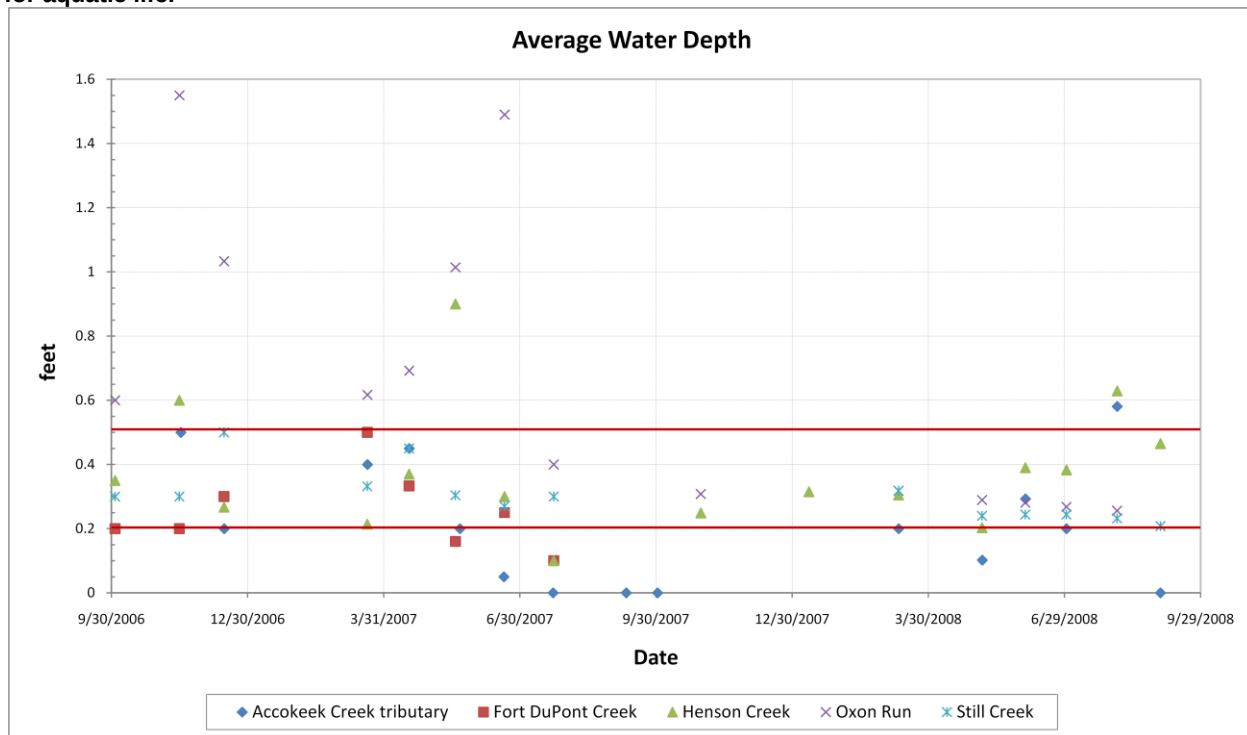


Figure 71: Water Depth in NACE streams FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 27: Hydrology data for Still Creek, National Capital Parks - East March 2006 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
3/6/2006	1.417	0.28	LOW	16.67
3/30/2006	0.827	0.46	LOW	14.0
4/24/2006	2.983	0.86	LOW	16.25
6/14/2006	1.067	0.1	LOW	13.33
7/5/2006	8.849	1.11	NORMAL	14.25
7/31/2006	1.184	0.37	LOW	10.67
8/24/2006	0.252	0.12	LOW	10.5
10/2/2006	0.590	0.18	LOW	13.25
11/14/2006	2.312	0.51	LOW	14.58
12/14/2006	2.973	0.41	LOW	14.5
1/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
2/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
3/20/2007	3.448	0.498	LOW	17.333
4/17/2007	9.113	0.828	NORMAL	22.25
5/18/2007	0.898	0.122	LOW	25.667
6/20/2007	*Not Reported	*Not Reported	NORMAL	28.25
7/23/2007	*Not Reported	*Not Reported	LOW	11.667
8/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
9/10/2007	*Not Reported	*Not Reported	LOW	13.250
10/1/2007	*Not Reported	*Not Reported	LOW	11.917
10/30/2007	*Not Reported	*Not Reported	LOW	13.917
11/27/2007	*Not Reported	*Not Reported	LOW	14.583
12/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/10/2008	*Not Reported	*Not Reported	LOW	19.25
2/5/2008	*Not Reported	*Not Reported	LOW	15.3
3/10/2008	3.3	0.638	LOW	16.04
4/2/2008	*Not Reported	*Not Reported	LOW	15.07
5/5/2008	1.4	0.342	LOW	17
6/3/2008	3.54	0.709	LOW	20.33
7/1/2008	1.37	0.351	LOW	16
8/4/2008	0.66	0.177	LOW	16
9/2/2008	0.55	0.157	LOW	16.75

Table 28: Hydrology data for Ft. Dupont Stream, National Capital Parks - East March 2006 to November 2007

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
3/6/2006	0.878	1.08	LOW	3.25
3/30/2006	0.095	0.11	LOW	4.5
4/24/2006	0.089	0.15	LOW	4.42
6/14/2006	*Not Reported	*Not Reported	LOW	2.08
7/5/2006	0.290	0.61	LOW	3.17
7/31/2006	0.759	1.47	LOW	2.58
8/24/2006	*Not Reported	0	DRY	0
10/2/2006	0.007	0.01	LOW	3.5
11/14/2006	0.630	0.61	LOW	5.17
12/14/2006	*Not Reported	0.05	LOW	4.5
1/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
2/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
3/20/2007	2.147	0.92	NORMAL	4.667
4/17/2007	1.103	0.532	NORMAL	6.25
5/18/2007	0.118	0.118	LOW	4.833
6/20/2007	*Not Reported	*Not Reported	LOW	4.333
7/23/2007	*Not Reported	*Not Reported	LOW	3.583
8/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
9/10/2007	*Not Reported	*Not Reported	FLOOD	6.833
10/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
10/30/2007	*Not Reported	*Not Reported	LOW	2.5
11/27/2007	*Not Reported	*Not Reported	DRY	*Not Reported

Table 29: Hydrology data for Henson Creek, National Capital Parks - East March 2006 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
3/6/2006	2.074	0.14	NORMAL	10.6
3/30/2006	1.661	0.143	NORMAL	11.67
4/24/2006	3.277	0.32	NORMAL	9.42
6/14/2006	3.962	0.29	NORMAL	14.08
7/5/2006	0.942	0.07	LOW	18.83
7/31/2006	1.118	0.45	LOW	12.42
8/24/2006	1.066	0.42	LOW	0.25
10/2/2006	0.978	0.34	LOW	23
11/14/2006	18.546	1.32	ABOVE NORMAL	23.42
12/14/2006	*Not Reported	1.03	NORMAL	*Not Reported
1/1/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
2/9/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/20/2007	4.178	.468	NORMAL	22.833
4/17/2007	5.863	0.548	NORMAL	23.25
5/18/2007	0.506	0.032	LOW	10.167
6/20/2007	*Not Reported	*Not Reported	LOW	17.750
7/23/2007	*Not Reported	*Not Reported	LOW	11.083
8/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/10/2007	*Not Reported	*Not Reported	LOW	16.250
10/1/2007	*Not Reported	*Not Reported	LOW	17.250
10/30/2007	3.867	1.933	NORMAL	19.083
11/27/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/10/2008	2.97	0.944	NORMAL	10
2/5/2008	*Not Reported	*Not Reported	LOW	20
3/10/2008	3.21	0.555	NORMAL	19
4/2/2008	*Not Reported	*Not Reported	LOW	19
5/5/2008	2.92	0.700	NORMAL	20.05
6/3/2008	3.46	0.457	NORMAL	18.92
7/1/2008	8.05	1.275	NORMAL	16.5
8/4/2008	1.6	0.128	NORMAL	19.92
9/2/2008	1.018	0.112	LOW	20.08

Table 30: Hydrology data for Oxon Run, National Capital Parks - East November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/29/2005	*Not Reported	0.52	LOW	*Not Reported
1/31/2006	*Not Reported	1.12	NORMAL	109.25
3/30/2006	*Not Reported	0.12	NORMAL	101.0
4/24/2006	*Not Reported	2.39	NORMAL	*Not Reported
6/14/2006	17.346	0.49	NORMAL	39.3
7/5/2006	5.713	0.08	LOW	41.5
7/31/2006	2.125	0.03	LOW	100
8/24/2006	*Not Reported	0	NO FLOW	*Not Reported
10/2/2006	2.054	0.10	LOW	52
11/14/2006	13.25	0.075	NORMAL	100
12/14/2006	2.035	0.037	LOW	53.083
1/1/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
2/9/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/20/2007	34.645	0.257	ABOVE NORMAL	50
4/17/2007	26.476	0.465	ABOVE NORMAL	52.167
5/18/2007	5.777	0.074	LOW	49.333
6/20/2007	*Not Reported	*Not Reported	LOW	70.0
7/23/2007	*Not Reported	*Not Reported	LOW	49.833
8/1/2007	*Not Reported	*Not Reported	DRY	*Not Reported
9/10/2007	*Not Reported	*Not Reported	NO FLOW	28.417
10/30/2007	9.754	1.112	NORMAL	30.0
11/27/2007	*Not Reported	*Not Reported	LOW	23.667
1/10/2008	*Not Reported	*Not Reported	LOW	24.25
2/5/2008	*Not Reported	*Not Reported	LOW	27.1
3/10/2008	9.52	1.200	NORMAL	24.1
4/2/2008	*Not Reported	*Not Reported	LOW	22.3
5/5/2008	9.42	1.161	NORMAL	28.02
6/3/2008	10.89	1.252	NORMAL	31
7/1/2008	11.8	1.289	NORMAL	34.02
8/4/2008	2.71	0.616	LOW	17.17
9/2/2008	*Not Reported	*Not Reported	LOW	27.58

Table 31: Hydrology data for Unnamed tributary of Accokeek Creek, National Capital Parks - East November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/29/2005	*Not Reported	0.13	NORMAL	*Not Reported
1/31/2006	0.108	0.18	NORMAL	3.0
3/30/2006	0.098	0.49	NORMAL	2.67
4/24/2006	0.546	0.78	NORMAL	3.51
6/14/2006	0.107	0.16	NORMAL	1.92
7/5/2006	0.273	0.63	NORMAL	2.17
7/31/2006	*Not Reported	0.0	NO FLOW	1.58
8/24/2006	*Not Reported	0	DRY	0
10/2/2006	0.016	0.04	LOW	2
11/15/2006	0.500	0.5	NORMAL	2
12/14/2006	0.303	0.65	NORMAL	2.33
1/1/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
2/9/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/20/2007	1.020	0.85	ABOVE NORMAL	3
4/17/2007	0.471	0.465	NORMAL	2.167
5/21/2007	0.081	0.23	NORMAL	1.833
6/20/2007	*Not Reported	*Not Reported	LOW	1.5
7/23/2007	0	0	DRY	0
9/10/2007	0	0	DRY	0
10/1/2007	0	0	DRY	0
10/30/2007	*Not Reported	*Not Reported	NORMAL	2.0
11/27/2007	*Not Reported	*Not Reported	LOW	1.417
1/10/2008	*Not Reported	*Not Reported	NORMAL	2
2/5/2008	*Not Reported	*Not Reported	FLOOD	4.3
3/10/2008	0.201	0.334	NORMAL	3
4/2/2008	*Not Reported	*Not Reported	LOW	1.5
5/5/2008	0.3	0.851	NORMAL	3.06
6/3/2008	0.24	0.234	NORMAL	3.5
7/1/2008	0.07	0.116	NORMAL	3
8/4/2008	0.05	0.018	NORMAL	4.42
9/2/2008	*Absent	0	DRY	*Absent

Prince William Forest Park (PRWI)

The park is located in Prince William and Stafford Counties, Virginia and crosses the Piedmont and Coastal Plain physiographic regions. PRWI streams alternate characteristics of both ecoregions, existing in an undulating transition zone (Fenneman 1938, Thornbury 1968, Blomquist et al. 1996, Roth et al. 1999, William & Mary 2000). Streams that cross the division of older, harder upland rocks of the Piedmont to loose, unconsolidated younger rocks of the Coastal Plain tend to have falls or rapids in their channels (Thornbury 1968). The Fall Line is an imaginary line connecting the waterfalls. PRWI contains portions of two stream systems: Quantico Creek and Chopawamsic Creek (Figure 72). The 30-square mile watershed of Quantico Creek is almost entirely forested. The headwaters of South Fork Quantico Creek, 9 square miles, lie within Quantico Marine Corps Base, while 4 square miles of watershed are in private ownership. The remaining 17 square miles of the watershed lie within the 29 sq miles of Prince William Forest Park. Thus, the park has the unique opportunity to preserve and protect a large portion of this ecosystem. Because the park includes two physiographic provinces (Piedmont and Coastal Plain) and lies in the transition zone between northern and southern climates, it exhibits a wide range of habitat and vegetative communities. It is now the only natural area in the National Park System that contains a significant expanse of piedmont forest.

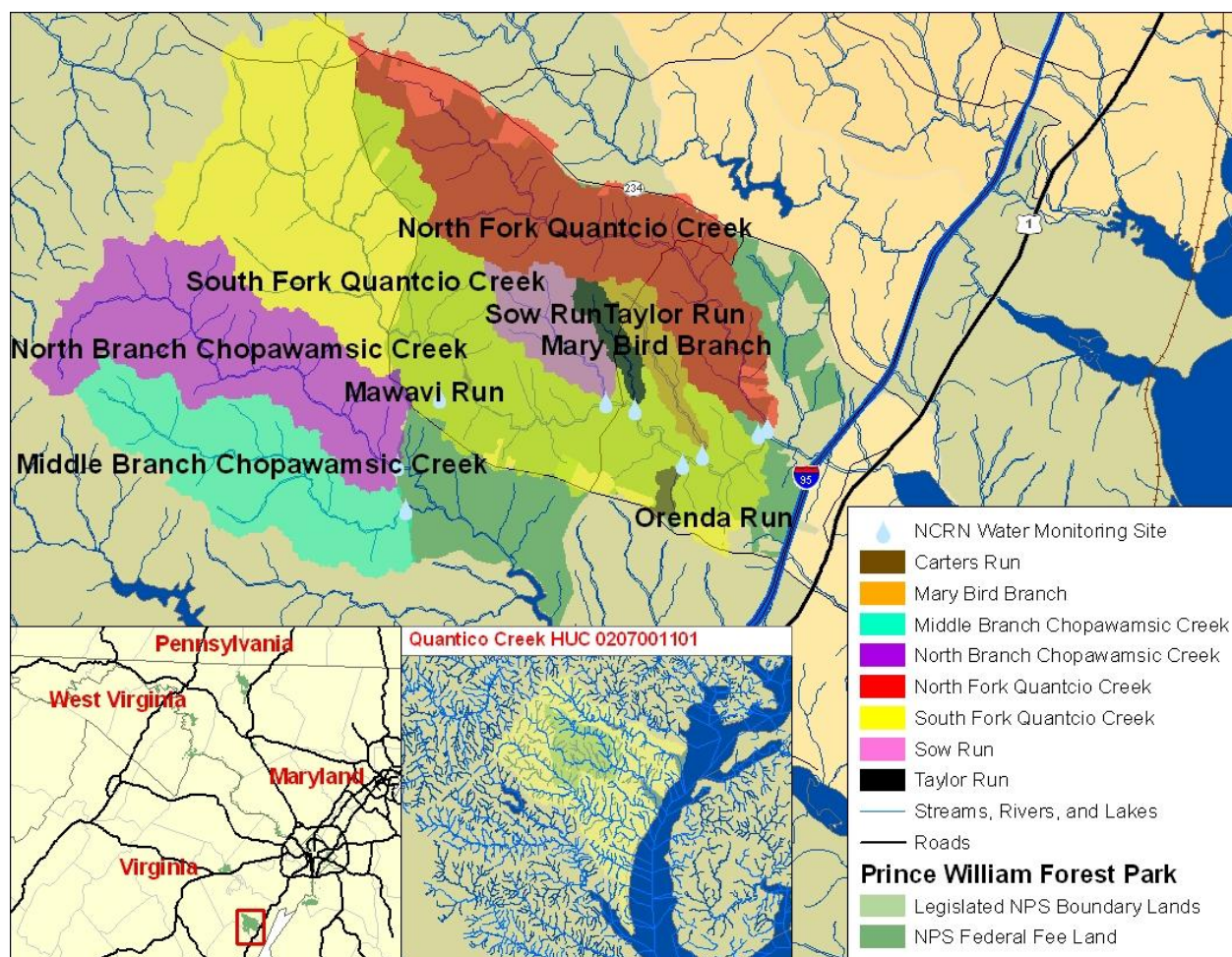


Figure 72: Relationship of PRWI stream monitoring sites to their watersheds and the park boundary

This report discusses data collected October 2006 through September 2008 for Mary Bird Branch (MBBR), Middle Branch Chopawamsik Creek (MBCH), North Fork Quantico Creek (NFQC), North Branch Chopawamsik Creek (NOBR), South Fork Quantico Creek (SFQC), and Sow Run (SORU). Carter's Run (CARU) and Taylor Run (TARU) were added in January 2007. Mawavi Run was added in April 2008. These three sites therefore have less data reported in this report. Summary statistics for the time period are shown in Table 32.

Table 32: Date range, number of site visits (N), and data range for the information covered in this report for PRWI.

Parameter	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/24/2006 - 9/15/2008	140	-8	34	18	21	9
ANC	µeq/L	10/24/2006 - 9/15/2008	156	24	932	316	309	142
Discharge	cfs	10/24/2006 - 9/15/2008	86	0.00	20.27	2.99	1.23	4.46
DO	mg/l	10/24/2006 - 9/15/2008	157	3.84	13.32	8.25	8.15	1.88
Flow	ft/sec	10/24/2006 - 9/15/2008	87	0.00	1.65	0.37	0.26	0.36
Nitrate	mg/l	10/24/2006 - 9/15/2008	154	0.0	1.2	0.6	0.5	0.3
Ammonia	mg/l	10/24/2006 - 9/15/2008	64	0.031	0.700	0.069	0.049	0.089
pH	None	10/24/2006 - 9/15/2008	149	5.89	7.80	6.92	7.00	0.36
Phosphate	mg/l	10/24/2006 - 9/15/2008	157	0.09	2.41	0.32	0.18	0.38
Salinity	ppt	10/24/2006 - 9/15/2008	160	0.0	0.3	0.0	0.0	0.0
Specific conductance	µS/cm	10/24/2006 - 9/15/2008	161	0	686	71	54	75
Water Depth	ft	10/24/2006 - 9/15/2008	102	0.0	1.5	0.5	0.4	0.4
Water Temperature	°C	10/24/2006 - 9/15/2008	157	1.0	25.4	14.26	15.9	6.175
Wetted Width	ft	10/24/2006 - 9/15/2008	161	0	42.67	11.51	7.33	10.69

Nitrate has not been above the desired level of 2.0 mg/L at any site during sampling 2005-2007 (Figure 73). Ammonia was above threshold in Sow Run in fall 2007 (Figure 75). Ammonia is a problematic parameter. We frequently get readings below zero and the EDL of 0.032. Given the very low readings we normally get, much of the data is excluded from analysis (104 of 168 readings in the case of PRWI FY2007-2008). Phosphorus is consistently above the desired range of 0.1 mg/L at all sites (Figure 74). Phosphorus levels improved during the drought, with the lowest values occurring during the driest months. There is no known source of phosphorus within the park and the Marine Corps Base is required to maintain the headwaters in pristine condition. Potential sources of PO₄ need to be fully investigated. Dissolved oxygen tends to be low in the parks in late summer and early fall (Figure 76). DO values fall below the desired level of 5mg/L at all sites in the summer. In 2007 DO values remained low into early fall. Mawavi Run and the Chopawamsik tributaries all peak in winter and decrease through early fall, falling below threshold before rebounding again.

Specific conductance is usually below the current threshold of 400 µS , except for peaks in summer and fall 2007 in North Fork Quantico Creek and Sow Run (Figure 77). Though pH was within desired range, pH tends to be at the low end of desirable condition in PRWI streams with Chopawamsik tributaries close to the lower threshold (Figure 78). This is of special concern due to the lower ANC in the park and the recent realization that streams in Shenandoah are acidified to the point of losing native trout populations(USGS 2007). Carter's Run is chronically low in acid neutralizing capacity, much lower than any other stream in the park (Figure 79). pH in

Carter's Run is also chronically low. ANC is decreasing across PRWI, while it appears to be increasing in the rest of the region. Carter's Run fails to meet ANC 100% of the time. MBBR, MBCH, NOBR, SORU, and TARU do not always meet the threshold, particularly in fall 2006 and winter 2007. However during the driest period, summer 2007, ANC improved.

Water temperature follows expected seasonal trends and stays within the comfort range of most organisms except incidental summer highs in North Fork Quantico Creek (Figure 80). The unusually lowered summer water temperatures at all sites for 2007 reflects the influx of colder groundwater during the drought.

The region experienced a drought in 2007. Several small streams in the region dried out, however Middle and North Branches of Chopawamsik Creek did not, though they did lack flow in August 2006 (Tables 36 and 37). The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements in water quality. Based on the data collected so far, normal water levels for North Branch Chopawamsik Creek can be defined as discharge between 1.3 cfs and 8.9 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 6.5 or more feet. Low is less than 1.2 cfs discharge and flow less than 0.15 f/s. Above normal is 10 or greater cfs. Normal water levels for Middle Branch Chopawamsik Creek can be defined as discharge between 4.5 cfs and 6 cfs, with a flow of 0.17 f/s or higher in a channel with a wetted width of 13 or more feet. Low is less than 3 cfs discharge, flow less than 0.2 f/s and a wetted width of less than 15 feet. When the stream has been above normal, it has not been possible to collect discharge safely. These two sites are located off of a Marine Corps road to which we are not always provided access. This occurred once in 2005 and once in 2008.

Sow Run went dry during the drought of 2007 (Table 41). Based on the data collected so far, normal water levels for Sow Run can be defined as discharge between 0.32 cfs and 4 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 4 or more feet. Low is less than 0.3 cfs discharge and flow less than 0.18 f/s. When the stream has been above normal, it has not been possible to collect discharge safely.

Mawavi Run was added to the sampling pool in April 2008 (Table 35). The hydrology of the stream was not observed during the drought of 2007. Based on the data collected so far, normal water levels for Mawavi Run can be defined as discharge between 0.03 cfs and 0.3 cfs, with a flow of 0.01 f/s or higher in a channel with a wetted width of 4 or more feet. When Mawavi Run is low, it is too shallow to measure discharge. Above normal flow conditions have not been observed at the site. This stream functions as a Coastal Plain stream, despite its location in the Piedmont.

Carter's Run had no flow July through October of the 2007 drought (Table 33). Based on the data collected so far, normal water levels for Carter's Run can be defined as discharge between 0.2 cfs and 0.5 cfs, with a flow of 0.1 f/s or higher in a channel with a wetted width of 3 or more feet. Low is less than 0.2 cfs discharge, and flow less than 0.5 f/s and a wetted width of less than 10 feet. Above normal flow conditions have not been observed at the site. The water depth in Carter's Run is frequently too little to cover the flowmeter making hydrology measurements impossible. Alternative methods are being investigated.

Taylor Run did not have flow August to October of the drought of 2007 (Table 41). Based on the data collected so far, normal water levels for Taylor Run can be defined as discharge between 0.6 cfs and 1 cfs, with a flow of 0.5 f/s or higher in a channel with a wetted width of 7 or more feet. Low is less than 0.3 cfs discharge, flow less than 0.4 f/s and a wetted width of less than 7 feet. Above normal flow conditions have not been observed at the site.

Mary Bird Branch lacked flow August through October of the 2007 drought (Table 34). The stream had also dried the previous August (2006). The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for Mary Bird Branch can be defined as discharge between 1.3 cfs and 1.6 cfs, with a flow of 0.4 f/s or higher in a channel with a wetted width of 7 or more feet. Low is less than 1 cfs discharge, flow less than 0.3 f/s and a wetted width of less than 10 feet. Above normal is 1.6 or greater cfs.

North Fork Quantico Creek did not go dry during the 2007 drought, though it did have flows too low to measure (Table 38). The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for North Fork Quantico Creek can be defined as discharge between 6 cfs and 15 cfs, with a flow of 0.7 f/s or higher in a channel with a wetted width of 17 or more feet. Low is less than 4 cfs discharge and flow less than 0.5 f/s. When the stream has been above normal, it has not been possible to collect discharge safely.

South Fork Quantico Creek did not go dry during the 2007 drought, though it did have flows too low to measure (Table 39). The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for South Fork Quantico Creek can be defined as discharge between 16 cfs and 20 cfs. Low is less than 12 cfs discharge. When the stream has been above normal, it has not been possible to collect discharge safely. Due to debris movement in the channel, flow width and velocity are too variable to define normal and low ranges.

North and Middle Branches of the Chopawamsik and South Fork Quantico Creek are the only streams that maintain enough flow to support continuous logger deployment (Figure 81). In addition to these three, Sow Run also has enough flow for consistent discharge measurements.

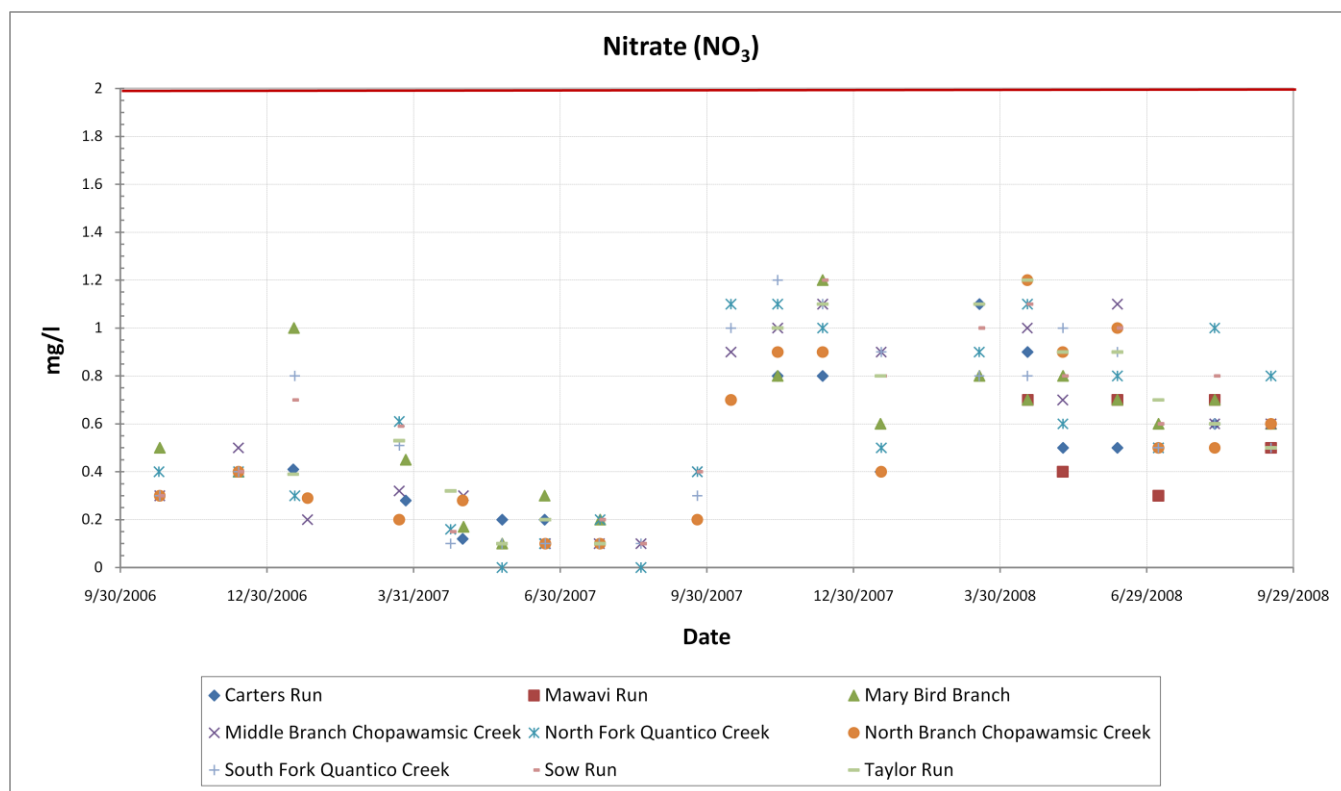


Figure 73: Nitrate in PRWI streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

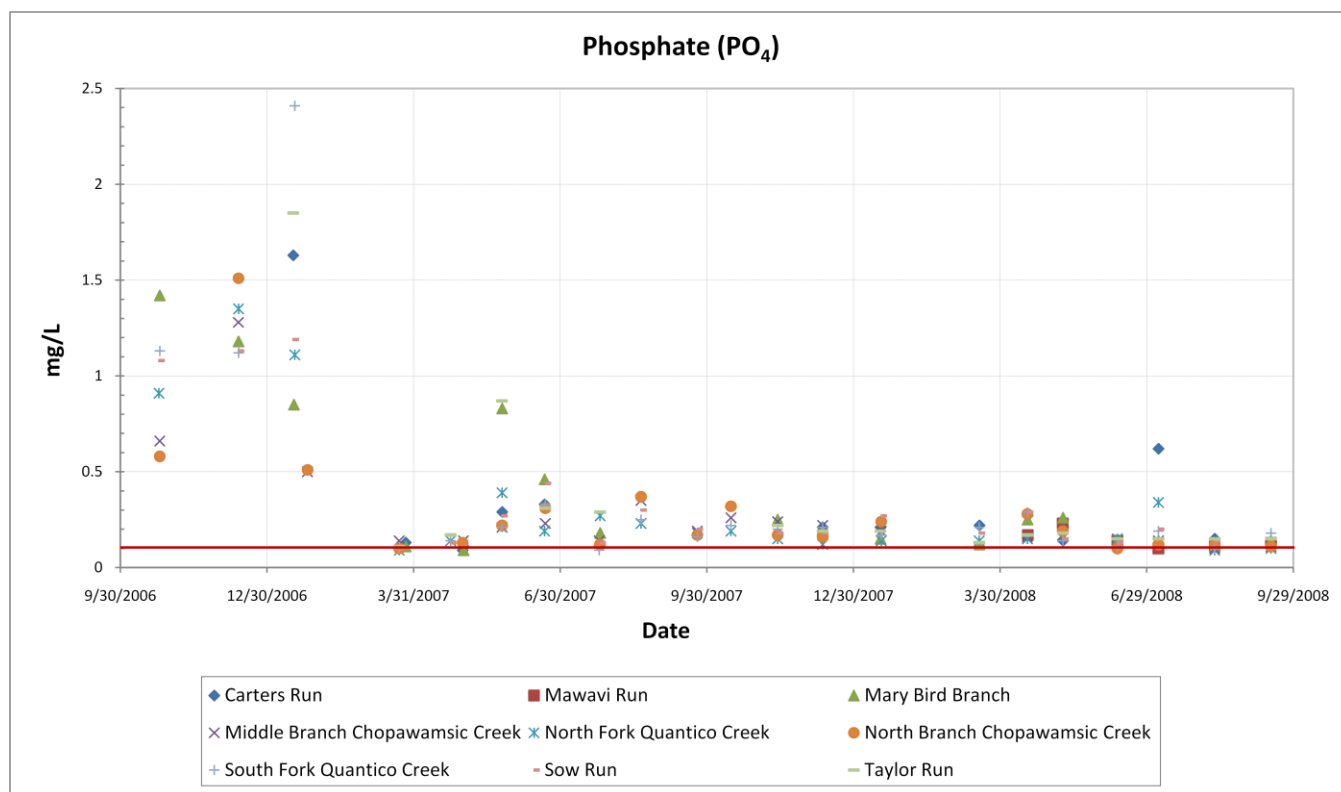


Figure 74: Phosphate in PRWI streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

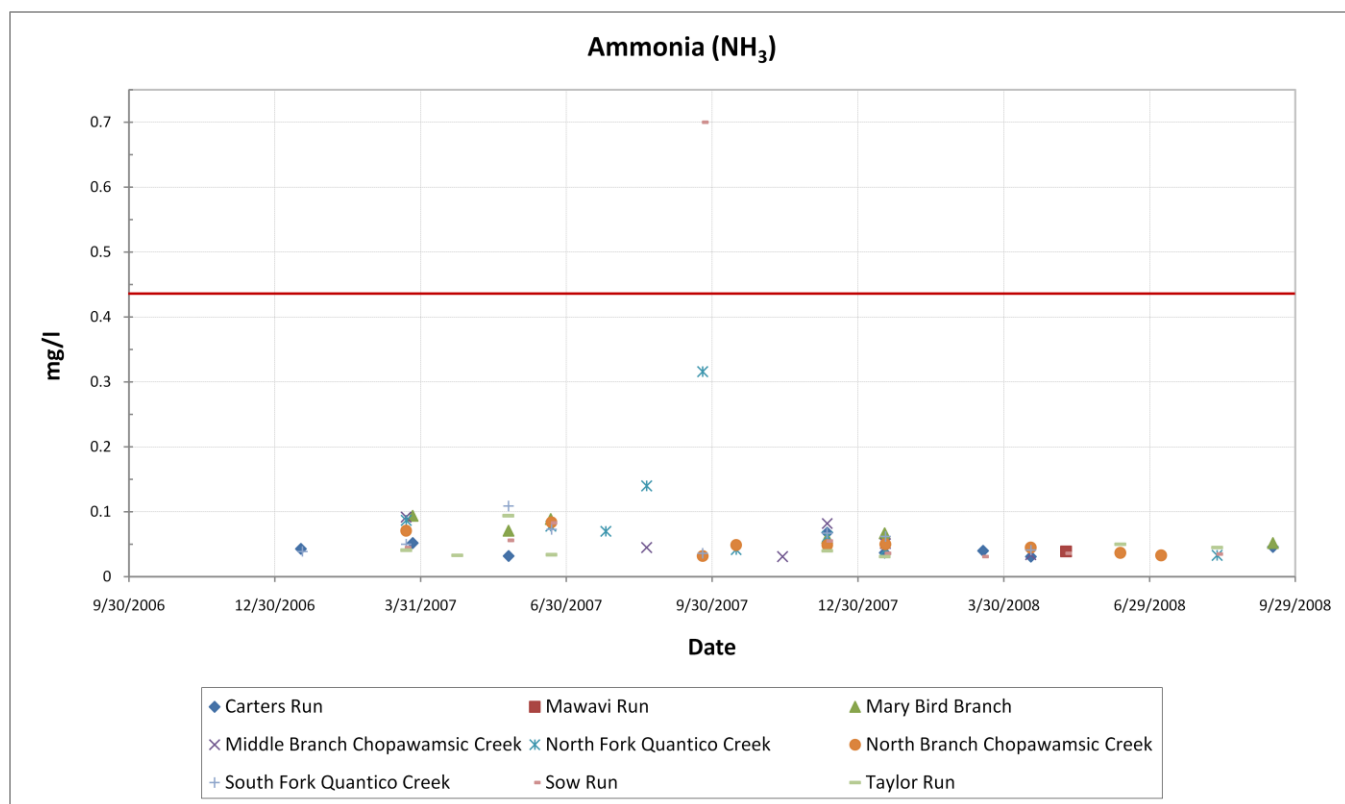


Figure 75: Ammonia in PRWI streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

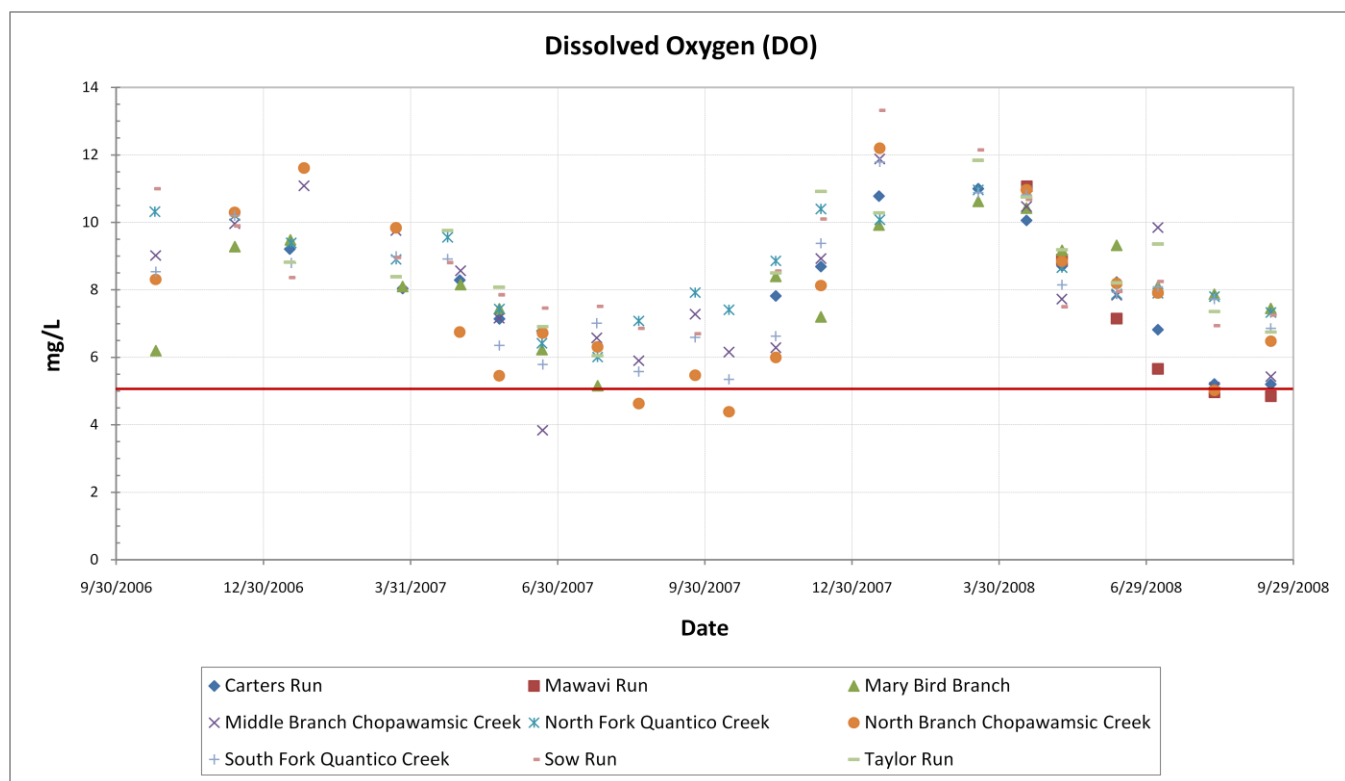


Figure 76: Dissolved oxygen in PRWI streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

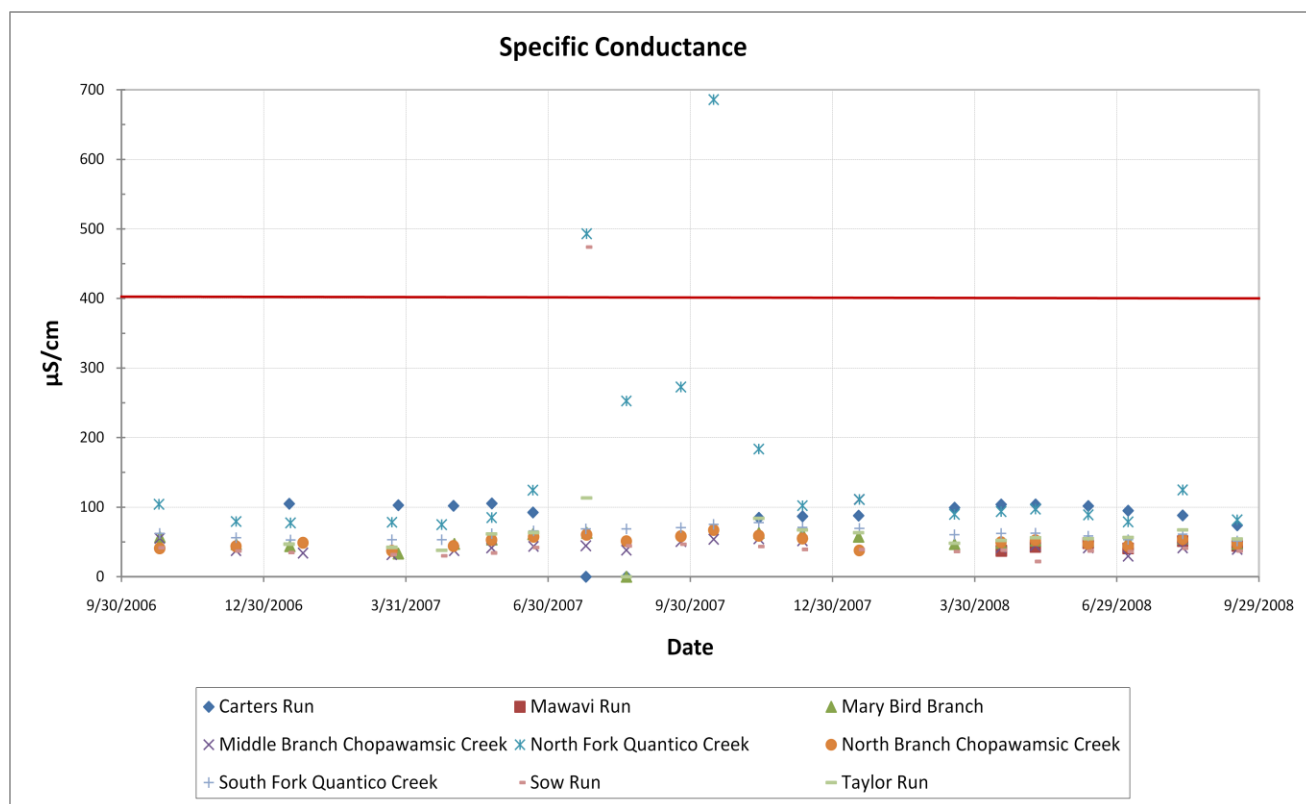


Figure 77: Specific Conductance in PRWI streams FY 2007-2008. Ideally, healthy waters would have less than 400 $\mu\text{S}/\text{cm}$ (red line).

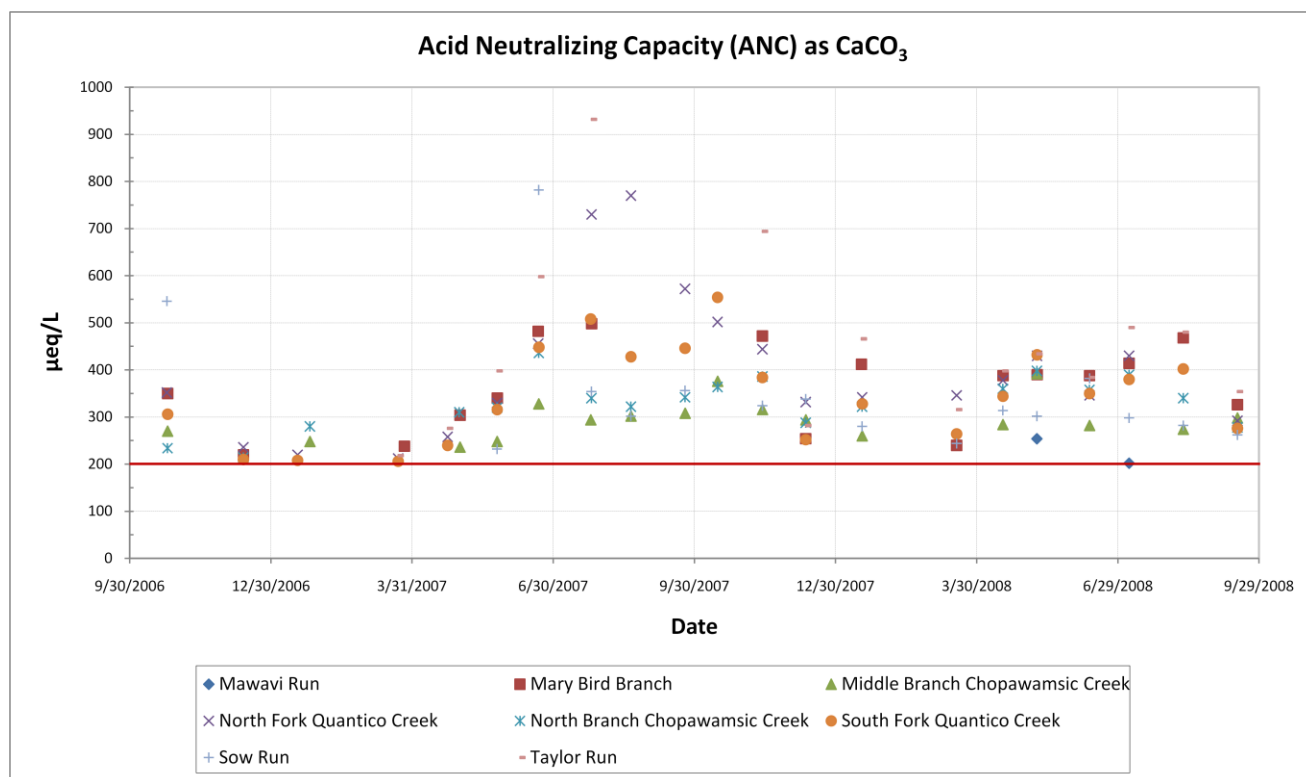


Figure 78: Acid Neutralizing Capacity in PRWI streams FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq}/\text{L}$ (the red line on the graph).

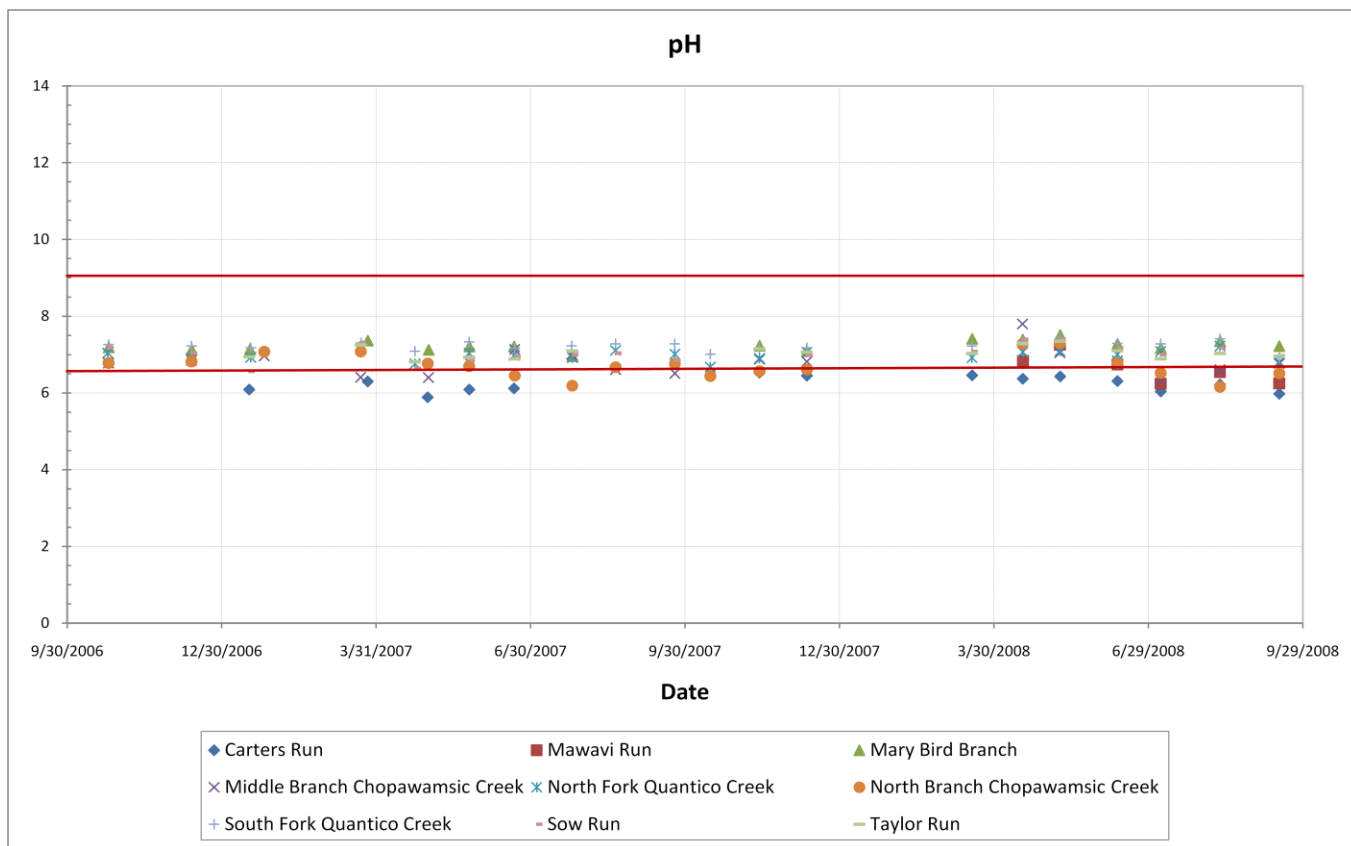


Figure 79: pH in PRWI streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

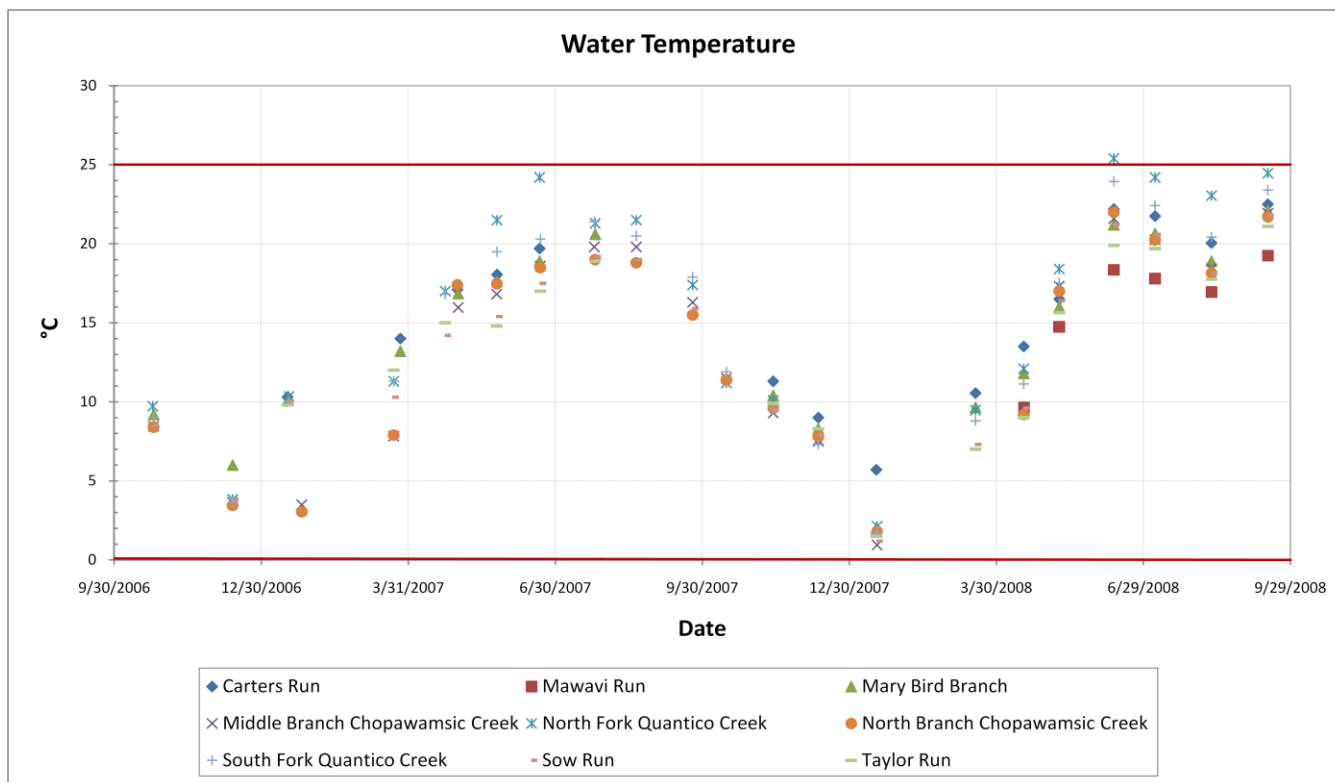


Figure 80: Water temperature in PRWI streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

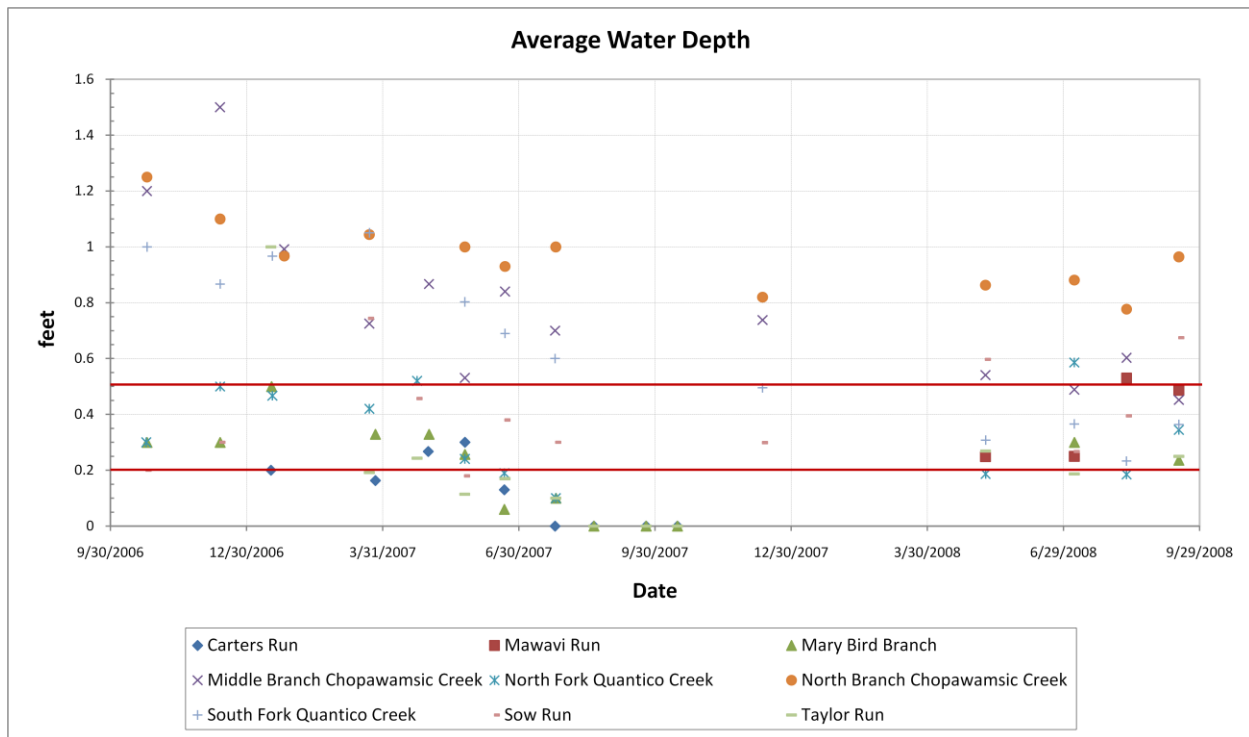


Figure 81: Water Depth (feet) in PRWI FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 33: Hydrology data for Carter's Run, January 2007 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
1/15/2007	*Not Reported	0.85	*Not Reported	4.833
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/26/2007	0.211	0.193	NORMAL	4.083
5/1/2007	0.584	0.683	NORMAL	3.167
5/25/2007	0.347	0.505	NORMAL	2.333
6/21/2007	*Not Reported	*Not Reported	NORMAL	3.5
7/25/2007	0	0	DRY	0
8/20/2007	0	0	DRY	0
9/24/2007	0	0	DRY	0
10/15/2007	0	0	DRY	0
11/13/2007	*Not Reported	*Not Reported	LOW	2.0
12/11/2007	*Not Reported	*Not Reported	LOW	3.5
1/16/2008	*Not Reported	*Not Reported	LOW	2.083
3/17/2008	*Not Reported	*Not Reported	LOW	2
4/16/2008	*Not Reported	*Not Reported	LOW	*Not Reported
5/8/2008	*Not Reported	*Not Reported	LOW	4.85
6/11/2008	*Not Reported	*Not Reported	LOW	4.04
7/7/2008	0.11	0.125	LOW	3.06
8/11/2008	*Not Reported	*Not Reported	LOW	1.5
9/15/2008	*Not Reported	*Not Reported	NORMAL	3.67

Table 34: Hydrology data for Mary Bird Branch, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	LOW	*Not Reported
7/14/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/18/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/15/2005	*Not Reported	0.11	LOW	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	9.0
2/2/2006	*Not Reported	*Not Reported	LOW	5.8
3/2/2006	0.750	0.24	LOW	6.25
3/27/2006	*Not Reported	0.1	LOW	6.0
4/26/2006	0.629	0.15	LOW	*Not Reported
5/30/2006	0.203	0.14	LOW	4.83
7/10/2006	0.951	0.31	LOW	7.67
7/27/2006	0.235	0.08	LOW	7.33
8/22/2006	*Not Reported	0	DRY	0
9/27/2006	0.037	0.07	LOW	6.16
10/24/2006	1.665	0.6	ABOVE NORMAL	9.25
12/12/2006	3.300	1.5	ABOVE NORMAL	7.33
1/16/2007	1.594	0.45	NORMAL	7.083
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/26/2007	1.313	0.483	NORMAL	7.917
5/1/2007	1.179	0.444	NORMAL	7.417
5/25/2007	0.268	0.106	LOW	6.5
6/21/2007	*Not Reported	*Not Reported	NORMAL	6.917
7/25/2007	*Not Reported	*Not Reported	LOW	3.250
8/20/2007	0	0	NO FLOW	0
9/24/2007	0	0	NO FLOW	0
10/15/2007	0	0	NO FLOW	0
11/13/2007	*Not Reported	*Not Reported	LOW	7.917
12/11/2007	*Not Reported	*Not Reported	LOW	7.417
1/16/2008	*Not Reported	*Not Reported	LOW	6.417
3/17/2008	*Not Reported	*Not Reported	LOW	5.833
4/16/2008	*Not Reported	*Not Reported	LOW	7.07
5/8/2008	*Not Reported	*Not Reported	LOW	7
6/11/2008	*Not Reported	*Not Reported	LOW	6.1
7/7/2008	0.29	0.192	LOW	5.06
8/11/2008	*Not Reported	*Not Reported	LOW	4.92
9/15/2008	0.461	0.372	LOW	5.21

Table 35: Hydrology data for Mawavi Run, April 2008 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
4/16/2008	0	*Not Reported	LOW	4.25
5/8/2008	0.1	0.086	NORMAL	4.42
6/11/2008	*Not Reported	*Not Reported	NORMAL	4.06
7/7/2008	0.21	0.168	NORMAL	4
8/11/2008	0.03	0.011	NORMAL	5
9/15/2008	0.039	0.017	NORMAL	4.83

Table 36: Hydrology data for Middle Branch Chopawamsik Creek June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	LOW	*Not Reported
7/14/2005	*Not Reported	*Not Reported	NO ACCESS	*Not Reported
8/16/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/18/2005	*Not Reported	0.38	NORMAL	*Not Reported
11/15/2005	*Not Reported	0.4	NORMAL	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	18.67
2/2/2006	*Not Reported	0.29	LOW	19.4
3/2/2006	*Not Reported	0.78	ABOVE NORMAL	21.2
3/27/2006	*Not Reported	0.11	LOW	13.54
4/26/2006	4.706	0.17	NORMAL	21.2
5/24/2006	*Not Reported	0.7	ABOVE NORMAL	*Not Reported
7/10/2006	2.162	0.28	LOW	11.5
7/27/2006	0.214	0.01	LOW	17.83
8/22/2006	*Not Reported	0	NO FLOW	*Not Reported
9/27/2006	1.929	0.13	LOW	11.42
10/24/2006	0.702	0.06	LOW	9.75
12/12/2006	4.541	0.21	NORMAL	14.42
1/24/2007	4.796	0.278	NORMAL	13.833
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/22/2007	5.045	0.347	NORMAL	15.833
5/1/2007	2.995	0.183	LOW	14.583
5/25/2007	1.272	0.128	LOW	14.25
6/21/2007	*Not Reported	*Not Reported	LOW	11.5
7/25/2007	*Not Reported	*Not Reported	LOW	9.583
8/20/2007	*Not Reported	*Not Reported	LOW	10.833
9/24/2007	*Not Reported	*Not Reported	LOW	9.583
10/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/13/2007	*Not Reported	*Not Reported	LOW	12.833
12/11/2007	0.954	.086	LOW	15.000
1/16/2008	*Not Reported	*Not Reported	LOW	14.833
3/17/2008	*Not Reported	*Not Reported	NO ACCESS	*Not Reported
4/16/2008	*Not Reported	*Not Reported	LOW	15
5/8/2008	1.34	0.124	LOW	20.25
6/11/2008	*Not Reported	*Not Reported	NORMAL	15.07
7/7/2008	6.76	0.462	NORMAL	29.92
8/11/2008	0.89	0.087	LOW	17.5
9/15/2008	2.43	0.195	LOW	28.25

Table 37: Hydrology data for North Branch Chopawamsik Creek June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	LOW	*Not Reported
7/14/2005	*Not Reported	*Not Reported	NO ACCESS	*Not Reported
8/16/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/18/2005	*Not Reported	0.1	LOW	*Not Reported
11/15/2005	*Not Reported	0.27	NORMAL	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	10.17
2/2/2006	8.918	0.44	NORMAL	10.7
3/2/2006	10.213	0.5	ABOVE NORMAL	10.75
3/27/2006	*Not Reported	0.21	NORMAL	8.4
4/26/2006	4.905	0.34	NORMAL	*Not Reported
5/24/2006	0.312	0.03	LOW	8.0
7/10/2006	2.262	0.24	NORMAL	7.25
7/27/2006	1.631	0.25	NORMAL	7.25
8/22/2006	*Not Reported	0	NO FLOW	*Not Reported
9/27/2006	0.954	0.06	LOW	9.1
10/24/2006	0.427	0.03	LOW	13.33
12/12/2006	4.400	0.4	NORMAL	10.0
1/24/2007	6.097	0.516	NORMAL	9.417
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/22/2007	5.376	0.467	NORMAL	9.417
5/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
5/25/2007	1.955	0.216	NORMAL	7.167
6/21/2007	*Not Reported	*Not Reported	LOW	7.167
7/25/2007	*Not Reported	*Not Reported	LOW	6.833
8/20/2007	*Not Reported	*Not Reported	LOW	6.667
9/24/2007	*Not Reported	*Not Reported	LOW	7.667
10/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/13/2007	*Not Reported	*Not Reported	LOW	6.667
12/11/2007	1.9	0.357	NORMAL	6.5
1/16/2008	*Not Reported	*Not Reported	LOW	7.25
3/17/2008	*Not Reported	*Not Reported	NO ACCESS	*Not Reported
4/16/2008	*Not Reported	*Not Reported	LOW	8.03
5/8/2008	1.37	0.199	NORMAL	8
6/11/2008	*Not Reported	*Not Reported	NORMAL	10.07
7/7/2008	4.13	0.361	NORMAL	13
8/11/2008	0.55	0.066	LOW	10.83
9/15/2008	1.14	0.152	LOW	7.83

Table 38: Hydrology data for North Fork Quantico Creek, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	LOW	*Not Reported
7/14/2005	*Not Reported	*Not Reported	LOW	*Not Reported
8/16/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/18/2005	*Not Reported	0.63	LOW	*Not Reported
11/15/2005	*Not Reported	1.25	NORMAL	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
2/2/2006	13.078	1.37	NORMAL	17.8
3/2/2006	7.317	0.83	NORMAL	18.7
3/27/2006	*Not Reported	0.34	LOW	16.33
4/26/2006	5.990	0.71	NORMAL	*Not Reported
5/24/2006	0.997	0.22	LOW	15.42
7/10/2006	6.179	0.73	NORMAL	19.25
7/27/2006	3.491	0.28	LOW	15.83
8/22/2006	*Not Reported	0.14	LOW	*Not Reported
9/27/2006	6.533	1.12	NORMAL	14.58
10/24/2006	0.970	0.2	LOW	16.2
12/12/2006	14.712	1.65	NORMAL	17.83
1/16/2007	11.333	0.917	NORMAL	20.0
2/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
3/22/2007	13.632	1.128	NORMAL	20
4/23/2007	11.465	0.889	NORMAL	20.417
5/25/2007	3.857	0.628	LOW	16.5
6/21/2007	*Not Reported	*Not Reported	NORMAL	17.333
7/25/2007	*Not Reported	*Not Reported	LOW	8.083
8/20/2007	*Not Reported	*Not Reported	LOW	6.833
9/24/2007	*Not Reported	*Not Reported	LOW	9.000
10/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/13/2007	*Not Reported	*Not Reported	LOW	16.917
12/11/2007	*Not Reported	*Not Reported	NORMAL	17.333
1/16/2008	*Not Reported	*Not Reported	LOW	9.917
3/17/2008	*Not Reported	*Not Reported	NORMAL	19.167
4/16/2008	*Not Reported	*Not Reported	NORMAL	19.07
5/8/2008	3.37	1.050	LOW	7.5
6/11/2008	*Not Reported	*Not Reported	NORMAL	19.04
7/7/2008	3.87	0.461	LOW	14.167
8/11/2008	*Not Reported	0.483	LOW	14.33
9/15/2008	1.57	0.657	LOW	23.08

Table 39: Hydrology data for South Fork Quantico Creek, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
7/14/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
8/16/2005	*Not Reported	*Not Reported	NO ACCESS	*Not Reported
10/18/2005	*Not Reported	1.59	NORMAL	*Not Reported
11/15/2005	*Not Reported	1.24	NORMAL	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	37.67
2/2/2006	*Not Reported	*Not Reported	NORMAL	*Not Reported
3/2/2006	70.388	2.00	ABOVE NORMAL	38.6
3/27/2006	*Not Reported	0.56	LOW	38.0
4/26/2006	19.304	0.83	NORMAL	*Not Reported
5/24/2006	3.679	0.31	LOW	25.66
7/10/2006	11.245	0.28	LOW	35.25
7/27/2006	5.993	0.16	LOW	35.25
8/22/2006	*Not Reported	0.13	LOW	*Not Reported
9/28/2006	4.360	0.099	LOW	36.3
10/24/2006	3.867	0.09	LOW	38.42
12/12/2006	10.265	0.27	LOW	37.83
1/16/2007	19.428	0.503	NORMAL	36.0
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/22/2007	20.273	0.463	NORMAL	36.583
4/23/2007	*Not Reported	*Not Reported	NORMAL	37.333
5/25/2007	3.163	0.084	LOW	37
6/21/2007	*Not Reported	*Not Reported	LOW	36.167
7/25/2007	*Not Reported	*Not Reported	LOW	33.250
8/20/2007	*Not Reported	*Not Reported	LOW	35.250
9/24/2007	*Not Reported	*Not Reported	LOW	33.000
10/15/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/13/2007	*Not Reported	*Not Reported	LOW	34.833
12/11/2007	2.687	0.151	LOW	36.0
1/16/2008	*Not Reported	*Not Reported	NORMAL	32.833
3/17/2008	*Not Reported	*Not Reported	LOW	31.5
4/16/2008	*Not Reported	*Not Reported	LOW	29.333
5/8/2008	9.637	0.929	LOW	17.5
6/11/2008	*Not Reported	*Not Reported	LOW	41.06
7/7/2008	16.24	1.073	NORMAL	41.4
8/11/2008	6.36	0.639	LOW	42.67
9/15/2008	11.41	0.829	LOW	38.17

Table 40: Hydrology data for Sow Run, June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/13/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
7/14/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
8/16/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
10/18/2005	*Not Reported	0.73	NORMAL	*Not Reported
11/15/2005	*Not Reported	1.24	NORMAL	*Not Reported
12/20/2005	*Not Reported	*Not Reported	ABOVE NORMAL	4.42
2/2/2006	1.730	1.73	NORMAL	5
3/2/2006	0.868	2.24	ABOVE NORMAL	5.17
3/27/2006	0.860	0.77	NORMAL	6.0
4/26/2006	2.742	0.81	NORMAL	*Not Reported
5/30/2006	0.463	0.36	NORMAL	5.0
7/10/2006	0.710	0.31	NORMAL	4.58
7/27/2006	0.486	0.13	NORMAL	6.0
8/22/2006	*Not Reported	0.03	LOW	*Not Reported
9/27/2006	1.450	0.2	NORMAL	7.25
10/24/2006	1.181	1.09	NORMAL	5.42
12/12/2006	1.701	0.83	NORMAL	6.83
1/15/2007	3.655	0.51	NORMAL	11.17
2/15/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
3/22/2007	1.277	0.122	NORMAL	9.25
4/23/2007	1.491	0.383	NORMAL	7.167
5/25/2007	0.551	0.410	NORMAL	4.75
6/21/2007	*Not Reported	*Not Reported	LOW	5.833
7/25/2007	*Not Reported	*Not Reported	LOW	3.667
8/20/2007	*Not Reported	*Not Reported	LOW	2.167
9/24/2007	*Not Reported	*Not Reported	LOW	3.083
10/15/2007	0	0	DRY	0
11/13/2007	*Not Reported	*Not Reported	LOW	4.333
12/11/2007	0.247	0.183	LOW	4.5
1/16/2008	*Not Reported	*Not Reported	LOW	2.167
3/17/2008	*Not Reported	*Not Reported	LOW	4.25
4/16/2008	*Not Reported	*Not Reported	NORMAL	9.04
5/8/2008	0.98	0.300	NORMAL	5.5
6/11/2008	*Not Reported	*Not Reported	LOW	1.07
7/7/2008	1.65	1.030	NORMAL	6.0
8/11/2008	0.32	0.199	NORMAL	4.17
9/15/2008	1.32	0.244	NORMAL	8

Table 41: Hydrology data for Taylor Run, January 2007 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
1/15/2007	1.097	0.14	NORMAL	7.833
2/15/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/22/2007	0.649	0.452	NORMAL	6.917
4/23/2007	1.091	0.584	NORMAL	7.167
5/25/2007	0.226	0.190	LOW	6.750
6/21/2007	*Not Reported	*Not Reported	LOW	6.833
7/25/2007	*Not Reported	*Not Reported	LOW	5.167
8/20/2007	0	0	INTERSTITIAL	0
9/24/2007	0	0	DRY	0
10/15/2007	0	0	DRY	0
11/13/2007	*Not Reported	*Not Reported	LOW	4.5
12/11/2007	*Not Reported	*Not Reported	NORMAL	7.583
1/16/2008	*Not Reported	*Not Reported	NORMAL	5.750
3/17/2008	*Not Reported	*Not Reported	NORMAL	*Not Reported
4/16/2008	*Not Reported	*Not Reported	LOW	5.05
5/8/2008	0.18	0.113	LOW	5.75
6/11/2008	*Not Reported	*Not Reported	NORMAL	5.04
7/7/2008	0.318	0.424	LOW	4
8/11/2008	*Not Reported	*Not Reported	LOW	5.83
9/15/2008	0.29	0.261	LOW	4

Rock Creek Park (ROCR)

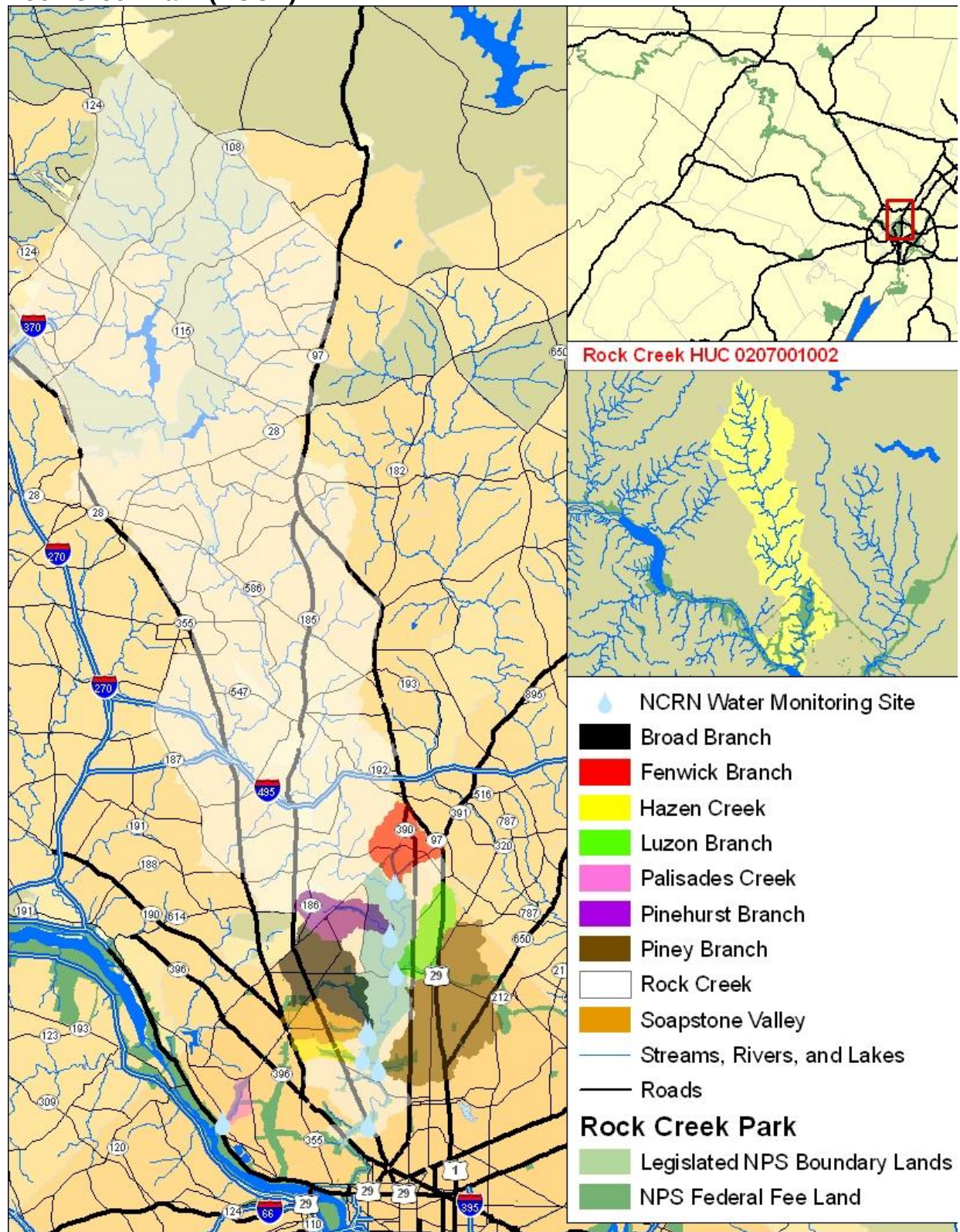


Figure 82: Relationship of ROCR stream monitoring sites to their watersheds and the park boundary

Rock Creek originates near Laytonsville, in Montgomery County, MD (Figure 82). Approximately 10 miles of its total length of 33 miles are located within the District of Columbia. Rock Creek becomes a fourth-order stream at the confluence of Rock Creek with the North Branch of Rock Creek, north of Rockville, Maryland. It remains a fourth-order stream for the remainder of its length. Except for the narrow extension of parkland into Maryland that is under Montgomery County administration, Rock Creek Park represents a largely isolated natural system surrounded by urban areas, which have significantly impacted the park. These effects include flooding and pollution in park streams, introductions of invasive non-native species into natural areas, extirpations or reductions of sensitive native species, and the artificial inflation of a few native species' populations adversely that affect other native plants and wildlife.

This report discusses data collected October 2006 through September 2008 for Broad Branch (BRBR), Rock Creek at Edgewater Stables (EGWA), Fenwick Branch (FEBR), Hazen Creek (HACR), Luzon Branch (LUBR), Palisades (Battery Kemble) Creek (PACR), Pinehurst Branch (PHBR), Piney Branch (PYBR), Rock Creek above Fenwick Branch (ROCR), and Soapstone Valley Stream (SVPS). Summary statistics for the time period are shown in Table 42.

Table 42: Date range, number of site visit (N), and data range for the information covered in this report for ROCR.

Local Name	Units	Period of Record	N	Minimum	Maximum	Mean	Median	Standard Deviation
Air Temperature	°C	10/10/2006 - 9/4/2007	88	-2	31	17	20	9
ANC	µeq/L	10/10/2006 - 9/4/2007	93	760	3224	1655	1624	483
DO	mg/l	10/10/2006 - 9/4/2007	93	3.19	15.12	8.67	8.59	2.74
Nitrate	mg/l	10/10/2006 - 9/4/2007	85	0.3	13.5	2.5	2.0	1.9
Ammonia	mg/l	10/10/2006 - 9/4/2007	57	0.01	13.50	0.38	0.08	1.78
pH	None	10/10/2006 - 9/4/2007	85	7.03	8.76	7.84	7.86	0.41
Phosphate	mg/l	10/10/2006 - 9/4/2007	93	0.08	1.85	0.65	0.53	0.44
Salinity	ppt	10/10/2006 - 9/4/2007	92	0.1	0.6	0.3	0.3	0.1
Specific conductance	µS/cm	10/10/2006 - 9/4/2007	93	209.5	1451.0	638.0	64.04	211.5
Water Temperature	°C	10/10/2006 - 9/4/2007	93	0.1	25.2	13.0	14.3	7.3

DO values were below the desired level of 5mg/L at all sites in spring and summer 2006, only Fenwick Branch, Rock Creek, and Pinehurst Branch had low readings in spring and summer 2007 (Figure 86). There is no seasonal pattern to nitrate, and all sites are frequently above the desired level of 2.0 mg/L nitrate (Figure 83). Ammonia is a problematic parameter. We frequently get readings below zero and with the EDL of 0.032 routine low readings result in much of the data being excluded from the analysis (36 of 93 readings in the case of ROCR FY2007-2008) (Figure 85). Phosphorus is consistently above the desired range of 0.1 mg/L at all sites (Figure 84). Ironically, Piney Branch, which is known as a CSO combined sewer overflow, meets phosphorus threshold 10% of the time. None of the other streams ever meet the phosphorus threshold.

pH was within desired range (Figure 89). Specific conductance is usually above the current threshold of 400 µS for all sites (Figure 87). ANC is well above the 200 µeq/L threshold for non-karst waters indicating the streams are well-buffered (Figure 88). Water temperature

follows expected seasonal trends and is within the comfort range of sensitive species, except in summer 2006 (Figure 90).

Rock Creek above Fenwick Branch was almost always too deep to wade and was determined to be unsampleable for macroinvertebrates by Versar. Therefore it was dropped in 2009.

Fenwick Branch did not dry out during the 2007 drought. Based on the data collected so far, normal water levels for Fenwick Branch can be defined as discharge between 0.49 cfs and 3.61 cfs, with a flow of 0.02 f/s or higher in a channel with a wetted width of 10 or more feet. Low is less than 0.41 cfs discharge and flow less than 0.44 f/s. A flow of 1 ft/s or greater is above normal (Table 43).

Pinehurst Branch went dry in October and November 2007 and January 2008 during the drought, and lacked flow in July 2006. Based on the data collected so far, normal water levels for Pinehurst Branch can be defined as discharge between 0.5 cfs and 0.7 cfs, with a flow of 0.1 f/s or higher in a channel with a wetted width of 16 or more feet. Low is less than 0.4 cfs discharge and flow less than 0.1 f/s. Above normal is 1.4 or greater cfs (Table 44).

Luzon Branch did dry out in December 2007. Based on the data collected so far, normal water levels for Luzon Branch can be defined as discharge between 2.1 cfs and 5.6 cfs, with a flow of 0.1 f/s or higher in a channel with a wetted width of 10 or more feet. Low is less than 1.2 cfs discharge and flow less than 0.15 f/s. Above normal is 8 or greater cfs (Table 45).

Soapstone Valley Stream did not dry out during the 2007 drought. The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for Soapstone Valley Stream can be defined as discharge between 0.5 cfs and 1.8 cfs, with a flow of 0.03 f/s or higher in a channel with a wetted width of 6.5 or more feet. Low is less than 0.5 cfs discharge and flow less than 0.03 f/s. Above normal is 1.87 or greater cfs (Table 46).

Broad Branch did not dry out during the 2007 drought, though it did dry out in May 2008. The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for Broad Branch can be defined as discharge between 4 cfs and 7 cfs, with a flow of 0.3 f/s or higher in a channel with a wetted width of 18 or more feet. Low is less than 3 cfs discharge and flow less than 0.6 f/s. Above normal flow conditions were not observed at the site (Table 47).

Hazen Creek dried out in June 2005 and October 2007. Based on the data collected so far, normal water levels for Hazen Creek can be defined as discharge between 1 cfs and 2 cfs, with a flow of 0.4 f/s or higher in a channel with a wetted width of 5 or more feet. Low is less than 1 cfs discharge. Above normal is 4 or greater cfs (Table 48).

Piney Branch did not dry out during the 2007 drought, though it lacked flow in September and October 2006. The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected

so far, normal water levels for Piney Branch can be defined as discharge between 1.6 cfs and 2 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 12 or more feet. Low is less than 0.9 cfs discharge and flow less than 0.1 f/s. Above normal is 2.4 or greater cfs (Table 49).

Rock Creek at Edgewater Stables did not dry out during the 2007 drought, though it lacked flow in June 2006. Based on the data collected so far, normal water levels for Rock Creek at Edgewater Stables can be defined as discharge between 28 cfs and 50 cfs, with a flow of 0.3 f/s or higher in a channel with a wetted width of 41 or more feet. Low is a flow less than 0.08 f/s. Above normal is 100 or greater cfs (Table 50).

When sites were added downstream at Normanstone and Dumbarton Oaks, the Rock Creek sites was moved below the last tributary monitored. The Rock Creek site currently monitored is ROC3 at Dumbarton Oaks.

Normanstone Branch did not dry out during the 2007 drought. Based on the data collected so far, normal water levels for Normanstone Branch can be defined as discharge between 0.05 cfs and 1.3 cfs, with a flow of 0.2 f/s or higher in a channel with a wetted width of 8 or more feet. Low is less than 0.5 cfs discharge and flow less than 0.2 f/s. Above normal flows have not been observed (Table 51).

Dumbarton Oaks Stream did not dry out during the 2007 drought. Based on the data collected so far, normal water levels for Dumbarton Oaks Stream can be defined as discharge between 0.6 cfs and 0.7cfs, with a flow of 0.6 f/s or higher in a channel with a wetted width of 5 or more feet. Low is less than 0.1 cfs discharge and flow less than 0.4 f/s. Above normal flows have not been observed at the site (Table 52).

Rock Creek at Dumbarton Oaks did not dry out during the 2007 drought, though it lacked flow in August 2006. The decreased precipitation and runoff and increase in percent groundwater in base flow in the stream may have contributed to the improvements. Based on the data collected so far, normal water levels for Soapstone Valley Stream can be defined as discharge between 22 cfs and 50 cfs, with a flow of 0.8 f/s or higher in a channel with a wetted width of 6.5 or more feet. Low is less than 25 cfs discharge and flow less than 1 f/s. It is not possible to cross the stream during above normal flows (Table 53)

Palisades Creek did not dry out during the 2007 drought, though it lacked flow in May 2006 (Table 54). The creek is difficult to measure for hydrology since it is rarely deep enough to accommodate the flowmeter. None of the streams maintain sufficient flow throughout the year to support deployment of continuous data loggers, except Rock Creek itself (Figure 91). Discharge measurements are haphazard at best throughout the year.

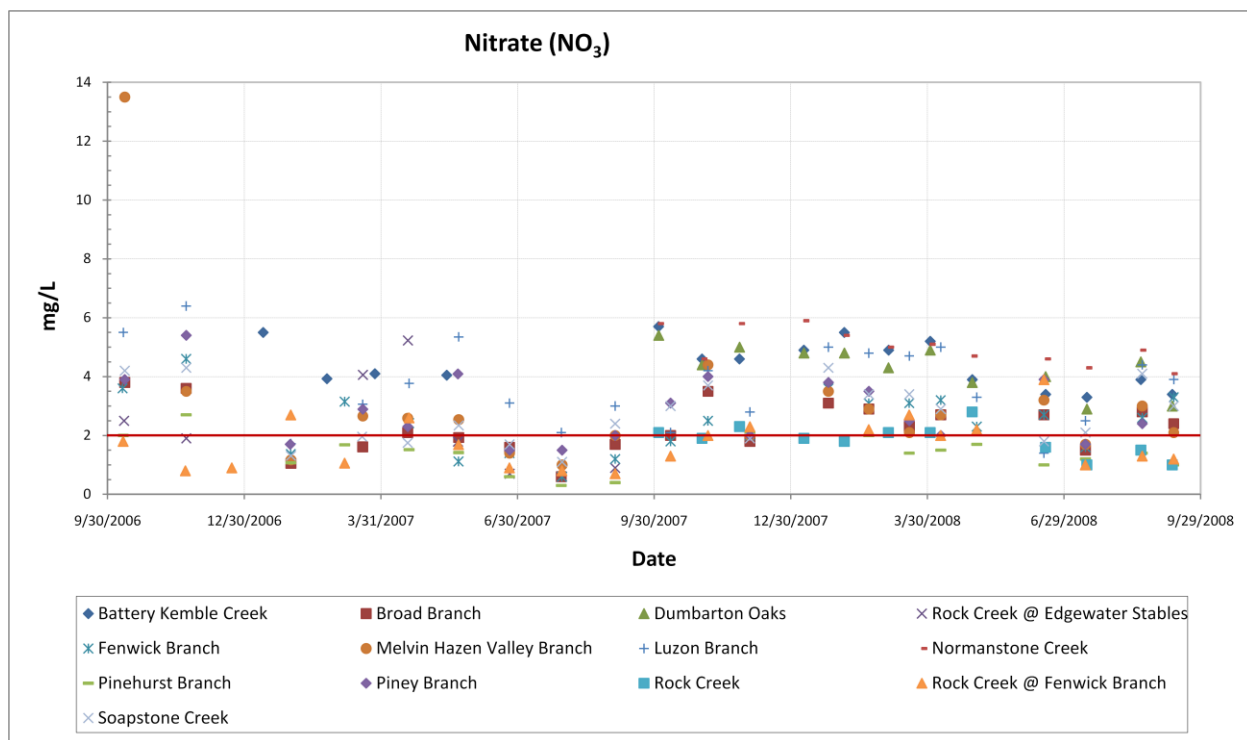


Figure 83: Nitrate in ROCR streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO_3 (red line).

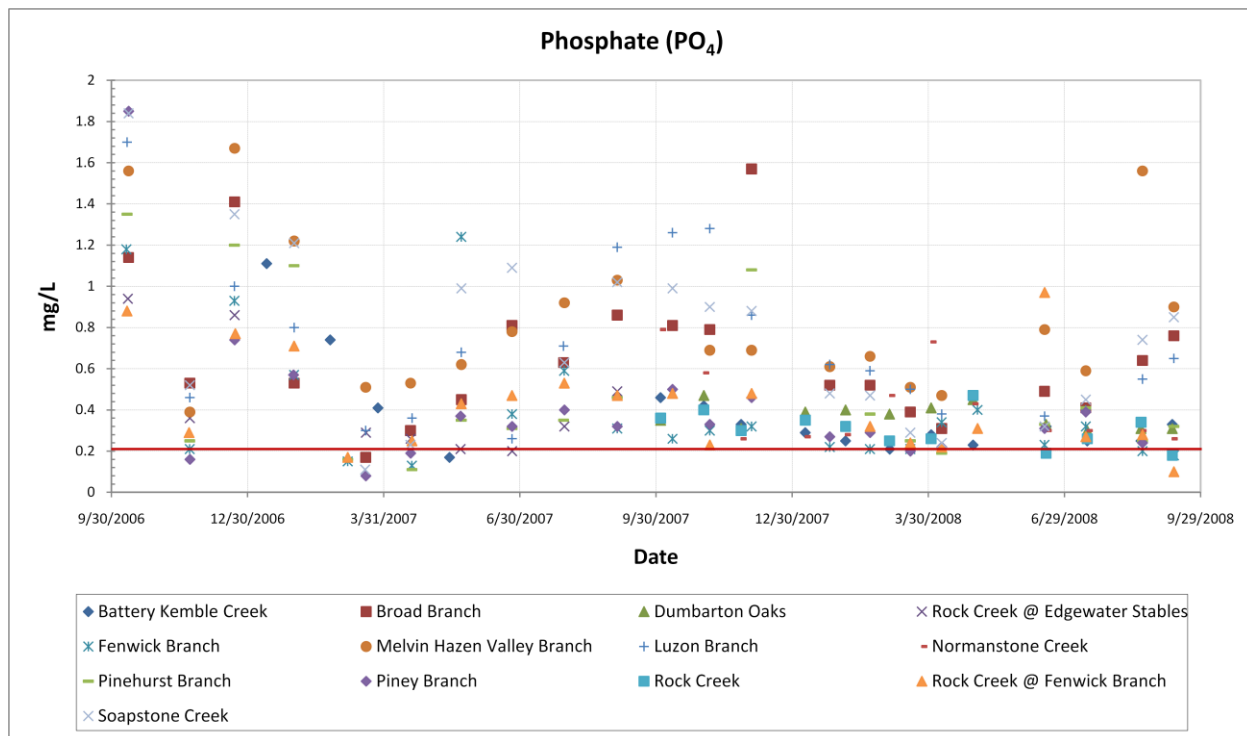


Figure 84: Phosphate in ROCR streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO_4 (red line).

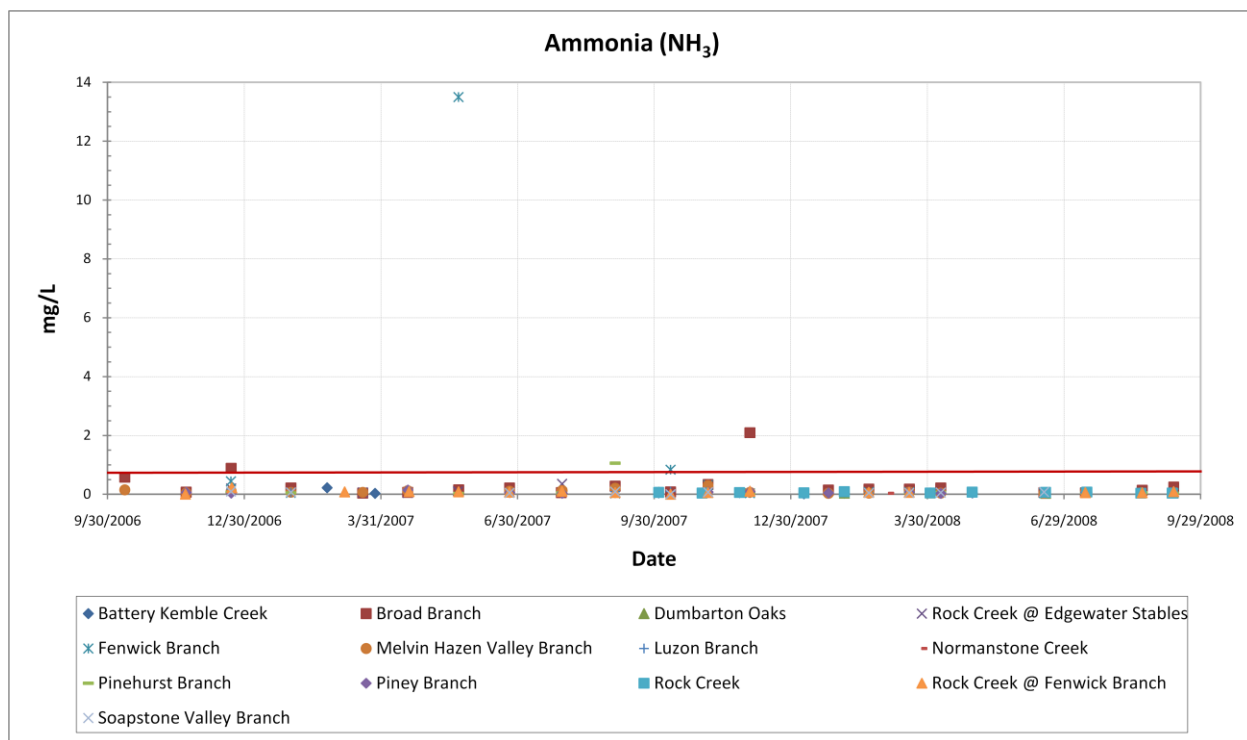


Figure 85: Ammonia in ROCR streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

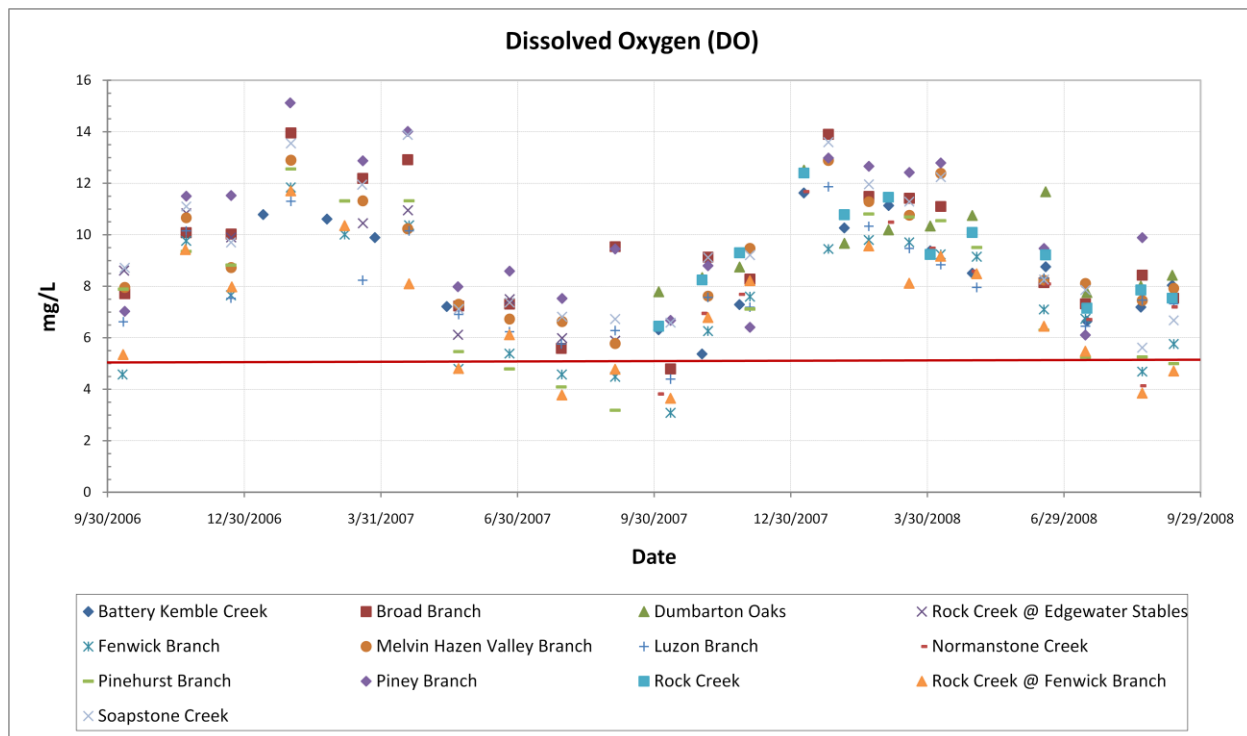


Figure 86: Dissolved oxygen in ROCR streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

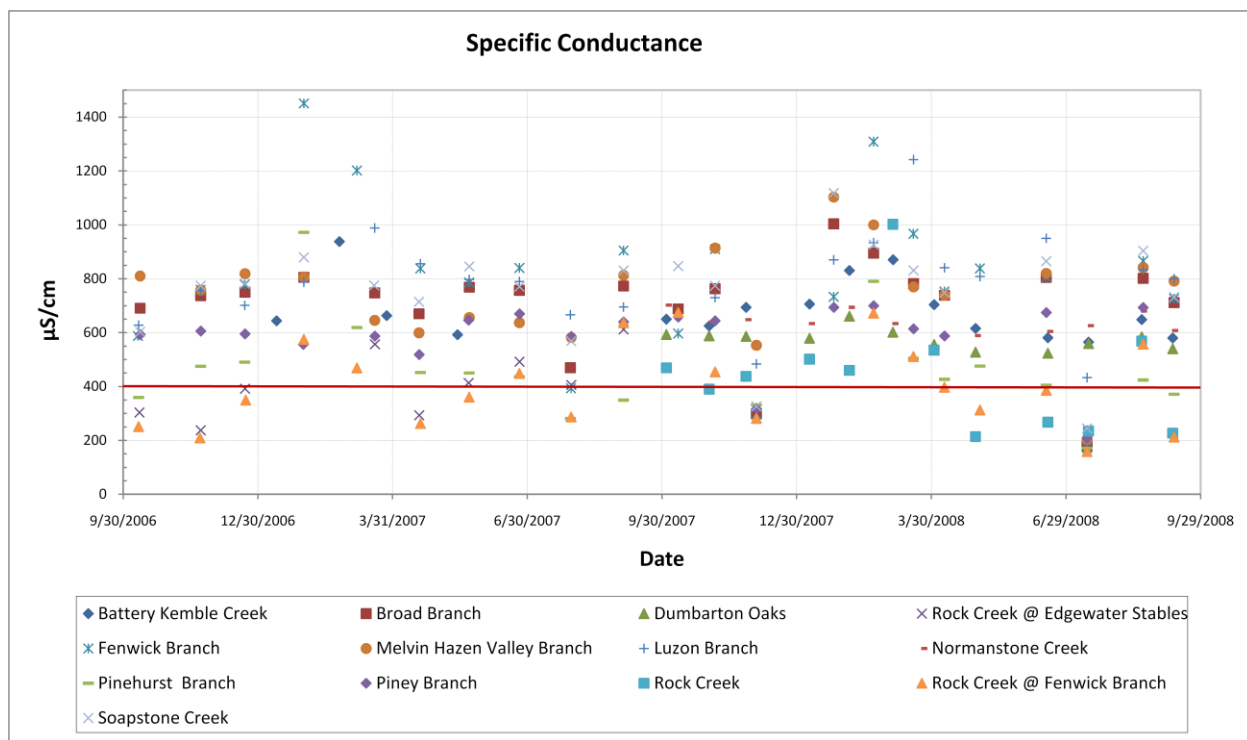


Figure 87: Specific Conductance in ROCR streams FY 2007-2008. Ideally, healthy waters would have less than 400 $\mu\text{S}/\text{cm}$ (red line).

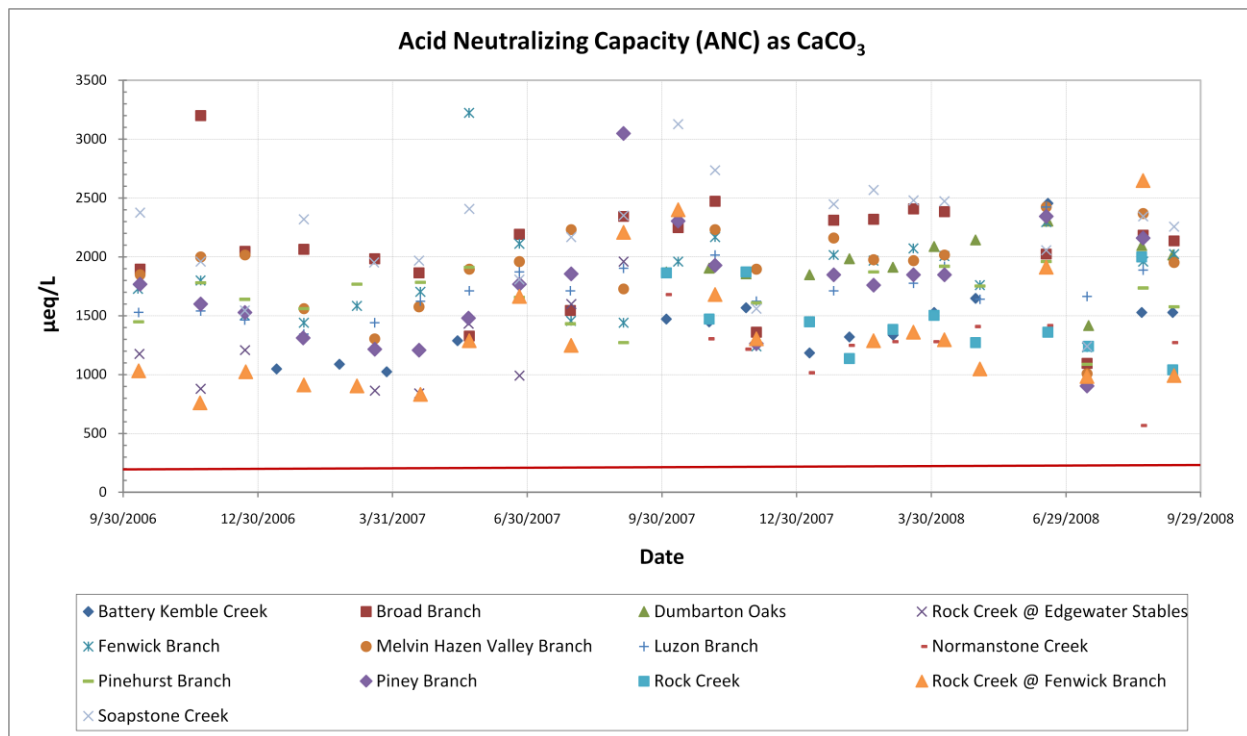


Figure 88: Acid Neutralizing Capacity in ROCR streams FY 2007-2008. Non-karst waters should have ANC above 200 $\mu\text{eq}/\text{L}$ (the red line on the graph).

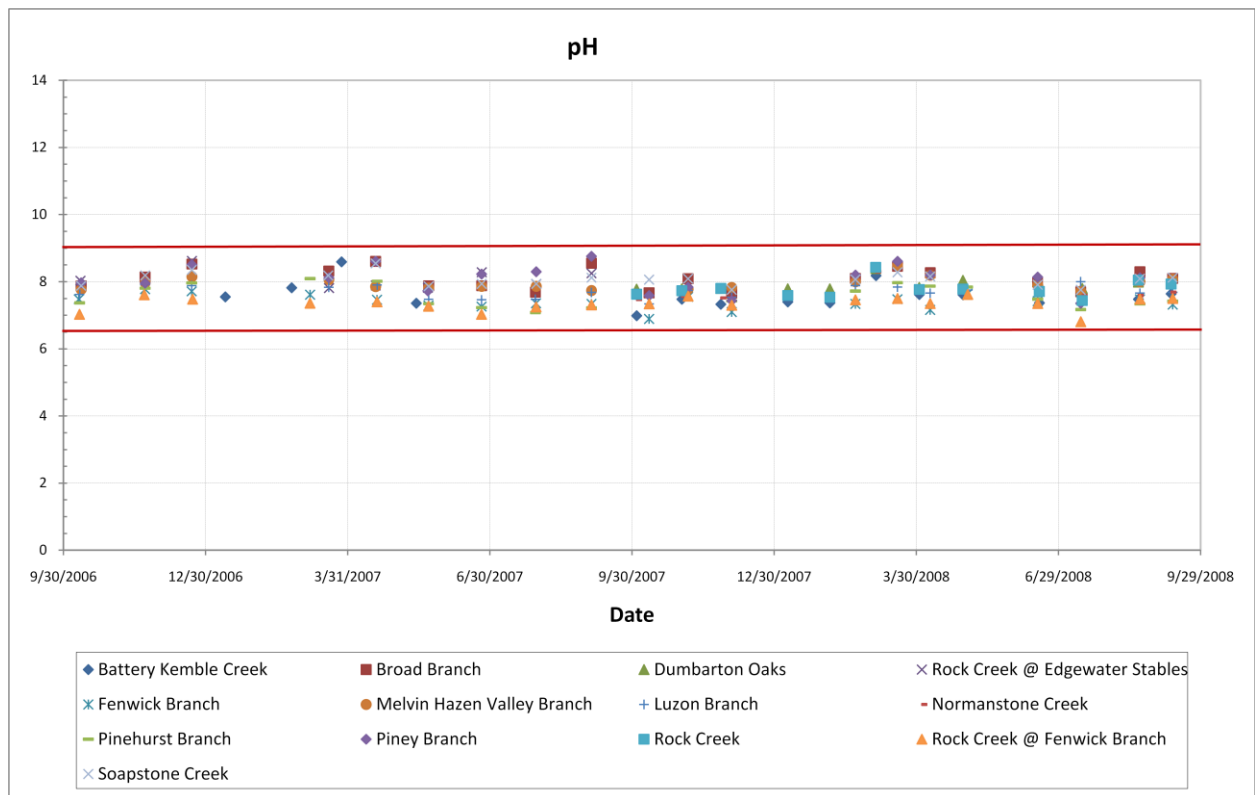


Figure 89: pH in ROCR streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

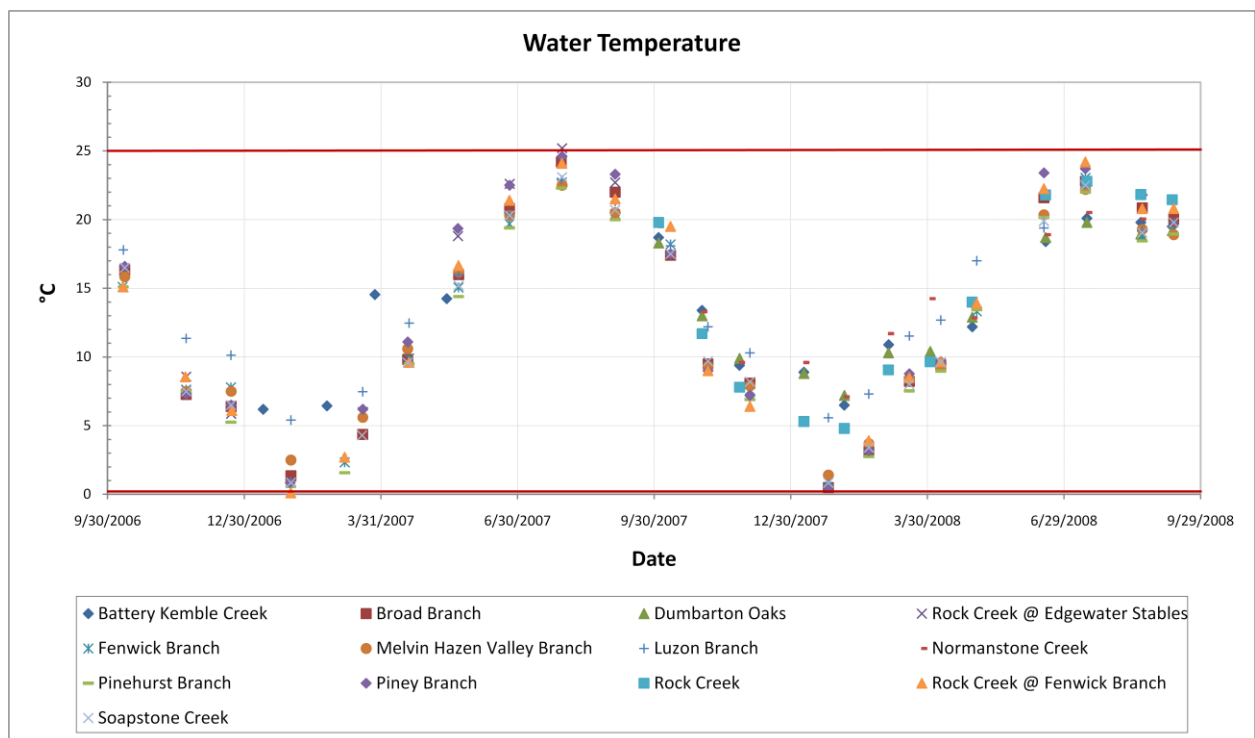


Figure 90: Water temperature in ROCR streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

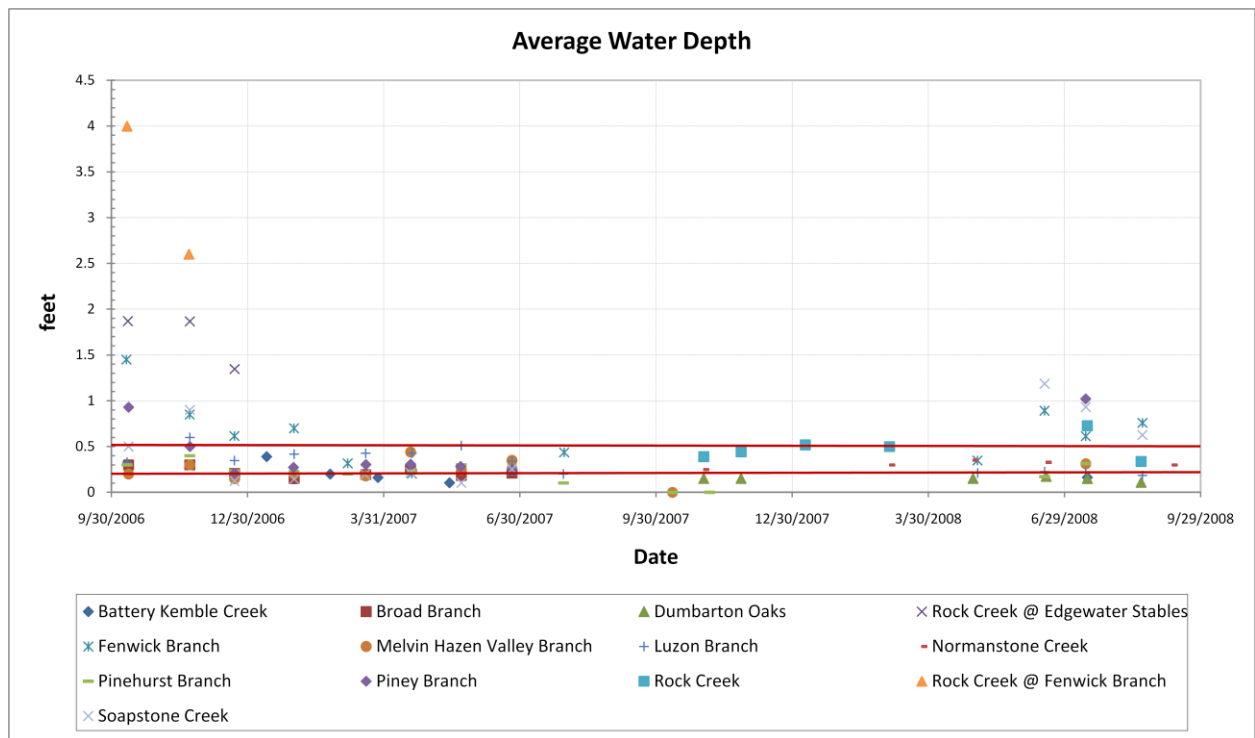


Figure 91: Water Depth (feet) in ROCR streams FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 43: Hydrology data for Fenwick Branch, Rock Creek Park June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	1.07	ABOVE NORMAL	*Not Reported
12/8/2005	*Not Reported	0.01	LOW	*Not Reported
1/3/2006	0.553	0.02	NORMAL	27.67
2/14/2006	0.415	0.03	LOW	25.9
3/8/2006	0.521	0.09	NORMAL	23.17
4/4/2006	0.389	0.44	LOW	24.8
5/4/2006	1.121	0.06	NORMAL	20.75
6/1/2006	0.586	0.0775	NORMAL	21.5
7/20/2006	*Not Reported	0.7	NORMAL	20.5
8/3/2006	0.686	0.11	NORMAL	15.58
9/11/2006	0.567	0.18	NORMAL	10.5
10/10/2006	0.6259	0.02	NORMAL	21.5833
11/21/2006	*Not Reported	0.035	LOW	*Not Reported
12/21/2006	0.491	0.124	NORMAL	13
1/30/2007	0.090	0.011	LOW	16
3/7/2007	0.506	0.031	NORMAL	30
4/19/2007	1.265	0.236	NORMAL	16.333
5/22/2007	*Not Reported	*Not Reported	LOW	*Not Reported
6/25/2007	*Not Reported	*Not Reported	LOW	30.667
7/30/2007	0.357	0.034	LOW	24.0
9/4/2007	*Not Reported	*Not Reported	LOW	15.667
10/11/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	3.9
2/20/2008	*Not Reported	*Not Reported	LOW	5.3
3/18/2008	*Not Reported	*Not Reported	LOW	4.333
4/8/2008	*Not Reported	*Not Reported	LOW	4
5/2/2008	1.24	0.187	NORMAL	18.08
6/16/2008	0.38	0.039	LOW	11
7/14/2008	3.61	0.332	NORMAL	17.75
8/21/2008	0.06	0 .007	LOW	11.42
9/11/2008	*Not Reported	*Not Reported	LOW	14

Table 44: Hydrology data for Pinehurst Branch, Rock Creek Park October 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	0.09	NORMAL	*Not Reported
12/8/2005	*Not Reported	0.1	NORMAL	*Not Reported
1/3/2006	0.512	0.04	NORMAL	20.92
2/14/2006	*Not Reported	0.47	NORMAL	17
3/8/2006	3.520	0.295	ABOVE NORMAL	18.33
4/4/2006	0.279	0.10	LOW	24.5
5/4/2006	0.527	0.11	NORMAL	18.83
6/1/2006	0.368	0.07	LOW	23.0
7/20/2006	*Not Reported	0.0	NO FLOW	17.3
8/3/2006	0.502	0.09	NORMAL	18.58
9/12/2006	0.598	0.1	NORMAL	3.58
10/10/2006	0.470	0.33	LOW	15.66
11/21/2006	0.889	0.115	NORMAL	19.33
12/21/2006	0.334	0.05	LOW	22.333
1/30/2007	0.068	0.015	LOW	23.167
3/7/2007	0.222	0.036	LOW	24
4/19/2007	1.464	0.231	ABOVE NORMAL	22.083
5/22/2007	0.174	0.059	LOW	20.333
6/25/2007	*Not Reported	*Not Reported	NORMAL	22.0
7/30/2007	0.152	0.379	LOW	13.417
9/4/2007	*Not Reported	*Not Reported	LOW	*Not Reported
10/11/2007	0	0	DRY	0
11/5/2007	0	0	DRY	0
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	DRY	*Not Reported
2/20/2008	*Not Reported	*Not Reported	LOW	20.8
3/18/2008	*Not Reported	*Not Reported	LOW	21.417
4/8/2008	*Not Reported	*Not Reported	LOW	21.02
5/2/2008	0.65	*Not Reported	NORMAL	22
6/16/2008	0.25	0.074	LOW	19
7/14/2008	0.73	0.101	NORMAL	23
8/21/2008	*Not Reported	*Not Reported	LOW	21.08
9/11/2008	*Not Reported	*Not Reported	LOW	16.92

Table 45: Hydrology data for Luzon Branch, Rock Creek Park June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	1.08	NORMAL	*Not Reported
12/8/2005	*Not Reported	*Not Reported	LOW	*Not Reported
1/3/2006	1.761	0.18	LOW	23.58
2/14/2006	0.489	0.115	LOW	21.25
3/8/2006	1.878	0.25	LOW	21.4
4/4/2006	0.322	0.03	LOW	15.33
5/4/2006	4.546	0.50	NORMAL	14.5
6/1/2006	2.148	0.19	NORMAL	16.92
7/20/2006	5.588	0.75	NORMAL	12.4
8/3/2006	8.098	1.23	ABOVE NORMAL	13.16
9/12/2006	1.239	0.16	LOW	11.9
10/10/2006	3.940	0.11	NORMAL	20.58
11/21/2006	1.008	0.14	LOW	12.0
12/21/2006	0.421	0.074	LOW	13.417
1/30/2007	0.103	0.017	LOW	11.583
3/19/2007	*Not Reported	*Not Reported	LOW	15.083
4/19/2007	0.532	0.060	LOW	12.833
5/22/2007	0.400	0.077	LOW	10.417
6/25/2007	*Not Reported	*Not Reported	LOW	14.0
7/30/2007	0.975	0.487	LOW	14.0
9/4/2007	*Not Reported	*Not Reported	LOW	13.167
10/11/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	DRY	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	13.5
2/20/2008	*Not Reported	*Not Reported	LOW	13.4
3/18/2008	*Not Reported	*Not Reported	LOW	18.5
4/8/2008	*Not Reported	*Not Reported	LOW	14
5/2/2008	1.36	0.404	LOW	16.02
6/16/2008	0.62	0.692	LOW	14.07
7/14/2008	1.99	0.582	LOW	15.42
8/21/2008	*Not Reported	0.185	NORMAL	12.25
9/11/2008	*Not Reported	*Not Reported	LOW	13.83

Table 46: Hydrology data for Soapstone Valley Stream, Rock Creek Park November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/3/2005	*Not Reported	1	ABOVE NORMAL	*Not Reported
12/8/2005	*Not Reported	*Not Reported	LOW	*Not Reported
1/3/2006	1.817	0.14	NORMAL	19.5
2/14/2006	4.730	0.78	ABOVE NORMAL	19.7
3/8/2006	3.587	1.02	ABOVE NORMAL	17.6
4/4/2006	0.517	0.15	NORMAL	16.5
5/4/2006	*Not Reported	0.82	ABOVE NORMAL	*Not Reported
6/1/2006	2.296	0.41	ABOVE NORMAL	18.66
7/20/2006	*Not Reported	0.29	NORMAL	17.1
8/3/2006	2.089	0.21	ABOVE NORMAL	16.58
9/12/2006	0.300	0.05	LOW	8.58
10/11/2006	2.798	0.462	ABOVE NORMAL	12.16
11/21/2006	0.566	0.05	NORMAL	12.58
12/21/2006	0.759	0.297	NORMAL	12.917
1/30/2007	0.190	0.089	LOW	11.083
3/19/2007	2.000	0.651	ABOVE NORMAL	12.167
4/18/2007	1.876	0.578	ABOVE NORMAL	12.75
5/22/2007	0.595	0.252	NORMAL	10.417
6/25/2007	*Not Reported	*Not Reported	LOW	10.417
7/30/2007	*Not Reported	*Not Reported	LOW	10.250
9/4/2007	*Not Reported	*Not Reported	LOW	9.083
10/11/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	9.5
2/20/2008	*Not Reported	*Not Reported	LOW	11.8
3/18/2008	*Not Reported	*Not Reported	LOW	10.917
4/8/2008	*Not Reported	*Not Reported	LOW	9.07
6/16/2008	0.62	0.045	LOW	11.08
7/14/2008	0.78	.076	NORMAL	11
8/21/2008	0.32	0.034	LOW	16.08
9/11/2008	*Not Reported	*Not Reported	LOW	12.92

Table 47: Hydrology data for Broad Branch, Rock Creek Park June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	0.52	LOW	*Not Reported
12/8/2005	*Not Reported	0.42	LOW	*Not Reported
1/3/2006	1.049	0.21	LOW	28.75
2/14/2006	2.752	0.35	LOW	27.25
3/8/2006	6.280	0.69	NORMAL	28.5
4/4/2006	0.991	0.16	LOW	24.75
5/4/2006	6.917	0.835	NORMAL	27.67
6/1/2006	0.986	0.18	LOW	21.66
7/20/2006	1.020	0.2	LOW	17.0
8/3/2006	5.530	1.01	NORMAL	18.25
9/12/2006	0.936	0.18	LOW	17.33
10/11/2006	1.260	0.59	LOW	23.33
11/21/2006	7.008	0.65	NORMAL	32
12/21/2006	1.594	0.112	LOW	30
1/30/2007	0.564	0.057	LOW	30.25
3/19/2007	2.988	0.352	LOW	31
4/18/2007	4.031	0.384	NORMAL	31.667
5/22/2007	1.066	0.216	LOW	18.667
6/25/2007	*Not Reported	*Not Reported	LOW	18.250
7/30/2007	*Not Reported	*Not Reported	LOW	30.750
9/4/2007	*Not Reported	*Not Reported	LOW	15.667
10/11/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	17.1
2/20/2008	*Not Reported	*Not Reported	LOW	19.1
3/18/2008	*Not Reported	*Not Reported	LOW	23.083
4/8/2008	*Not Reported	*Not Reported	LOW	19.11
5/2/2008	*Not Reported	*Not Reported	DRY	*Not Reported
6/16/2008	*Not Reported	*Not Reported	LOW	19.07
7/14/2008	*Not Reported	*Not Reported	LOW	19
8/21/2008	*Not Reported	*Not Reported	LOW	18.83
9/11/2008	*Not Reported	*Not Reported	LOW	19

Table 48: Hydrology data for Hazen Creek, Rock Creek Park June 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	DRY	*Not Reported
10/4/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
11/3/2005	*Not Reported	0.75	NORMAL	*Not Reported
12/8/2005	*Not Reported	*Not Reported	LOW	*Not Reported
1/3/2006	*Not Reported	1.48	ABOVE NORMAL	5.58
2/14/2006	1.495	0.69	NORMAL	5.4
3/8/2006	0.655	0.34	LOW	6.4
4/4/2006	0.070	0.2	LOW	6.9
5/4/2006	0.663	0.30	LOW	4.5
6/1/2006	0.324	0.16	LOW	6.75
7/20/2006	1.625	1.00	NORMAL	5.42
8/3/2006	0.530	0.19	LOW	5.58
9/12/2006	*Not Reported	*Not Reported	NO FLOW	0.25
10/11/2006	0.253	0.627	LOW	6.66
11/21/2006	1.104	0.48	NORMAL	7.58
12/21/2006	0.300	0.210	LOW	6.333
1/30/2007	0.466	0.229	LOW	7.167
3/19/2007	0.699	0.380	LOW	7.917
4/18/2007	0.978	0.217	LOW	9.417
5/22/2007	0.166	0.11	LOW	8.333
6/25/2007	*Not Reported	*Not Reported	LOW	6.417
7/30/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/4/2007	*Not Reported	*Not Reported	LOW	4.167
10/11/2007	0	0	DRY	0
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/20/2008	*Not Reported	*Not Reported	LOW	*Not Reported
3/18/2008	*Not Reported	*Not Reported	LOW	5.5
4/8/2008	*Not Reported	*Not Reported	LOW	5.05
5/2/2008	*Not Reported	*Not Reported	LOW	*Not Reported
6/16/2008	*Not Reported	*Not Reported	LOW	8.08
7/14/2008	4.34	1.325	ABOVE NORMAL	10.21
8/21/2008	*Not Reported	*Not Reported	LOW	*Not Reported
9/11/2008	*Not Reported	*Not Reported	LOW	*Not Reported

Table 49: Hydrology data for Piney Branch, Rock Creek Park October 2005 to August 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	0.88	ABOVE NORMAL	*Not Reported
12/8/2005	*Not Reported	*Not Reported	LOW	*Not Reported
1/3/2006	*Not Reported	0.16	LOW	13.17
2/14/2006	*Not Reported	*Not Reported	NORMAL	12.9
3/8/2006	2.410	0.3	ABOVE NORMAL	20.1
4/4/2006	0.409	0.11	LOW	11.5
5/4/2006	*Not Reported	0.47	ABOVE NORMAL	*Not Reported
6/1/2006	0.432	0.095	LOW	15.16
7/20/2006	1.161	0.27	NORMAL	14.29
8/3/2006	3.257	1.01	ABOVE NORMAL	10.75
9/12/2006	*Not Reported	0	NO FLOW	17.1
10/11/2006	*Not Reported	0	NO FLOW	15.83
11/21/2006	*Not Reported	0.26	LOW	13.58
12/21/2006	0.322	0.105	LOW	12
1/30/2007	0.144	0.037	LOW	11.833
3/19/2007	0.322	0.072	LOW	13.333
4/18/2007	0.749	0.202	LOW	12.333
5/22/2007	0.307	0.058	LOW	12.333
6/25/2007	*Not Reported	*Not Reported	LOW	11.083
7/30/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/4/2007	*Not Reported	*Not Reported	LOW	10.750
10/11/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/5/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/24/2008	*Not Reported	*Not Reported	LOW	*Not Reported
2/20/2008	*Not Reported	*Not Reported	LOW	12.4
3/18/2008	*Not Reported	*Not Reported	LOW	17.5
4/8/2008	*Not Reported	*Not Reported	LOW	13.07
6/16/2008	*Not Reported	*Not Reported	LOW	12.06
7/14/2008	0.46	0.026	LOW	15.46
8/21/2008	*Not Reported	*Not Reported	LOW	16.42

Table 50: Hydrology data for Rock Creek at Edgewater Stables, Rock Creek Park June 2005 to September 2007

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	LOW	*Not Reported
10/4/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/3/2005	*Not Reported	0.09	LOW	*Not Reported
12/8/2005	*Not Reported	*Not Reported	NORMAL	*Not Reported
1/3/2006	*Not Reported	0.76	ABOVE NORMAL	*Not Reported
2/14/2006	*Not Reported	*Not Reported	NORMAL	*Not Reported
3/8/2006	*Not Reported	0.325	NORMAL	*Not Reported
4/4/2006	113.86	2.81	ABOVE NORMAL	61.0
5/4/2006	*Not Reported	0.41	NORMAL	41
6/1/2006	*Not Reported	0	NO FLOW	*Not Reported
7/20/2006	48.945	0.41	NORMAL	62.2
8/3/2006	*Not Reported	0.08	LOW	*Not Reported
9/12/2006	*Not Reported	0.08	LOW	*Not Reported
10/11/2006	*Not Reported	0.48	NORMAL	*Not Reported
11/21/2006	*Not Reported	0.563	NORMAL	*Not Reported
12/21/2006	28.728	0.224	NORMAL	70.25
1/30/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
3/19/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
4/18/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
5/22/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
6/25/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
7/30/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported
9/4/2007	*Not Reported	*Not Reported	NORMAL	*Not Reported

Table 51: Hydrology data for Normanstone Branch, Rock Creek Park October 2007 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/1/2007	0.140	0.280	LOW	2.0
11/26/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/8/2008	*Not Reported	*Not Reported	LOW	2.750
2/4/2008	*Not Reported	*Not Reported	LOW	6.083
3/4/2008	0.14	0.246	LOW	1.833
4/1/2008	*Not Reported	*Not Reported	LOW	2.083
4/29/2008	1.3	0.373	NORMAL	10.1
6/17/2008	0.51	0.194	NORMAL	8.04
7/15/2008	0.12	0.016	LOW	10.5
8/20/2008	*Not Reported	*Not Reported	NORMAL	*Not Reported
9/10/2008	0.05	0.025	LOW	7.17

Table 52: Hydrology data for Dumbarton Oaks Stream, Rock Creek Park October 2007 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/3/2007	*Not Reported	*Not Reported	LOW	2.167
11/1/2007	0.365	1.217	LOW	2.0
11/26/2007	0.068	0.122	LOW	3.667
1/8/2008	*Not Reported	*Not Reported	LOW	3.833
2/4/2008	*Not Reported	*Not Reported	NORMAL	10.583
3/4/2008	*Not Reported	*Not Reported	LOW	3.5
4/1/2008	*Not Reported	*Not Reported	LOW	3.75
4/29/2008	0.27	0.362	LOW	5.05
6/17/2008	0.71	0.670	NORMAL	6.02
7/15/2008	0.6	0.750	NORMAL	5.04
8/20/2008	0.1	0.147	LOW	6
9/10/2008	*Not Reported	*Not Reported	LOW	3.42

Table 53: Hydrology data for Rock Creek at Dumbarton Oaks, Rock Creek Park October 2007 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
10/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/1/2007	18.570	0.821	LOW	58.167
11/26/2007	16.354	0.621	LOW	59.583
1/8/2008	24.142	0.847	LOW	55.167
2/4/2008	*Not Reported	*Not Reported	LOW	*Not Reported
3/4/2008	27.47	1.012	LOW	54.5
4/1/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
4/29/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
6/17/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported
7/15/2008	50.4	1.214	NORMAL	57
8/20/2008	11.64	0.681	LOW	50.83
9/10/2008	*Not Reported	*Not Reported	ABOVE NORMAL	*Not Reported

Table 54: Hydrology data for Palisades Creek, Rock Creek Park May 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
6/27/2005	*Not Reported	*Not Reported	LOW	*Not Reported
11/8/2005	*Not Reported	0.09	LOW	*Not Reported
12/8/2005	*Not Reported	*Not Reported	LOW	*Not Reported
1/26/2006	1.360	0.48	LOW	11.33
2/28/2006	1.974	1.03	LOW	9.6
3/8/2006	*Not Reported	*Not Reported	LOW	*Not Reported
4/12/2006	0.105	0.14	LOW	10.4
5/18/2006	*Not Reported	0	NO FLOW	13.67
6/1/2006	*Not Reported	*Not Reported	LOW	*Not Reported
7/20/2006	*Not Reported	*Not Reported	LOW	*Not Reported
8/3/2006	*Not Reported	*Not Reported	LOW	*Not Reported
9/12/2006	*Not Reported	*Not Reported	LOW	*Not Reported
10/11/2006	*Not Reported	*Not Reported	LOW	*Not Reported
11/21/2006	*Not Reported	*Not Reported	LOW	*Not Reported
12/21/2006	*Not Reported	*Not Reported	LOW	*Not Reported
1/12/2007	*Not Reported	0.3	LOW	*Not Reported
2/23/2007	0.293	0.083	LOW	12.083
3/27/2007	0.208	0.065	LOW	10.667
4/18/2007	*Not Reported	*Not Reported	LOW	*Not Reported
5/14/2007	0.318	0.124	LOW	10.083
6/25/2007	*Not Reported	*Not Reported	LOW	*Not Reported
7/30/2007	*Not Reported	*Not Reported	LOW	*Not Reported
9/4/2007	*Not Reported	*Not Reported	LOW	*Not Reported
10/3/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/1/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/26/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/8/2008	*Not Reported	*Not Reported	LOW	7.333
2/4/2008	*Not Reported	*Not Reported	LOW	*Not Reported
3/4/2008	*Not Reported	*Not Reported	LOW	10
4/1/2008	*Not Reported	*Not Reported	LOW	5.833
4/29/2008	*Not Reported	*Not Reported	LOW	7.02
6/17/2008	*Not Reported	*Not Reported	LOW	*Not Reported
7/15/2008	0.1	0.084	LOW	10.5
8/20/2008	*Not Reported	*Not Reported	LOW	3
9/10/2008	*Not Reported	*Not Reported	LOW	2.83

Wolf Trap National Park for the Performing Arts (WOTR)

WOTR is entirely within the Piedmont ecoregion and Fairfax County, VA. Within the boundaries of the park are streams, meadows and wooded areas. The park's two streams, Old Court House Branch, and Wolf Trap Creek, part of the Difficult Run watershed (Figure 92) and their riparian forest are among the park's most important natural resources. Water quality is a major concern. Stream bank erosion has occurred due to increased development around the park. The erosion may threaten the maintenance yard in the future. This has lead to sediment deposition. Runoff from the Dulles Toll Road (see figure 58) may have detrimental effects. Streams are also impacted by fertilizer runoff from the park's management, parking lot runoff, and runoff from salt storage in the maintenance yard.

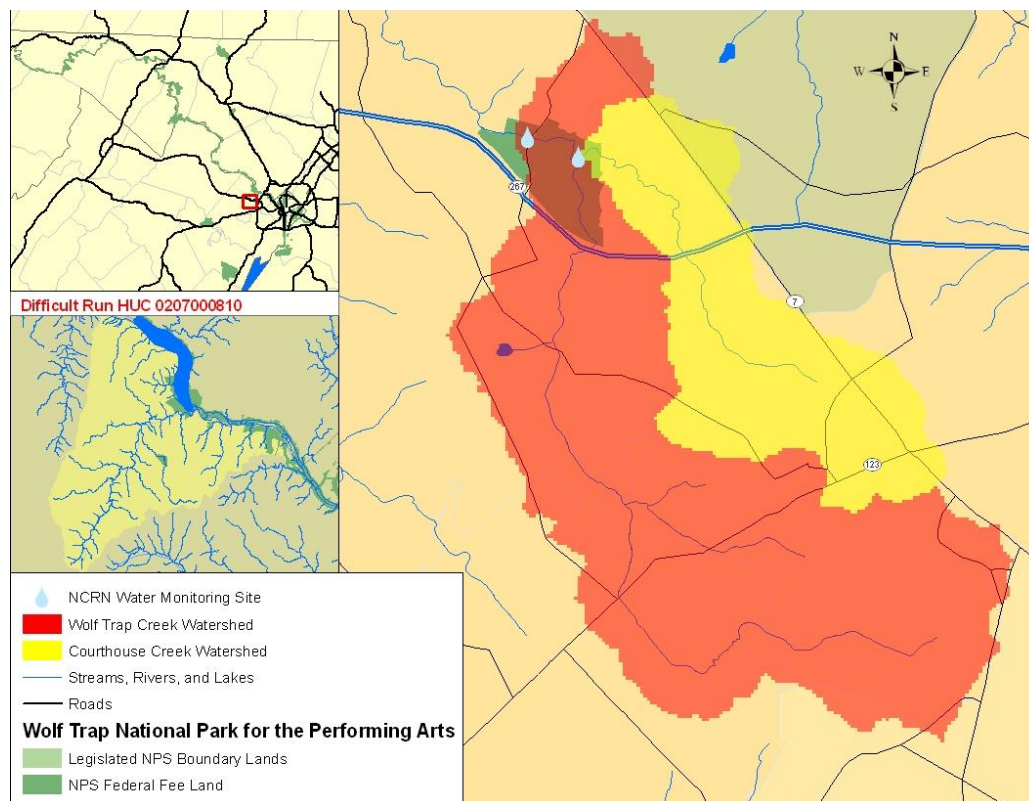


Figure 92: Relationship of the Wolf Trap and Courthouse Creek monitoring sites to the watershed and the WOTR park boundary

This report discusses data collected October 2006 through September 2008 for Courthouse Creek (CHCK) and Wolf Trap Creek (WOTR). Summary statistics for the time period are shown in Table 55.

Table 55: Date range, number of site visits (N), and data range for the information covered in this report.

<i>Local Name</i>	<i>Units</i>	<i>Period of Record</i>	<i>N</i>	<i>Min.</i>	<i>Max.</i>	<i>Mean</i>	<i>Median</i>	<i>Standard Deviation</i>
Air Temperature	°C	10/19/2006 - 8/22/2007	16	-8	30	17	22	12
ANC	µeq/L	10/19/2006 - 9/25/2007	18	334	898	653	660	140
DO	mg/l	10/19/2006 - 9/25/2007	18	4.98	11.82	7.68	7.25	2.15
Nitrate	mg/l	10/19/2006 - 9/25/2007	18	0.50	2.59	1.49	1.50	0.58
Ammonia	mg/l	10/19/2006 - 9/25/2007	11	0.000	0.184	0.066	0.066	0.048
pH	None	10/19/2006 - 9/25/2007	18	6.270	7.555	7.076	7.210	0.446
Phosphate	mg/l	10/19/2006 - 9/25/2007	18	0.05	8.29	0.83	0.31	1.88
Salinity	ppt	10/19/2006 - 9/25/2007	18	0.1	0.2	0.1	0.1	0.0
Specific conductance	µS/cm	10/19/2006 - 9/25/2007	18	173.3	460.9	284.0	289.5	80.2
Water Temperature	°C	10/19/2006 - 9/25/2007	18	4.05	19.90	14.20	15.65	5.64

Some monthly nitrate values exceeded the threshold in 2007 (Figure 93). In 2008 nitrate exceeded threshold in Courthouse Creek 83% of the time and in Wolf Trap Creek 58 % of the time. Phosphorus exceeded threshold 100% of the time in Courthouse Creek (Figure 94). Phosphorus exceeded threshold in Wolf Trap Creek 100% of the time in 2007 and 89% in 2008. Ammonia exceeded threshold in Wolf Trap Creek once though the mean did not exceed threshold (Figure 95). Ammonia is a difficult parameter to measure. We frequently get readings below zero and the EDL of 0.032 with the very low readings we normally get means that much of the data is excluded from analysis (7 of 18 readings in the case of WOTR in FY2007-2008). DO values below the desired level of 5mg/L occurred in summer in Wolf Trap Creek (Figure 96).

Specific conductance never significantly exceeded threshold in either stream (Figure 97). pH met threshold as did ANC (Figures 98 and 99). Water temperature follows expected seasonal trends and stays within the comfort zone of desired organisms (Figure 100).

The region experienced a drought in 2007. Several small streams in the region dried out, however Wolf Trap Creek did not, though it was dry in November 2006. Based on the data collected so far, Normal water levels for Wolf Trap Creek can be defined as Discharge between 6 cfs and 10 cfs, with a flow of 0.5 f/s or higher in a channel with a wetted width of 21 or more feet. Low is less than 3.5 cfs discharge and flow less than 0.3 f/s. Above normal flow conditions have been observed, but not quantified at the site (Table 56).

Courthouse Creek did not dry out during the 2007 drought, though it was dry in November 2006. Based on the data collected so far, normal water levels for Courthouse Creek can be defined as discharge between 2 cfs and 6 cfs, with a flow of 0.8 f/s or higher in a channel with a wetted width of 14 or more feet. Low is less than 2 cfs discharge and flow less than 0.4 f/s. Above normal flow conditions have not been observed at the site (Table 57).

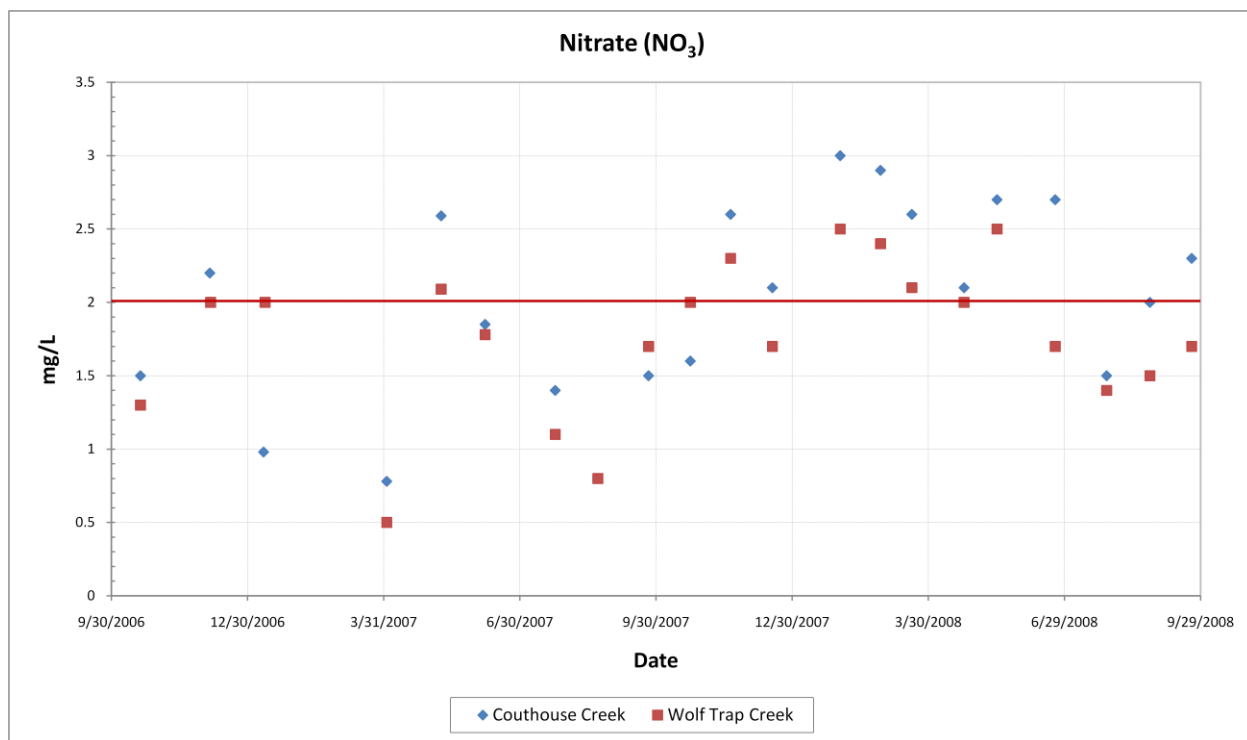


Figure 93: Nitrate in WOTR streams FY 2007-2008. Healthy waters would ideally have less than 2.0 mg/L NO₃ (red line).

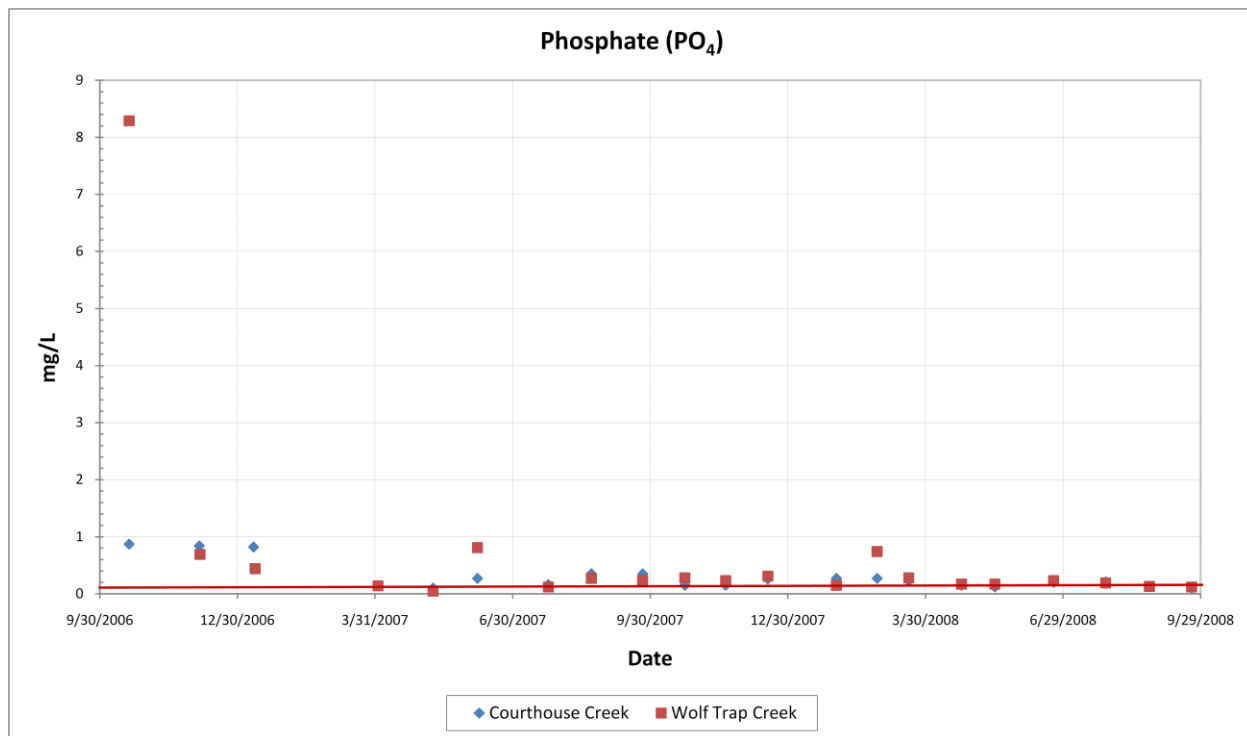


Figure 94: Phosphate in WOTR streams FY 2007-2008. Ideally, healthy waters would have less than 0.1 mg/L PO₄ (red line).

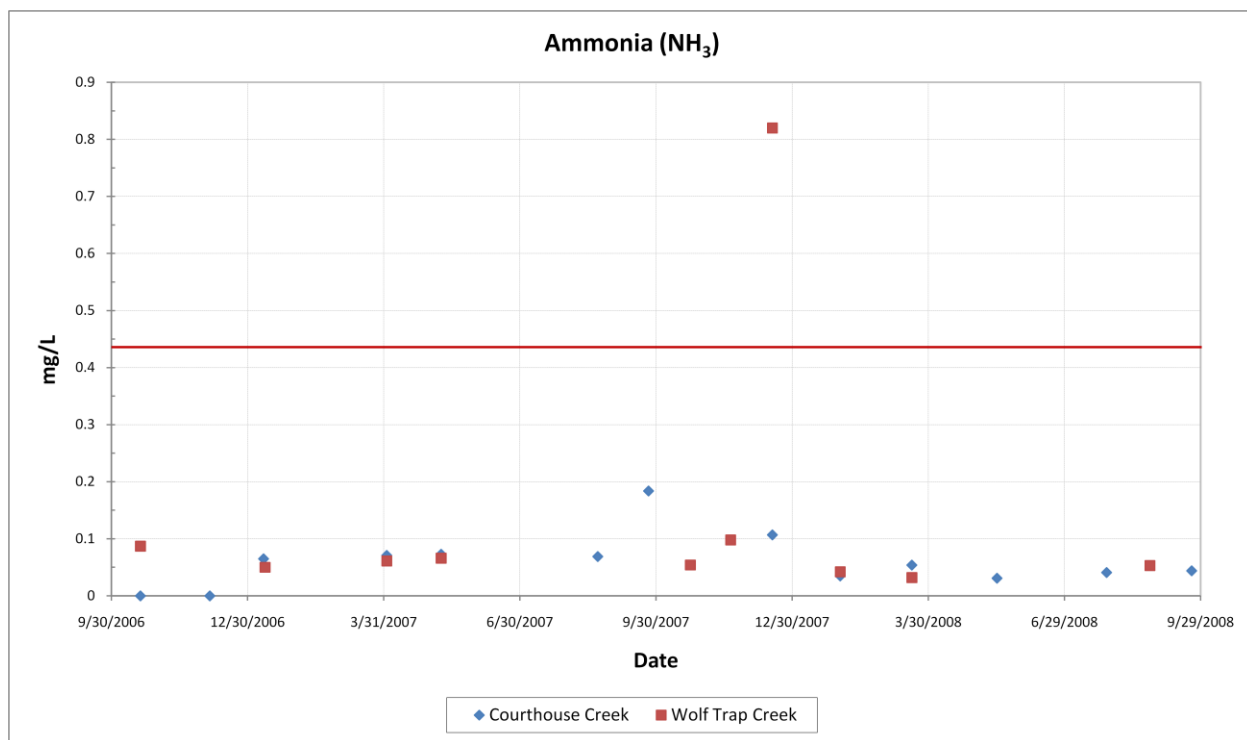


Figure 95: Ammonia in WOTR streams FY 2007-2008. Healthy waters would ideally have less than 0.433 mg/L NH₃ (red line).

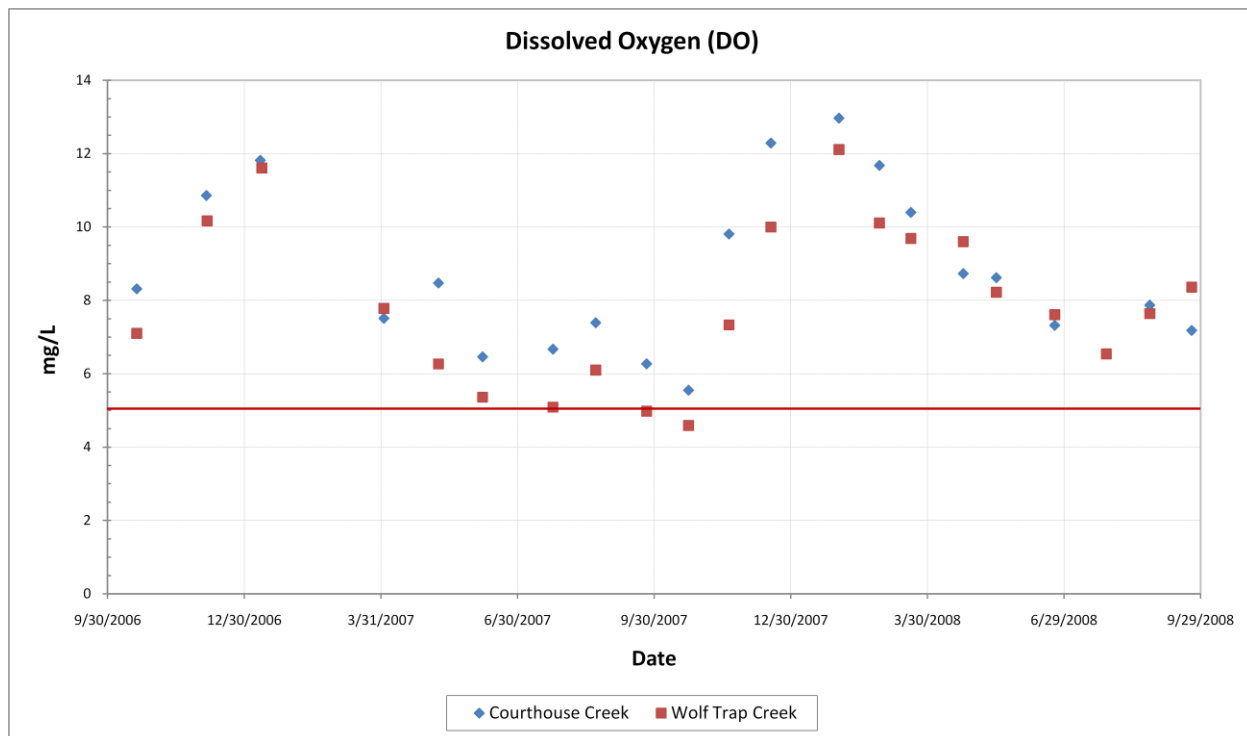


Figure 96: Dissolved oxygen in WOTR streams FY 2007-2008. Healthy waters should have 5.00 mg/L or more of oxygen to support aquatic life (the red line on the graph).

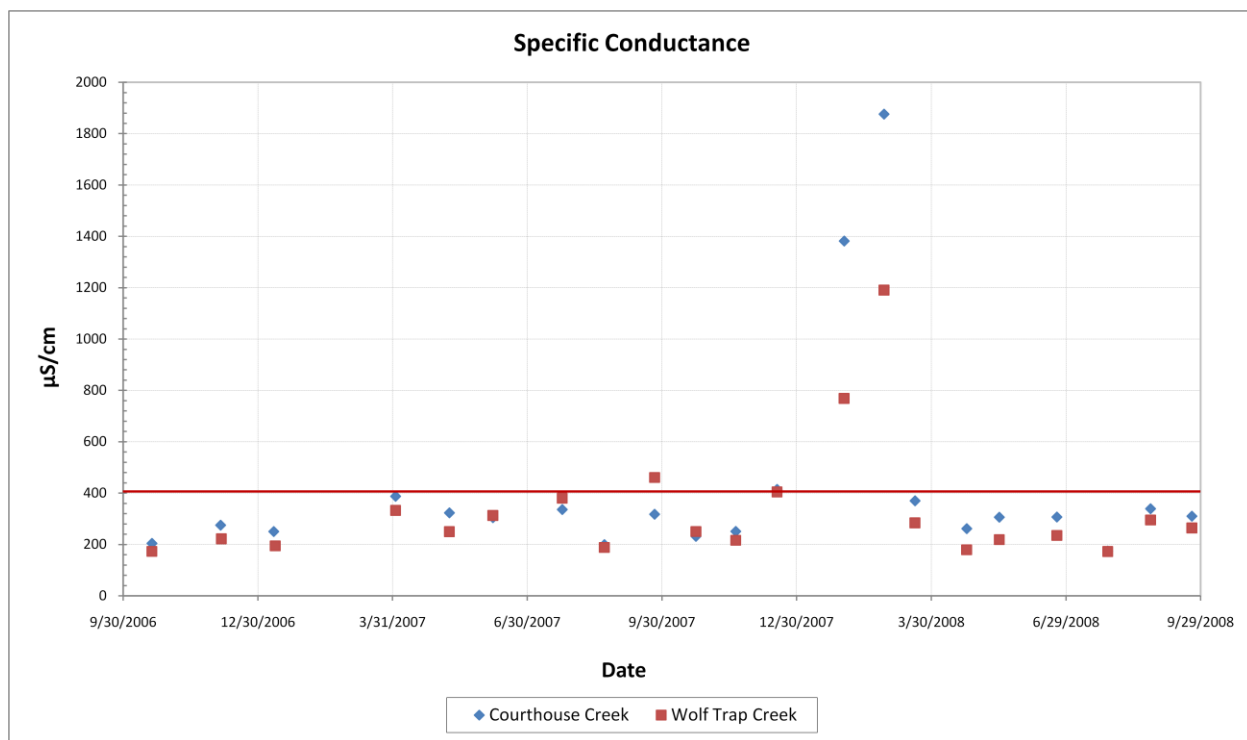


Figure 97: Specific Conductance in WOTR streams FY 2007-2008. Ideally, healthy waters would have less than 400 µS/cm (red line).

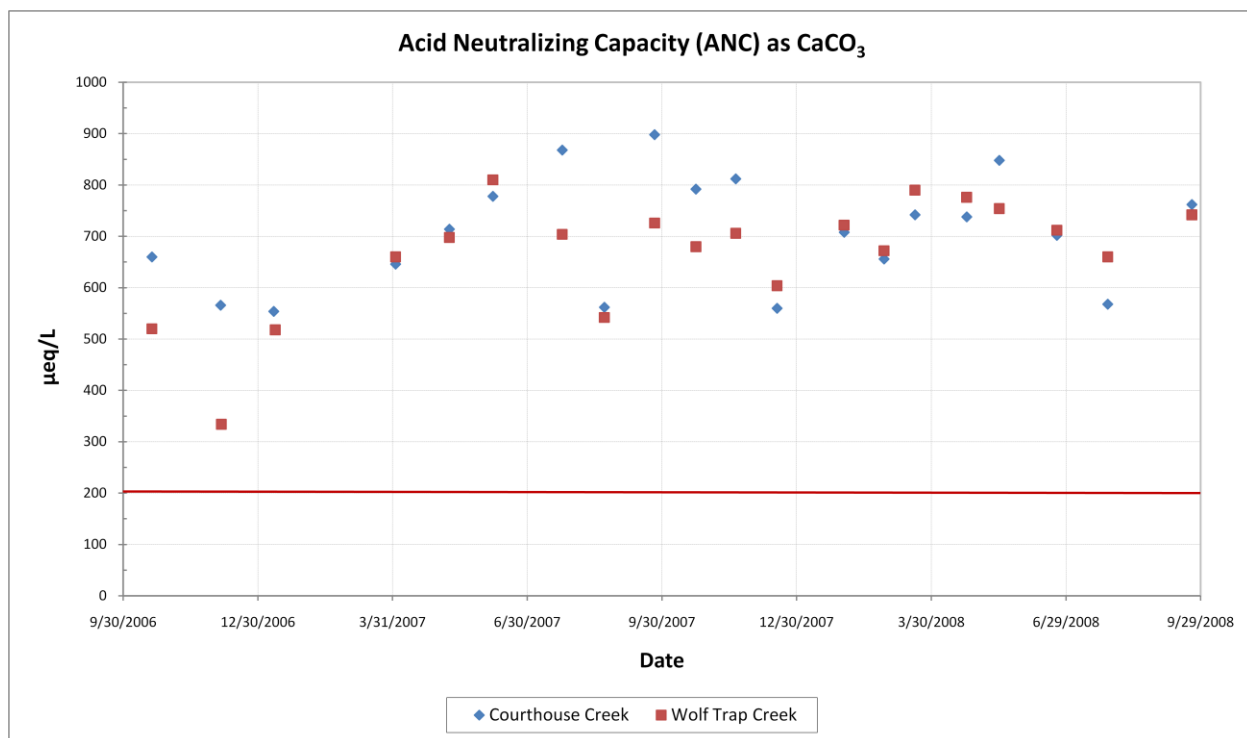


Figure 98: Acid Neutralizing Capacity in WOTR streams FY 2007-2008. Non-karst waters should have ANC above 200 µeq/L (the red line on the graph).

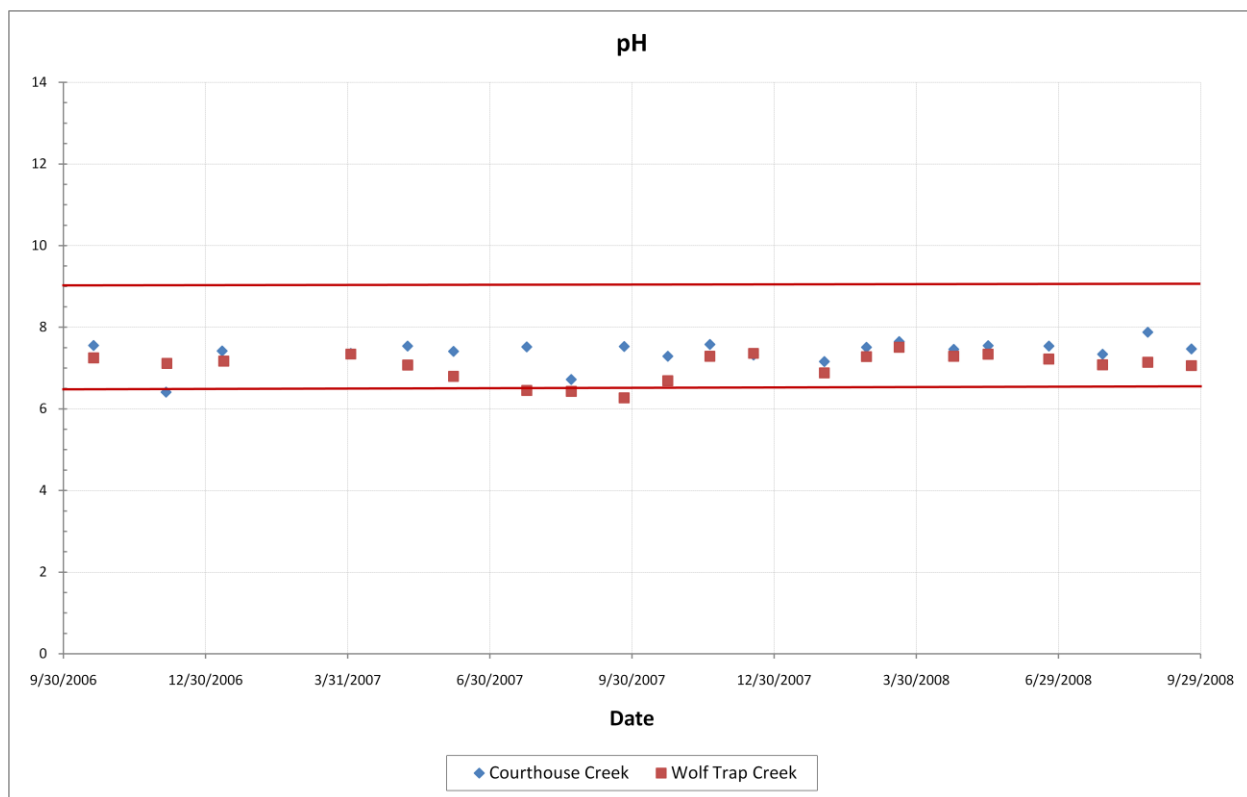


Figure 99: pH in WOTR streams FY 2007-2008. Healthy waters are ideally between 6.5 and 9 pH to promote aquatic life (red line).

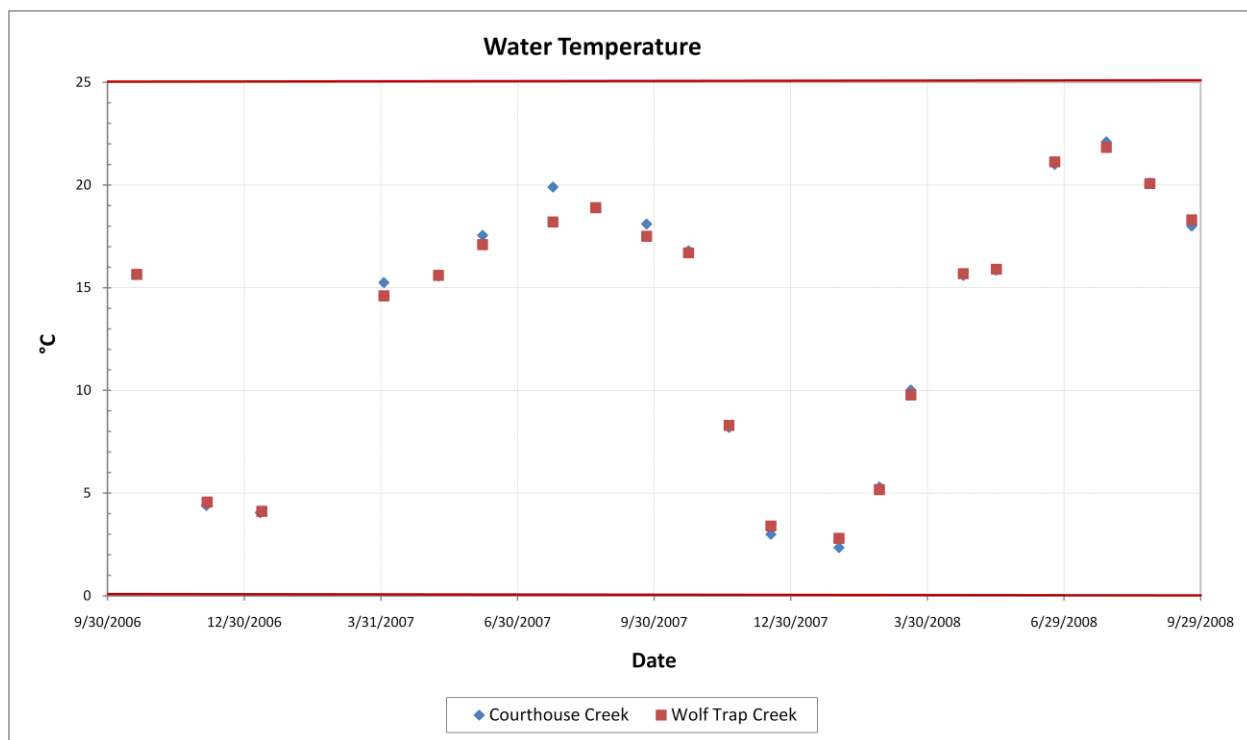


Figure 100: Water temperature in WOTR streams FY 2007-2008. Temperatures between 0° and 25° C are ideal for aquatic life.

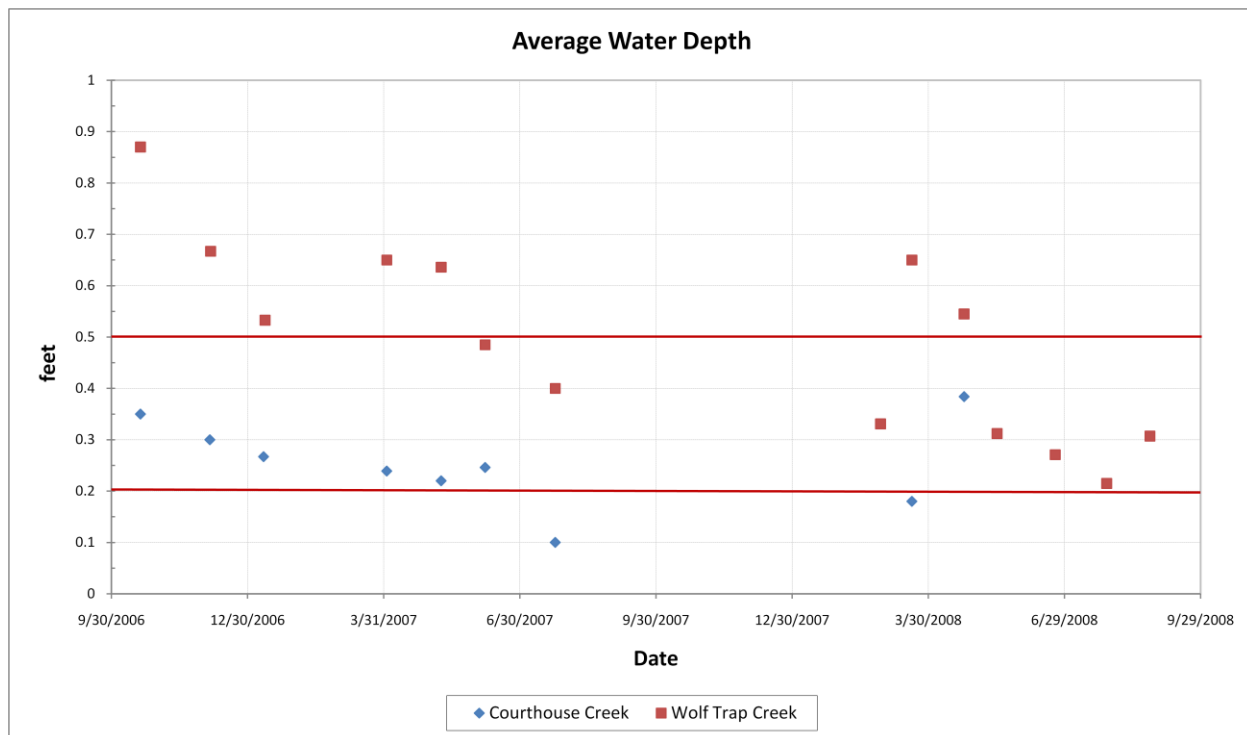


Figure 101: Water Depth (feet) in WOTR streams FY 2007-2008. The flow meter and water quality sensors require a minimum depth of 0.2 feet (redline). Continuous loggers require a minimum of 0.5 feet.

Table 56: Hydrology data for Wolf Trap Creek, Wolf Trap National Park for the Performing Arts November 2005 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
11/1/2005	*Not Reported	1.29	NORMAL	*Not Reported
12/5/2005	*Not Reported	0.69	NORMAL	*Not Reported
1/10/2006	7.132	0.49	NORMAL	23.17
2/16/2006	*Not Reported	0.90	LOW	0.75
3/15/2006	*Not Reported	0.46	LOW	22.83
4/6/2006	6.871	0.98	NORMAL	24.2
5/2/2006	1.819	0.20	LOW	19.08
6/15/2006	2.509	0.53	LOW	18.583
7/12/2006	2.198	0.09	LOW	25.17
8/7/2006	10.053	0.35	NORMAL	26.7
9/25/2006	*Not Reported	*Not Reported	LOW	*Not Reported
10/19/2006	6.508	0.31	NORMAL	25
11/1/2006	*Not Reported	*Not Reported	DRY	*Not Reported
12/5/2006	2.371	0.143	LOW	25.58
1/11/2007	3.427	0.243	LOW	24.42
2/16/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/1/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
4/2/2007	2.862	0.119	LOW	28
5/9/2007	1.205	0.052	LOW	27.75
6/7/2007	0.577	0.031	LOW	26.667
7/24/2007	*Not Reported	*Not Reported	LOW	24.667
8/22/2007	*Not Reported	*Not Reported	NORMAL	24.250
9/25/2007	*Not Reported	*Not Reported	NORMAL	24.167
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	25.4
2/27/2008	2.24	0.272	LOW	25
3/19/2008	3.28	0.302	LOW	16.75
4/23/2008	6.48	0.555	NORMAL	21.5
5/15/2008	7.55	1.046	NORMAL	23.02
6/23/2008	3.29	0.477	LOW	25.07
7/28/2008	2.09	0.397	LOW	25.25
8/26/2008	0.34	0.051	LOW	21.5
9/23/2008	*Not Reported	*Not Reported	ABOVE NORMAL	21.25

Table 57: Hydrology data for Courthouse Creek, Wolf Trap National Park for the Performing Arts May 2006 to September 2008

DATE	Discharge	Flow	Flow, qualitative	Wetted Width
5/2/2006	0.338	0.042	LOW	9.917
6/15/2006	2.717	0.49	NORMAL	10.083
7/12/2006	6.233	1.10	NORMAL	14.167
8/7/2006	3.673	0.83	NORMAL	14.750
9/25/2006	*Not Reported	*Not Reported	LOW	*Not Reported
10/19/2006	0.766	0.15	LOW	14.583
11/1/2006	*Not Reported	*Not Reported	DRY	*Not Reported
12/5/2006	0.85	0.1	LOW	17.0
1/10/2007	2.725	0.643	NORMAL	15.250
2/16/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
3/1/2007	*Not Reported	*Not Reported	FROZEN	*Not Reported
4/2/2007	1.347	0.334	LOW	14.667
5/9/2007	1.139	0.196	LOW	15.167
6/7/2007	0.742	0.166	LOW	12.833
7/24/2007	*Not Reported	*Not Reported	LOW	14.167
8/22/2007	*Not Reported	*Not Reported	LOW	13.833
9/25/2007	*Not Reported	*Not Reported	LOW	8.917
10/23/2007	*Not Reported	*Not Reported	LOW	*Not Reported
11/19/2007	*Not Reported	*Not Reported	LOW	*Not Reported
12/17/2007	*Not Reported	*Not Reported	LOW	*Not Reported
1/31/2008	*Not Reported	*Not Reported	LOW	13.7
2/27/2008	*Not Reported	*Not Reported	LOW	13.333
3/19/2008	2.19	.851	NORMAL	14.733
4/23/2008	4.54	.766	NORMAL	16.417
5/15/2008	*Not Reported	*Not Reported	LOW	17
6/23/2008	*Not Reported	*Not Reported	LOW	17.02
7/28/2008	*Not Reported	*Not Reported	LOW	16.92
8/26/2008	*Not Reported	*Not Reported	LOW	11.92
9/23/2008	*Not Reported	*Not Reported	LOW	5.25

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