



National Capital Region Network Inventory and Monitoring Program Stream Water Quality and Quantity Monitoring Protocol

*Water Chemistry, Nutrient Dynamics, and Surface Water Dynamics
Vital Signs, Version 3.0, 2025*



Big Hunting Creek at Catoclin Mountain Park.

NPS

National Capital Region Network Inventory and Monitoring Program Stream Water Quality and Quantity Monitoring Protocol: Water Chemistry, Nutrient Dynamics, and Surface Water Dynamics Vital Signs, Version 3.0, 2025

Science Report NPS/SR—2025/362

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Please cite this publication as:

Myers, D.T., D. Oviedo-Vargas, L. Ashley, and A. Brolis. 2025. National Capital Region Network Inventory and Monitoring Program Stream Water Quality and Quantity Monitoring Protocol: Water Chemistry, Nutrient Dynamics, and Surface Water Dynamics Vital Signs, Version 3.0, 2025. Science Report NPS/SR—2025/362. National Park Service, Fort Collins, Colorado.
<https://doi.org/10.36967/2315848>

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Abstract

The Potomac River Basin is home to more than six million people and the second largest drainage of the nine river basins that form the Chesapeake Bay watershed. Although great progress has been made toward water quality improvement in the basin, streams and rivers in the area have continued to show trends in increasing salinity, higher stream temperature, higher concentrations of nutrients, and other indicators of degraded water quality.

In 2005, the National Capital Region Inventory & Monitoring Network (NCRN I&M) of the National Park Service (NPS) initiated a long-term water quality and quantity monitoring program, carried out through discrete sampling visits to long-term monitoring stream sites within NCRN parks. Parks monitored with this protocol include Antietam National Battlefield, Catoctin Mountain Park, Harpers Ferry National Historical Park, George Washington Memorial Parkway, Manassas National Battlefield Park, Monocacy National Battlefield, National Capital Parks–East, Prince William Forest Park, Rock Creek Park, and Wolf Trap National Park for the Performing Arts. The streams monitored are all part of the Potomac River watershed. The monitoring sites include streams whose watersheds are undeveloped and within National Park boundaries, as well as streams whose watersheds are mostly external to park boundaries, encompassing a variety of urban and agricultural landscapes outside the parks.

The goal of the NCRN is to monitor whether stream water quality in park streams is suitable to meet management goals for well-functioning, native ecological communities. The vital sign selection process of the NCRN I&M identified water quality and quantity information as a critical need for the parks of the NCRN. Data collected using this protocol provides much needed status and trend information for park streams, to better understand how changes in watershed land use, climate, and other factors are affecting the stream ecosystems.

This protocol contains background information about the purposes of the NCRN water vital signs monitoring, stream water sampling design, field and laboratory methods, and data quality procedures. Acid neutralizing capacity (ANC), dissolved oxygen (DO), pH, specific conductance (including conductivity, salinity, and total dissolved solids (TDS)), and water temperature are monitored to better understand stressors to stream ecosystems such as acidification, increased temperatures, and pollutant pulses. Nitrogen and phosphorus (as total nitrogen and total phosphorus) are monitored to provide information about nutrient pollution in park streams. Water depth, wetted width, velocity, and discharge are monitored to better understand water quantity, and better explain water physical and chemical dynamics.

List of Acronyms

ANC: Acid neutralizing capacity

ANTI: Antietam National Battlefield

CATO: Catoctin Mountain Park

CHOH: Chesapeake and Ohio Canal National Historical Park

DO: Dissolved oxygen

GWMP: George Washington Memorial Parkway

HAFE: Harpers Ferry National Historical Park

I&M: Inventory and Monitoring

IMLOCID: Inventory and Monitoring Location ID

MANA: Manassas National Battlefield Park

MONO: Monocacy National Battlefield

NACE: National Capital Parks-East

NCRN: National Capital Region Network

NHD: National Hydrography Dataset

NPS: National Park Service

NTU: Nephelometric Turbidity Units

PRWI: Prince William Forest Park

ROCR: Rock Creek Park

TDS: Total dissolved solids

TN: Total nitrogen

TP: Total phosphorus

WOTR: Wolf Trap National Park for the Performing Arts

Acknowledgments

Additional assistance in preparing Version 3.0 of this protocol was provided by Emma Brentjens, Bonnie Campbell, David Jones, Elizabeth Matthews, Megan Nortrup, John Paul Schmit, and Charlie Wainright. We also thank Jinjun Kan, Melinda Daniels, and Marc Peipoch of Stroud Water Research Center for participation in the 2022 protocol science review.

1. Background and Objectives

1.1. Background and Purpose

Changes to land use and climate are impacting the water quality of stream ecosystems through disrupted thermal and flow regimes, habitat degradation, alteration of biogeochemical cycles of major elements, and introduction of human-made contaminants, with major implications for the ecosystem services they provide (Allan 2004; Dudgeon 2019; Kaushal et al. 2019; Palmer et al. 2008; Van Vliet et al. 2023; Wang et al. 2024). As the second largest drainage basin of the Chesapeake Bay watershed, people have depended on water resources of the Potomac River Basin for centuries for their food, recreation, transportation, and water supply. Additionally, this river network is of great importance as aquatic habitat for native ecological communities (ICPRB 2018). Interestingly, studies on water quality and quantity in the Potomac River Basin are amongst the oldest nationwide (Babb 1893; Parker et al. 1907). Although great progress has been made toward water quality improvement (ICPRB 2018), streams and rivers in the Basin have continued to show trends in higher alkalinity and salinity, higher stream temperature, and higher concentrations of total nitrogen and total phosphorus, along with other indicators of degraded water quality (Kaushal et al. 2019; Duan et al. 2021; Ding and Elmore 2015).

Almost all of the parks in the National Capital Region Inventory and Monitoring Network (NCRN I&M) lie within the Potomac River Basin, with the exception of parts of Suitland Parkway and Baltimore–Washington Parkway of National Capital Parks–East (NACE), which are located in the Patuxent River watershed (Figure 1).

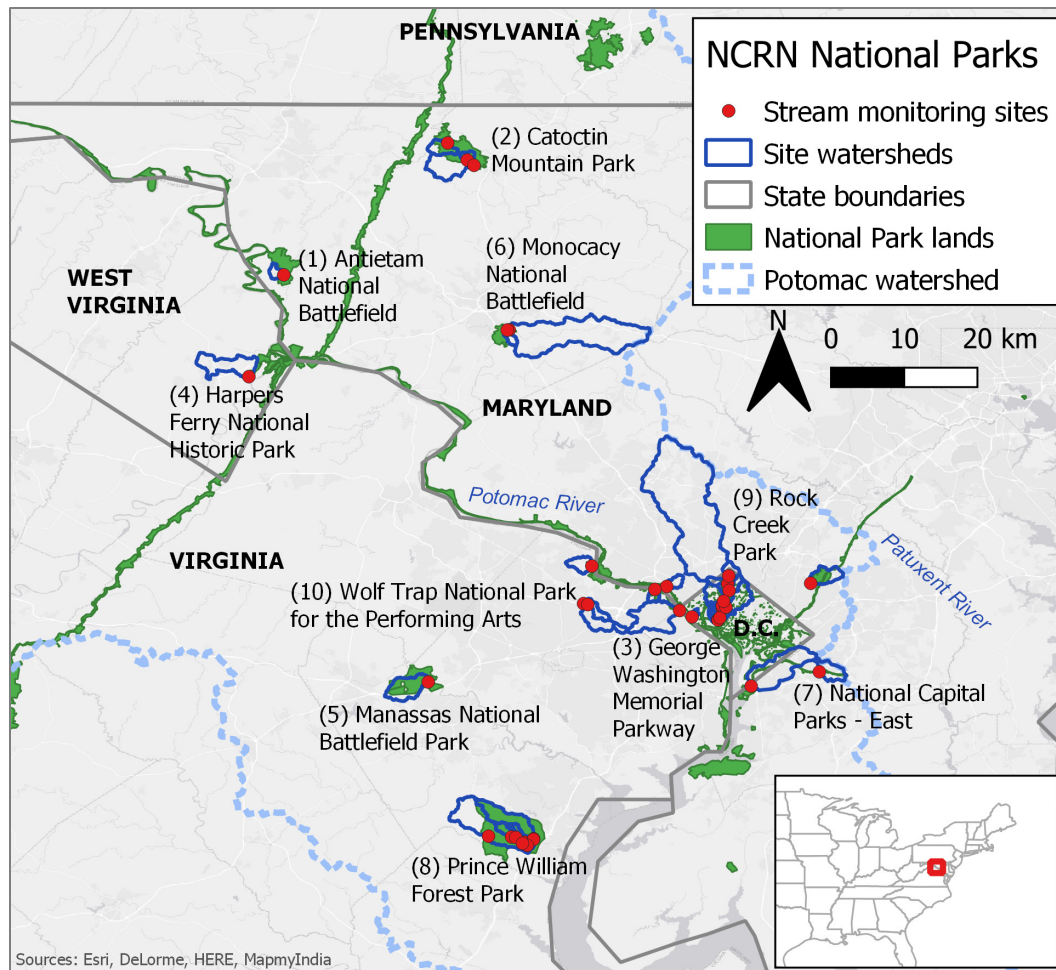


Figure 1. Locations of streams and watersheds monitored in the National Capital Region Network.
NPS

The parks of NCRN are:

1. Antietam National Battlefield (ANTI)
2. Catoctin 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)

11. Wolf Trap National Park for the Performing Arts (WOTR)

Water resources are a vital component of National Park Service (NPS) lands in the National Capital Region. In parks across the region, water resources are a dominant landscape feature, and the quality of the visitor experience largely depends on the quality of the resource. In addition to the ecological implications discussed above, the condition of water resources also has direct bearing on public health and safety when water quality is degraded. A significant number of NCRN park streams contribute to public drinking water supplies. To this end, the Clean Water Act and other regulatory mandates set minimum water quality standards. In addition, the enabling legislation for GWMP, NACE, PRWI, and ROCR requires that these parks protect the water quality of streams within the park in order to prevent pollution to the Anacostia River, the Potomac River, Rock Creek, and Quantico Creek.

The purpose of this protocol is to provide a rationale and overview for the monitoring of non-tidal, freshwater wadeable streams in the NCRN to better understand how park streams are impacted by stressors such as changing land use and climate. There are numerous historic or ongoing monitoring projects within the region. Most have been set up by park personnel, previous staff with the Office on Natural Resources and Science, universities, partner agencies, and even volunteer organizations. The NPS I&M program was not designed to replace park-based monitoring efforts but can provide additional information through the network's vital signs.

The scope of this protocol is to document the rationale and approaches to measure core water physicochemical parameters including temperature, dissolved oxygen (DO), pH, acid neutralizing capacity (ANC), specific conductance (including conductivity, salinity, and total dissolved solids (TDS)), nutrient concentrations, turbidity and water quantity parameters in priority streams of the NCRN. The water quantity protocol (previously known as surface water dynamics protocol) was originally published separately (Fisher 2005), but the two protocols were combined into a single protocol and republished as Version 2.0 in 2010 after peer-review comments were addressed. The current revision addresses changes made since the 2010 revision.

In 2022, the NCRN collaborated with the nonprofit Stroud Water Research Center to provide a science review of the NCRN water quality and quantity monitoring protocol. The scientific review examined the adequacy of the program for meeting objectives and their alignment with vital signs, the appropriateness of the analyses, the compatibility of methods (including quality control), data reliability, and the format of the reporting. The review followed 15+ years of water quality monitoring in NCRN parks, allowing for evaluation of data management, protocol, and data analyses. The review process called for a technical report that identifies and prioritizes potential protocol improvements. External reviewers from the Stroud Center evaluated the National Capital Region Network Inventory and Monitoring Program Water Chemistry and Quantity Monitoring Protocol Version 2.0 (<https://irma.nps.gov/DataStore/Reference/Profile/2172524>) and assessed how NCRN is meeting the objectives listed in the protocol. The NCRN water monitoring protocol was updated following the suggestions in the science review that fit within existing capacities. The outcome was

an improved ability to assess watershed health and provide natural resource information to NCRN parks.

1.2. Vital Sign Selection

The NCRN long-term water monitoring program is designed to ensure that the network's parks possess the science-based information needed for effective management of water resources. Parks in the NCRN contain a variety of significant water resources including major rivers and riparian zones, stream resources (lotic), ponds and pools (lentic), as well as seeps and springs. The NCRN has numerous monitoring protocols that are designed to monitor the chemical, physical and biological components of many of these resources. To achieve this, the program collects data for the following vital signs (ecological elements or processes that help indicate the overall condition of park resources):

- Water physicochemistry (includes the water chemistry and nutrient dynamics vital signs)
- Water quantity
- Stream biology (fish and macroinvertebrates) and habitat
- Vernal pool water quality and amphibians

Three network vital signs are included in this protocol: (1) water core physicochemical parameters (ANC, DO, pH, specific conductance, water temperature, turbidity, total nitrogen and total phosphorus); and (2) water quantity parameters (stream width, depth, streamflow and velocity). Note that conductivity and temperature can be used to calculate specific conductance, salinity, and TDS. The network may report any or all of those values as needed.

The separate NCRN Biological Stream Sampling Protocol was developed through a collaboration with researchers from Frostburg State University and The Maryland Department of Natural Resources (Hilderbrand et al. 2005), who collaborated with NCRN to adapt the Maryland Biological Stream Survey (MBSS) for use in NCRN parks. The resulting Biological Stream Survey protocol includes a physical habitat index and indexes of biological integrity for aquatic macroinvertebrates and fish (Norris and Sanders 2009) and is published separately. It can be found here: <https://irma.nps.gov/DataStore/DownloadFile/152609>.

The separate NCRN Amphibian Monitoring Protocol was developed by the USGS BRD – Amphibian Research and Monitoring Initiative (ARMI) for the monitoring of amphibian populations in streams and pools in NCRN parks. Water quality can significantly impact amphibian populations so water chemistry data are collected as a part of this protocol. More information about this protocol and related products can be found here: <https://irma.nps.gov/DataStore/Reference/Profile/2195285>.

1.3. Rationale for Monitoring

The NPS is legally responsible for protecting water quality and improving impaired water quality (Rosenlieb and Long 2006). Thus, the NCRN monitors water quality indicators based on water quality and quantity that were chosen to provide information characterizing stream ecosystems and that are fundamental components of monitoring and regulatory programs (Table 1). Further details

about each parameter are provided below. Through monitoring these parameters, the NCRN is able to better understand the health of stream ecosystems in the network's parks and how they are affected by stressors such as land use and climate change.

Table 1. Water quality metrics and the priority issues they represent.

Water Quality Metric	Priority Issue(s)
Acid neutralizing capacity	Resistance to acidification
pH	Acidification
Dissolved oxygen (DO)	Fish population stressor
Specific conductance (sometimes reported as salinity or total dissolved solids)	Salinization
Water temperature	Fish population stressor
Total phosphorus	Nutrient pollution
Total nitrogen	Nutrient pollution
Turbidity	Sediment pollution and habitat availability
Stream depth	Water and habitat availability
Stream width	Water and habitat availability
Streamflow	Water availability, hydrology
Water velocity	Water availability, hydrology

1.3.1. pH and Acid Neutralizing Capacity (ANC)

Water pH directly affects physiological functions of aquatic organisms, and is, therefore, an important indicator of the health of an aquatic ecosystem (NPS 2002; Stednick and Gilbert 1998; USGS 1980). Also, the pH of water is important in the toxicity and solubility of many constituents. Deviations in pH from the normal range into extreme ranges can result in severe harm to aquatic life (Hem 1985). Temporal causes of variation of pH can range from ecosystem metabolism (diurnal and seasonal; Allan et al. 2021) to fractionation during snowmelt (Winnick et al. 2017), changes in runoff processes, and changes in atmospheric deposition (monthly and/or seasonal; MacDonald et al. 1991). Maryland water quality standards regarding pH for aquatic life are 6.5 to 8.5, while Virginia pH standards are 6 to 9 (Code of Maryland Regulations (COMAR) 26.08.02.03-3; 9VAC25-260-50).

Acid neutralizing capacity (ANC) is an indicator of a waterbody's susceptibility to acidification. ANC is particularly important to measure in areas where acid mine drainage (e.g., PRWI) or acid precipitation (entire NCRN) is a potential concern. Generally, waters with <0 $\mu\text{eq/L}$ are acidic, <50 $\mu\text{eq/L}$ are considered extremely acid sensitive, $50\text{--}200$ $\mu\text{eq/L}$ are susceptible to acidification, and >200 $\mu\text{eq/L}$ have a good buffer against acidification (Kaufmann et al. 1991; Schindler 1988). In karst terrain, ANC below 600 $\mu\text{eq/L}$ is cause for concern (Weeks et al. 2007). Reporting on stream water quality should specifically state if a stream meets the acid sensitive criteria.

State geologic maps show that two NCRN monitoring sites (Sharpsburg Creek of Antietam National Battlefield and Flowing Springs Creek of Harpers Ferry National Park) are in karst terrain with

greater than 30% carbonate bedrock (limestone and dolostone) in their watershed, and thus can be expected to have much higher ANC concentrations than the other sites (Horton et al. 2017). In these sites, the weathering of carbonate bedrock is influencing the ANC and pH of the streams, as has been documented for other streams in the Chesapeake Bay Watershed (Kaushal et al. 2013; Liu et al. 2001). All other NCRN watersheds do not have carbonate lithology, with zero percent limestone or dolostone bedrock.

1.3.2. Dissolved Oxygen (DO)

The presence of oxygen in aquatic ecosystems is necessary for the survival and growth of many organisms and is used as an indicator of the health of surface and groundwater systems. Oxygen can be limiting for aquatic organisms due to low availability and difficulty of extraction from the water (Kramer 1987). Urbanization has historically increased oxygen demand due to point- and nonpoint-source pollution, in particular stormwater with increased temperatures and organic materials (O'Driscoll et al. 2010). This can lead to oxygen deficits and fluctuations in urban streams (Keefer et al. 1979; Paul and Meyer 2001). As stream temperatures increase, the solubility of oxygen in the water decreases, leading to lower availability of DO at saturation (Allan et al. 2021). DO can also be affected by hydrological changes in streams, such as a decrease in oxygen due to reduced flows (Ahmadi and Moradkhani 2019). The standard for minimum DO concentration varies by state and stream designated use. It is 5 mg/L for Maryland streams, 4 to 6 mg/L for Virginia streams, 5 to 6 mg/L for West Virginia streams, and 5 mg/L in Washington, DC (COMAR 26.08.02.03-3; 9VAC25-260-50; W. Va. Code §§ 22-11-4(a)(16), 22-11-7b; D.C. Mun. Regs. tit. 21, §1104). In streams that support trout the higher standard is typically used.

1.3.3. Specific Conductance (Conductivity), Salinity, and Total Dissolved Solids (TDS)

Conductivity is a measure of the capacity of water to conduct an electrical current, which is a function of the types and quantities of dissolved ions in water (Radtke et al. 2005). Specific conductance is a conductivity measurement made at or corrected to 25°C and is the standardized method of reporting conductivity (USGS 2019). Natural stream specific conductance levels range from approximately 50 µS/cm in the Prince William Forest to over 250 µS/cm in Harpers Ferry (Olson and Cormier 2019). In this monitoring program, we measure specific conductance directly, using field sensors. From this measurement, we also derive salinity and total dissolved solids (TDS). Salinity refers to the sum of the concentrations of all dissolved electrically charged substances (ions) and therefore can be directly calculated from specific conductance. TDS corresponds to the total amount of dissolved materials (including but not limited to ions, thus including non-ionic dissolved substances as well), and can also be estimated from direct measurements of conductivity (Rusydi 2018).

Increases in stream salinity are associated with increases in impervious surface coverage from changing land use (Kaushal et al. 2005) and existing proportions of impervious surfaces in a watershed (Utz et al. 2022). 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, about 25 million tons of road salt are used each year, primarily in the Northeast and Midwest, and quantities have increased dramatically since 1950 (Hintz et al. 2022).

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 (Kaushal et al. 2023). Increased stream salinity can have profound implications for aquatic life (Silver and Donini 2021). Changes in the ion concentrations can affect osmoregulation (Cunillera-Montcusí et al. 2022; Hintz and Relyea 2019; Silver and Donini 2021) and can also result in other threats such as alkalization (Kaushal et al. 2013), mobilization of other contaminants such as toxic metals, base cations, and nutrients (Haq et al. 2018) and the facilitation of invasion of salt tolerant species (Kaushal et al. 2005).

Although there are no regulatory limits for salinity (or specific conductance) of freshwater streams in the National Capital Region, they can be screening indicators of likely high concentrations of chloride. Chloride is a primary component of road salts and other urban pollutants and can be toxic to aquatic life. The United States Environmental Protection Agency (EPA) recommends chloride should not be over 230 mg/L for acute toxicity and 860 mg/L for chronic toxicity for aquatic organisms (Benoit and Stephan 1988).

1.3.4. Water Temperature

In addition to decreasing DO, increases to stream temperatures can affect aquatic ecosystems by threatening temperature-sensitive fish populations, expanding the ranges of invasive species, and amplifying problems with freshwater pathogens (Ficke et al. 2007; Knouft and Ficklin 2017). Stream temperatures can respond almost linearly over time to increases in air temperature (Stefan and Preud'homme 1993) and can also be influenced by changing land use and hydrology (Ficklin et al. 2012). Maximum allowable water temperature standards vary by state and stream designated use, but are as low as 20°C for Maryland and Virginia coldwater streams and can be as high as 32°C for some stream uses (COMAR 26.08.02.03-3; 9VAC25-260-50; W. Va. Code §§ 22-11-4(a)(16), 22-11-7b; D.C. Mun. Regs. tit. 21, §-1104).

1.3.5. Total Phosphorus

Phosphorus is frequently a limiting nutrient in aquatic ecosystems. A minor increase in phosphorus concentration can significantly affect water quality by changing the population and community dynamics of algae and diatoms leading to eutrophication (Allan et al. 2021; Duhamel 2025; Carpenter et al. 1998). Phosphorus is singled out as an especially important indicator for the state of nation's ecosystems (Mackey 2003). Anthropogenic sources of phosphorus to aquatic ecosystems include excess fertilizer application, and discharge of wastewater treatment facilities (Allan et al. 2021; Duhamel 2025). A total phosphorus concentration of 0.01 mg/L is the published threshold for eutrophication of flowing surface waters for streams in the Central and Eastern Forested Uplands ecoregion (XI), which includes northwestern ANTI, CATO, CHOH, and HAFE (EPA 2000a). The total phosphorus threshold is 0.037 mg/L in the Southeastern Temperate Forested Plains and Hills ecoregion (IX) which includes southeastern CHOH, GWMP, MANA, MONO, NACE, PRWI, ROCR, and WOTR (EPA 2000b).

1.3.6. Total Nitrogen

Along with phosphorus, nitrogen is an essential element for life and often a limiting nutrient in aquatic ecosystems. Therefore, excess nitrogen may enhance the growth of algae and thus cause

eutrophication (Allan et al. 2021). Increased nitrogen concentrations in aquatic ecosystems result from many anthropogenic activities, including excess fertilizer applications, discharge from wastewater treatment facilities, and atmospheric precipitation enriched in nitrogen from fossil fuel burning (Allan et al. 2021). The drinking water standard for nitrate, which presents human health concerns, particularly for infants, is 10 mg/L (40 CFR 141.11). A reference total nitrogen concentration of 0.69 mg/L is estimated as a threshold for susceptibility to eutrophication in water bodies of Nutrient Ecoregion IX which includes southeastern CHOH, GWMP, MANA, MONO, NACE, PRWI, ROCR, WOTR (EPA 2000b), while 0.31 mg/L is estimated for Nutrient Ecoregion XI which includes northwestern ANTI, CATO, CHOH, and HAFE (EPA 2000a).

1.3.7. Water Quantity

This protocol includes various metrics associated with stream water quantity: instantaneous streamflow (discharge), water velocity, channel wetted width, and channel depth. These metrics are important because they influence the distribution of suspended sediment, bed material, dissolved and particulate organic matter, and other chemical substances as well as riverine biota (Statzner et al. 1988; Vannote et al. 1980; Vannote and Minshall 1982). Discharge combines with other channel and basin conditions to influence meander pattern and floodplain dynamics (Gore 2007; Leopold et al. 1964), which are important in providing habitat for riverine biota. Discharge, and therefore water velocity, depth, and width, vary seasonally under natural conditions, however any extreme variation can be stressful to organisms and damaging to the physical environment (Allan et al. 2021). Land use change (e.g., urban or agricultural developments) and climate change can disrupt discharge regimes with many negative implications for stream biota (Coles et al. 2012; Allan et al. 2021; Knouft and Ficklin 2017).

1.3.8. Turbidity

Turbidity is the measure of relative clarity of a liquid. Turbidity is often measured as a proxy for suspended sediment in aquatic systems because nowadays it can be measured inexpensively with in-situ sensors and does not require laboratory analysis. High turbidity can indicate impacts to habitat and productivity of aquatic ecosystems (Bilotta and Brazier 2008). Turbidity is useful for detecting episodic pulses of suspended sediment during storm events and chronic sources of sediment loading or suspension during baseflow. In Maryland coldwater and warmwater streams, the water quality standards for turbidity are 150 Nephelometric Turbidity Units (NTU) for acute events or 50 NTU for monthly averages (COMAR 26.08.02.03-3).

1.4. Mission, Goal, and Objectives

The *mission* of this NCRN protocol is to monitor whether water quality and quantity in park streams is suitable for well-functioning, native ecological communities. The overarching *goal* is to determine the status and trends, in selected indicators, of the condition of park aquatic ecosystems. Indicators of water quality and quantity included in this protocol were selected to allow managers to make informed decisions for the benefit of park resources.

The measurable *objectives* of the protocol are:

1. Monitor water quality parameters and water quantity in priority streams of NCRN parks following an established monitoring schedule and quality assurance and quality control guidelines.
2. Assess stream condition and trends in relation to biological thresholds, EPA and state standards, park ecological needs, previous variability, or changes in land use, habitat, climate, hydrology, and biological communities.
3. Communicate findings by creating user-friendly reports and visualizations that enable internal and external stakeholders to easily use up-to-date information for decision making and promptly share evidence of abnormal conditions.
4. Publish curated data annually through a public repository such as the Water Quality Portal.

Early versions of this protocol indicated that developing rating curves for monitored streams was a measurable objective. Due to the highly variable flow regime of NCRN streams and constantly shifting stream morphology, the NCRN I&M Program concluded that there is no reasonable approach for us to accurately and consistently develop rating curves for all NCRN streams. The program will still monitor flow and calculate discharge during stream monitoring events.

2. Sampling Design

2.1. Site Selection and Justification

At the beginning of the implementation of the protocol, a 2005 version of the National Hydrography Dataset (NHD) was used to identify streams that could be sampled. The original sampling site design (including active and inactive sites) was developed in 2005. Sites of significant value to park managers were selected based on the following criteria:

- Approved by the parks
- 1st–4th Strahler order perennial streams based on NHD data
- Wadeable
- Non-tidal
- Must have at least 250 m of stream length in a park to match Maryland Biological Stream Survey criteria
- Preference for downstream locations in the watershed within a park
- Safe from water-related hazards such as deep water, high velocities, or obstructions (e.g., deep muck in stream margins).
- In 2024, the requirement was added to have sufficient water depth and flow to regularly collect a quality discharge measurement
- In 2024, the requirement was added to have reasonable access, which includes travel times not being detrimental to other efforts and no logistical barriers such as landowner permissions

The C&O Canal National Historical Park was excluded because of a multitude of sites that only had small parts of their watersheds within park boundaries and were not considered the most relevant from a management standpoint. The remaining locations of sites were chosen to be a complete census of streams from all parks besides C&O that met the criteria. The sites were chosen to make inferences about water quality at the level of a stream, which is still a primary goal, while alternative inferences could be at the network or park level.

2.2. Watersheds Being Monitored

A list of currently monitored sites can be found in Table 2. As of September 2025, there are 37 actively monitored NCRN sites out of 55 total that have historic data. NCRN is scheduled to add 15 sites into active monitoring starting January 2026. Sites are divided into two panels that are sampled in alternating years: Panel 1 and Panel 2 (Table 2).

They have a diverse sampling of forest and urban watershed land cover and NPS ownership, but generally have a low amount of agricultural land cover, have <25 km² watersheds, and are largely located in two parks (PRWI and ROCR), although WOTR and ROCR have the greatest number of monitoring sites per mile of stream in the park (Figure 2). Further, the proportion of NPS protected

land in the watersheds of the monitoring sites ranges from <1% to 100%, providing information that could inform decisions for internal resources management vs. engagement with external stakeholders to address water quality concerns at the watershed level.

Table 2. Active water quality monitoring sites excluding CHOH streams.

X	Y	Site Name	I&M Name	State	County	Stream Order	Designated Use	Nutrient Ecoregion	Start Date	Panel
-77.730833	39.461389	Newcomer Spring	ANTI_NECS	MD	Washington	1	MD Class IV-P: Recreational Trout Waters and Public Water Supply	XI: Central and Eastern Forested Uplands	2026	1
-77.737697	39.454865	Sharpsburg Creek	ANTI_SHCK	MD	Washington	1	MD Class IV-P: Recreational Trout Waters and Public Water Supply	XI: Central and Eastern Forested Uplands	2005	2
-77.440368	39.626189	Big Hunting Creek	CATO_BGHC	MD	Frederick	2	MD Class III-P: Nontidal Cold Water and Public Water Supply	XI: Central and Eastern Forested Uplands	2005	1 & 2
-77.450901	39.634406	Blue Blazes Creek	CATO_BLBZ	MD	Frederick	1	MD Class III-P: Nontidal Cold Water and Public Water Supply	XI: Central and Eastern Forested Uplands	2005	1
-77.48529676	39.68821586	Braestrup Creek	CATO_BRCK	MD	Frederick	1	MD Class III-P: Nontidal Cold Water and Public Water Supply	XI: Central and Eastern Forested Uplands	2026	2
-77.4334758	39.6496875	Lower Owens Creek	CATO_LOWC	MD	Frederick	3	MD Class III-P: Nontidal Cold Water and Public Water Supply	XI: Central and Eastern Forested Uplands	2026	1 & 2
-77.481524	39.661079	Owens Creek	CATO_OWCK	MD	Frederick	2	MD Class III-P: Nontidal Cold Water and Public Water Supply	XI: Central and Eastern Forested Uplands	2005	2
-77.139134	38.968009	Minnehaha Creek	GWMP_MICR	MD	Montgomery	2	MD Class I-P: Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-77.256152	38.999879	Mine Run	GWMP_MIRU	VA	Fairfax	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.119019	38.93047	Pimmit Run	GWMP_PIRU	VA	Arlington	3	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-77.083909	38.901179	Spout Run	GWMP_SPRU	VA	Arlington	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.157642	38.963418	Turkey Run	GWMP_TURU	VA	Fairfax	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.75226481	39.30766426	Chestnut Hill Run	HAFE_CHRU	WV	Jefferson	1	WV Class B2: Trout Waters	XI: Central and Eastern Forested Uplands	2026	1
-77.792258	39.295894	Flowing Springs Run	HAFE_FLSP	WV	Jefferson	2	WV Class B2: Trout Waters	XI: Central and Eastern Forested Uplands	2005	2

Table 2 (continued). Active water quality monitoring sites excluding CHOH streams.

X	Y	Site Name	I&M Name	State	County	Stream Order	Designated Use	Nutrient Ecoregion	Start Date	Panel
-77.511934	38.818704	Youngs Branch	MANA_YOBR	VA	Prince William	3	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.385437	39.369106	Bush Creek	MONO_BUCK	MD	Frederick	3	MD Class I-P: Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.388383	39.368724	Visitor's Center (Gambrill Mill) Creek	MONO_GAMI	MD	Frederick	2	MD Class I-P: Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-76.9591095	38.8808863	Fort Dupont Stream (south)	NACE_FTDS	DC	Washington	1	DC Class A,B,C,D (primary & secondary contact, aquatic life, and public health)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-76.95765433	38.88139564	Fort Dupont Stream	NACE_FTDU	DC	Washington	1	DC Class A,B,C,D (primary & secondary contact, aquatic life, and public health)	IX: Southeastern Temperate Forested Plains and Hills	2006–2007, 2026	2
-76.900598	38.834636	Henson Creek	NACE_HECR	MD	Prince Georges	1	MD Class I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life	IX: Southeastern Temperate Forested Plains and Hills	2006	1
-77.00851075	38.81081684	Oxon Cove Run	NACE_OXCO	MD	Prince Georges	2	MD Class I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.007154	38.812212	Oxon Run	NACE_OXRU	MD	Prince Georges	2	MD Class I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-76.914102	38.972984	Still Creek	NACE_STCK	MD	Prince Georges	1	MD Class I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life	IX: Southeastern Temperate Forested Plains and Hills	2006	1
-76.952054	38.90818	Watts Branch	NACE_WABR	DC	Washington	3	DC Class A,B,C,D (primary & secondary contact, aquatic life, and public health)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.364022	38.566619	Boneyard Run	PRWI_BONE	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2010	1

Table 2 (continued). Active water quality monitoring sites excluding CHOH streams.

X	Y	Site Name	I&M Name	State	County	Stream Order	Designated Use	Nutrient Ecoregion	Start Date	Panel
-77.364625	38.56654	Carter's Run	PRWI_CARU	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2007	1
-77.4120605	38.6062228	Farms to Forest Run (south)	PRWI_FFRS	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.39957144	38.60773607	Farms to Forest Run	PRWI_FFRU	VA	Prince William	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.3722877	38.5669699	Liming Run (south)	PRWI_LIRS	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	1
-77.36993512	38.56997015	Liming Run	PRWI_LIRU	VA	Prince William	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	1
-77.417682	38.577732	Mawavi Run	PRWI_MARU	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2008	2
-77.360687	38.568161	Mary Byrd Branch	PRWI_MBBR	VA	Prince William	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-77.347194	38.573661	North Fork Quantico Creek	PRWI_NFQC	VA	Prince William	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.3992257	38.60817983	North Fork Quantico Creek (north)	PRWI_NFQN	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2026	2
-77.357087	38.563458	Orenda Run	PRWI_ORRU	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2008	1
-77.347458	38.572656	South Fork Quantico Creek	PRWI_SFQC	VA	Prince William	3	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.381641	38.576509	Sow Run	PRWI_SORU	VA	Prince William	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1
-77.375028	38.575762	Taylor Run	PRWI_TARU	VA	Prince William	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2007	1
-77.0995	38.920429	Battery Kemble	ROCR_BAKE	DC	Washington	1	DC Class A,B,C,D (primary & secondary contact, aquatic life, and public health)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2

Table 2 (continued). Active water quality monitoring sites excluding CHOH streams.

X	Y	Site Name	I&M Name	State	County	Stream Order	Designated Use	Nutrient Ecoregion	Start Date	Panel
-77.050406	38.944973	Broad Branch	ROCR_BRBR	DC	Washington	2	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.059144	38.915874	Dumbarton Oaks	ROCR_DUOA	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2007	1 & 2
-77.042248	38.98462	Fenwick Branch	ROCR_FEBR	DC	Washington	2	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.051825	38.933372	Klinge Valley Stream	ROCR_KLVA	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2009	2
-77.041676	38.961775	Luzon Branch	ROCR_LUBR	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.05609	38.919201	Normanstone Creek	ROCR_NOST	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2007	2
-77.043804	38.972074	Pinehurst Branch	ROCR_PHBR	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.046652	38.935659	Piney Branch	ROCR_PYBR	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2
-77.052385	38.938127	Reservation 630 Creek	ROCR_R630	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2005	2
-77.058869	38.91564	Rock Creek below Dumbarton Oaks	ROCR_ROC3	DC	Washington	4	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2007	1 & 2

Table 2 (continued). Active water quality monitoring sites excluding CHOH streams.

X	Y	Site Name	I&M Name	State	County	Stream Order	Designated Use	Nutrient Ecoregion	Start Date	Panel
-77.0596676	38.94599666	Soapstone Valley Stream (west)	ROCR_SVPW	DC	Washington	1	DC Class A,B,C,D,E (primary & secondary contact, aquatic life, public health, navigation)	IX: Southeastern Temperate Forested Plains and Hills	2026	1 & 2
-77.262544	38.939719	Courthouse Creek	WOTR_CHCK	VA	Fairfax	1	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2006	1
-77.269164	38.941158	Wolf Trap Creek	WOTR_WOTR	VA	Fairfax	2	VA Class III: Nontidal Waters (Coastal and Piedmont Zones)	IX: Southeastern Temperate Forested Plains and Hills	2005	1 & 2

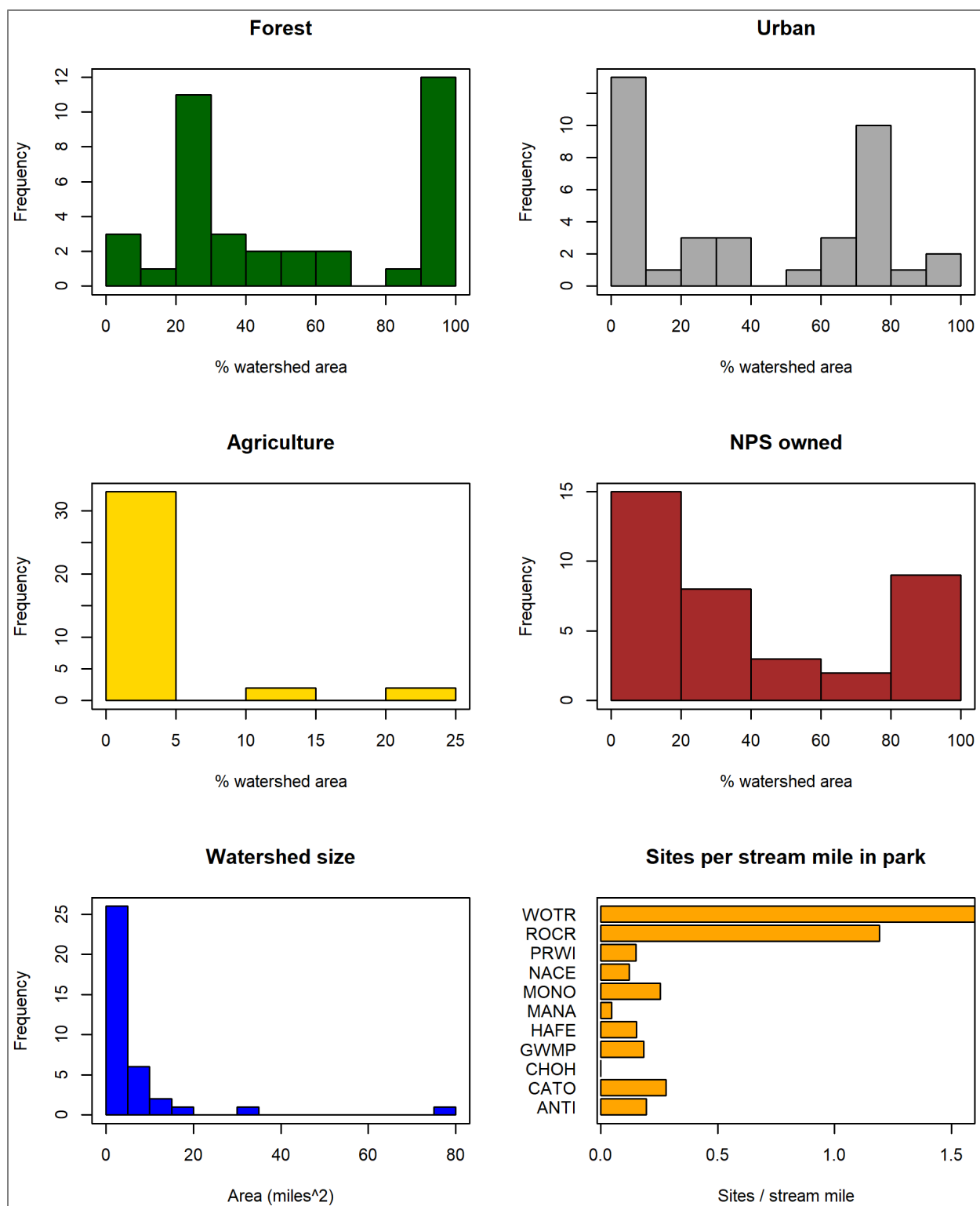


Figure 2. Distribution of watershed land cover (Dewitz and USGS 2021), NPS ownership, watershed sizes, and parks among the 37 NCRN water sites monitored as of September 2025.

NPS

2.3. Changes to the Sampling Frame

Since the inception of the monitoring protocol there have been changes to the sampling frame. Some streams have been removed for various reasons and in some cases new streams have been added.

Table 3 provides a summary of those changes:

Table 3. Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-77.7302	39.44978	ANTI_ANCR	Antietam Creek	ANTI_ANCR was monitored by NCRN for continuous water quality 2015–2018 and discrete water quality in 2015 and 2016. NCRN abandoned ANCR as a continuous water quality site when NCRN stopped continuous water quality monitoring in 2018. NCRN abandoned ANCR as a discrete water quality monitoring site in 2016 because it was determined not to be a wadeable stream.
-77.7308	39.46139	ANTI_NECS	Newcomer Spring	ANTI_NECS already exists as a NCRN BSS monitoring location, where it was only monitored in 2004. ANTI_NECS has never been monitored by NCRN for discrete or continuous water quality. Originally it was deemed to have too low of flow for a monitoring site. NCRN visited ANTI_NECS in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.4509	39.63441	CATO_BLBZ	Blue Blazes Creek	Site name “Whiskey Still Creek” (CATO_WHST) retired and replaced by “Blue Blazes Creek” (CATO_BLBZ) in 2023
-77.4853	39.68822	CATO_BRCK	Braestrup Creek	CATO_BRCK has never been monitored by NCRN for BSS or water quality under this or any other I&M Location ID (IMLOCID). NCRN visited CATO_BRCK in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.4335	39.64969	CATO_LOWC	Lower Owens Creek	CATO_LOWC has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. Owens Creek was historically monitored at CATO_OWCK. CATO_LOWC is the lowest reach of Owens Creek and is distinct from CATO_OWCK; they are different places, and NCRN plans to monitor both. The site was scouted in 2023 and decided it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.2444	38.97661	GWMP_DIRU	Difficult Run	GWMP_DIRU was monitored by NCRN for discrete water quality 2005–2009. The site was abandoned in 2009 because it was unsafe to access. NCRN visited GWMP_DIRU in 2023 to determine its viability for discrete water quality monitoring and decided that it is still too unsafe to monitor and redundant with USGS gauge.

Table 3 (continued). Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-77.1083	38.9195	GWMP_DORU	Donaldson Run	GWMP_DORU was monitored by NCRN for discrete water quality in 2005. This site was abandoned for unknown reasons after 2005. NCRN visited GWMP_DORU in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring due to not meeting criteria for minimum length within the park.
-77.1142	38.925	GWMP_GUBR	Gulf Branch	GWMP_GUBR was monitored by NCRN for discrete water quality in 2005. This site was abandoned for unknown reasons after 2005. NCRN visited GWMP_GUBR in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring due to not meeting criteria for minimum length within the park.
-77.0839	38.90118	GWMP_SPRU	Spout Run	GWMP_SPRU has never been monitored by NCRN or BSS or water quality under this or any IMLOCID. Originally excluded because of access and safety issues due to location along parkway but decided it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.7523	39.30766	HAFE_CHRU	Chestnut Hill Run	HAFE_CHRU has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited HAFE_CHRU in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.5282	38.81768	MANA_CHBR	Chinn's Branch	MANA_CHBR was monitored by NCRN for discrete water quality in 2005–2008. This site was abandoned after 2008 because it was believed not to be perennial. NCRN visited MANA_CHBR in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring.
-77.544	38.81412	MANA_DOBR	Dogan's Branch	MANA_DOBR was monitored by NCRN for discrete water quality in 2005–2008. This site was abandoned after 2008 because it was believed not to be perennial. NCRN visited MANA_DOBR in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring.

Table 3 (continued). Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-77.5073	38.81572	MANA_HOBR	Holkum Branch	MANA_HOBR was monitored by NCRN for discrete water quality in 2005–2008. This site was abandoned after 2008 because it was believed not to be perennial. NCRN visited MANA_HOBR in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring.
-77.4007	39.35919	MONO_HARU	Harding's Run	MONO_HARU was monitored by NCRN for discrete water quality in 2005–2008. This site was abandoned after 2008 because it was believed not to be perennial. NCRN visited MONO_HARU in 2023 to determine its viability for discrete water quality monitoring and decided that it was unsuitable for monitoring.
-77.0541	38.6908	NACE_ACCK	Unnamed tributary to Accokeek Creek (NACE – PISC)	NACE_ACCK was monitored by NCRN for discrete water quality and BSS 2004–2012. This site was abandoned because it is influenced by tidal flows and is occasionally dry. NCRN did not visit NACE_ACCK in 2023 to determine its viability for discrete water quality monitoring and decided that it was not suitable for monitoring because of tidal influence.
-76.9591	38.88089	NACE_FTDS	Fort Dupont Stream (south)	NACE_FTDS has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. The stream called “Fort Dupont Stream” was historically monitored by NCRN for discrete water quality at NACE_FTDU. NACE_FTDS is distinct from NACE_FTDU; they are different places, and NCRN plans to monitor both. Scheduled for monitoring to start 2026.
-76.9577	38.8814	NACE_FTDU	Fort Dupont Stream	NACE_FTDU was monitored by NCRN for discrete water quality in 2006–2007. The site was abandoned in 2007 for unknown reasons. NCRN visited NACE_FTDU in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.0085	38.81082	NACE_OXCO	Oxon Cove Run	NACE_OXCO has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. The stream called “Oxon Run” was historically monitored by NCRN for discrete water quality at NACE_OXRU. NACE_OXCO is distinct from NACE_OXRU; they are different places, and NCRN plans to monitor both. Scheduled for monitoring to start 2026.

Table 3 (continued). Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-76.9521	38.90818	NACE_WABR	Watts Branch	NACE_WABR has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited NACE_WABR in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.3641	38.56659	PRWI_BONE	Boneyard Run	This stream was added to the sampling frame in 2010, as it was a 1 st order stream that had been missed earlier.
-77.4121	38.60622	PRWI_FFRS	Farms to Forest Run (south)	PRWI_FFRS has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited PRWI_FFRS in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.3996	38.60774	PRWI_FFRU	Farms to Forest Run	PRWI_FFRU has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited PRWI_FFRU in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.3723	38.56697	PRWI_LIRS	Liming Run (south)	PRWI_LIRS has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited PRWI_LIRS in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.3699	38.56997	PRWI_LIRU	Liming Run	PRWI_LIRU has never been monitored by NCRN for BSS or water quality under this or any other IMLOCID. NCRN visited PRWI_LIRU in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.4237	38.55774	PRWI_MBCH	Middle Branch Chopawamsic Creek	PRWI_MBCH was monitored by NCRN for discrete water quality and BSS 2004–2011. MBCH was retired because field crews must access it through Quantico Marine Reservation, which is a security risk. NCRN visited PRWI_MBCH in 2023 to determine its viability for discrete water quality monitoring and decided that it was not suitable for monitoring because it is still difficult to access.

Table 3 (continued). Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-77.3992	38.60818	PRWI_NFQN	North Fork Quantico Creek (north)	PRWI_NFQN has never been monitored by NCRN for water quality or BSS. The creek called “North Fork Quantico Creek” is monitored under PRWI_NFQC. NCRN visited PRWI_NFQN in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.
-77.4258	38.56503	PRWI_NOBR	North Branch Chopawamsic Creek	PRWI_NOBR was monitored by NCRN for discrete water quality and BSS 2004–2011. NOBR was retired because field crews must access it through Quantico Marine Reservation, which is a security risk. NCRN visited PRWI_NOBR in 2023 to determine its viability for discrete water quality monitoring and decided that it was not suitable for monitoring because it is still difficult to access.
-77.4008	38.54838	PRWI_NOCH	North Branch Chopawamsic below Confluence with Middle Branch	PRWI_NOCH was monitored by NCRN for discrete water quality monitoring 2005–2009. NOCH was retired for unknown reasons in 2009. NCRN visited PRWI_NOCH in 2023 to determine its viability for discrete water quality monitoring and decided that it was not suitable for monitoring because it is too deep and is not a wadeable stream.
-77.3472	38.57194	PRWI_QUIR	Quantico Creek	PRWI_QUIR was monitored by NCRN for discrete water quality monitoring in 2005. QUIR was retired for unknown reasons in 2005. As of 2024, NCRN does not monitor the mainstem “Quantico Creek”. Instead, NCRN monitors the “North Fork Quantico Creek” at site PRWI_NFQC, and “South Fork Quantico Creek” at site PRWI_SFQC. PRWI_QUIR is distinct from PRWI_NFQC, PRWI_SFQC, and retired site PRWI_SFQR; they are different places, and NCRN plans to only monitor PRWI_NFQC and PRWI_SFQC.
-77.353	38.56654	PRWI_SFQR	South Fork Quantico Creek at Orenda Road	PRWI_SFQR was monitored by NCRN for discrete water quality monitoring in 2005. SFQR was retired for unknown reasons in 2005. As of 2024, NCRN monitors the stream called “South Fork Quantico Creek” at site PRWI_SFQC. PRWI_SFQR is distinct from PRWI_SFQC; they are different places, and NCRN plans to only monitor PRWI_SFQC.
-77.0505	38.92091	ROCR_EGWA	Rock Creek at Edgewater Stables	ROCR_EGWA was monitored by NCRN for discrete water quality in 2005 and 2006. NCRN retired EGWA after 2006 because NOST and DUOA made EGWA obsolete. EGWA was replaced by ROC3. NCRN visited ROCR_EGWA in 2023 to determine its viability for discrete water quality monitoring and decided that it was not suitable for monitoring.

Table 3 (continued). Changes to the sampling frame for NCRN water sites.

X	Y	I&M Name	Site Name	Change
-77.0524	38.93813	ROCR_R630	Reservation 630	Site name “Hazen Creek” (ROCR_HACR) retired and replaced by “Reservation 630” (ROCR_R630) in 2023.
-77.043	38.98403	ROCR_ROCR	Rock Creek at Fenwick Branch	ROCR_ROCR was monitored by NCRN for discrete water quality 2005–2008. NCRN retired ROCR_ROCR after 2008 because it was not a wadeable stream. ROCR_ROCR is a site on the mainstem of Rock Creek. As of 2024, NCRN monitors the mainstem of Rock Creek at ROCR_ROC3.
-77.0518	38.94526	ROCR_SVPS	Soapstone Valley Stream	ROCR_SVPS was monitored by NCRN for discrete water quality 2005–2012. NCRN retired SVPS after 2012 because it was determined that this site falls outside Park Service land boundaries.
-77.0597	38.946	ROCR_SVPW	Soapstone Valley Stream (west)	ROCR_SVPW has never been monitored by NCRN for water quality or BSS. However, SVPW is a site on the stream called “Soapstone Valley Stream”, which was historically monitored at site ROCR_SVPS. ROCR_SVPS was retired after 2012 and remained un-monitored since. As of 2025, NCRN plans to monitor the stream called “Soapstone Valley Stream” at site ROCR_SVPW. ROCR_SVPW is distinct from ROCR_SVPS; they are different places on the same stream. NCRN visited ROCR_SVPW in 2023 to determine its viability for discrete water quality monitoring and decided that it was suitable for monitoring. Scheduled for monitoring to start 2026.

2.4. Sites That Were Considered but Not Included

During the fall of 2023 and winter of 2024, an investigation of potential new sites to add to the monitoring schedules was performed after examining the 2023 National Hydrography Dataset revealed potential additional streams. Table 4 lists sites that were surveyed but not included in the monitoring program, as well as providing the reason. Additionally, several additional sites were identified as meeting the site selection criteria and are being incorporated into monitoring schedules.

Table 4. Potential monitoring sites that were considered but not included in the protocol. “SCOUT” ending indicates a site was scouted in person, but no monitoring took place.

X	Y	I&M Name	Site Name	Reason
-77.7262081	39.4693691	ANTI_MUSP_SCOUT	Mumma Spring (south)	Dry. Confirmed dry downstream of old BSS sites near confluence with Antietam creek in 2023
-77.7371627	39.4452847	ANTI_SNFO_SCOUT	Snavelly Ford Creek	Dry. Confirmed in 2023.
-77.4826738	39.6817064	CATO_ADCK_SCOUT	Adirondack Creek	Flow too low, difficult access. In 2023, confirmed previous assessment of stream.
-77.4792821	39.6719913	CATO_MZCK_SCOUT	Mount Zion Creek	Flow too low. Similar for nearby unnamed tributary. Confirmed in 2023.
-77.484718	39.6584077	CATO_NBOW_SCOUT	North Branch Owens Creek	Flow too low. In 2023, decided that it is the upstream reach of CATO_OWCK. Good flow at the site.
-77.485364	39.658398	CATO_NBON_SCOUT	North Branch Owens Creek (north)	Dry. Confirmed dry in 2023.
-77.4847985	39.6581167	CATO_SBOU_SCOUT	South Branch Owens Creek	Flow too low and intermittent. Confirmed in 2023
-77.484775	39.658359	CATO_SBON_SCOUT	South Branch Owens Creek (north)	In 2023, confirmed that it does not flow through the park for >75 m.
-77.45561716	39.67143763	CATO_PGCK_SCOUT	Poplar Grove Creek	In 2023 the site was found to be flowing but accessing too difficult to be included as a new site. The nearest parking area is over 1km away from the site and the hike to the site is difficult. It would be a viable site if new lands are acquired by the park allowing for closer access.
-77.4563	39.670799	CATO_PGCS_SCOUT	Poplar Grove Creek (south)	Access: Parking is 1.3 km away, through thicket or train tracks. In 2023, found that the reach was not long enough within park. Located south of CATO_PGCK
-77.083909	38.901179	GWMP_SPRU	Spout Run	Access and safety issues due to location along parkway.
-77.17405	38.965186	GWMP_DERU	Dead Run	Access and safety issues due to location along parkway
-77.751358	39.307646	HAFE_CHRE_SCOUT	Chestnut Hill Run (east)	In 2023 found that the stream was an intermittent stream that runs into HAFE_CHRU
-77.3974547	39.3489202	MONO_SBVR_SCOUT	South Baker Valley Run	Mostly outside of the park and hard to access, with infrequent flow. Confirmed in 2023.
-77.3879397	39.3667705	MONO_WGAM_SCOUT	West Fork Gambrill Mill	Dry. Confirmed in 2023.
-77.387876	39.366777	MONO_SGAM_SCOUT	South Fork Gambrill Mill	Dry. Considered upstream reach of MONO_GAMI. Confirmed in 2023.

Table 4 (continued). Potential monitoring sites that were considered but not included in the protocol. “SCOUT” ending indicates a site was scouted in person, but no monitoring took place.

X	Y	I&M Name	Site Name	Reason
-77.3971249	39.3580009	MONO_TFRU _SCOUT	Thomas Farm Run	Dry. Confirmed in 2023.
-77.3952538	39.3498605	MONO_NBVR _SCOUT	North Baker Valley Run	Dry. Confirmed in 2023.
-76.957462	38.9080619	NACE_HIRU _SCOUT	Hickey Run	Tidal and difficult to access. Confirmed in 2023
-76.942877	38.910745	NACE_KERU _SCOUT	Kenilworth Run	In 2023, not long enough within park before it becomes tidal
-77.008363	38.8107099	NACE_OXCN _SCOUT	Oxon Cove Run (north)	In 2023, decided it was not a long enough reach before it exits the park
-77.0084587	38.810659	NACE_OXCS _SCOUT	Oxon Cove Run (south)	In 2023, found it is a perennial stream flowing through a concrete channel, but it was decided it was the main branch of OXCO and therefore redundant
-77.0076368	38.809805	NACE_OXCW _SCOUT	Oxon Cove Run (west)	In 2024, found perennial stream flowing from pond within interior of park. Considered continuation of mainstem of OXCO
-77.0075568	38.8098287	NACE_OXCE _SCOUT	Oxon Cove Run (east)	In 2024, found perennial stream flowing out of culvert, reach too short within park to be included.
-76.8862456	38.9810294	NACE_SBSC _SCOUT	South Branch Still Creek	Not wadeable and stagnant flow due to beaver dams. Confirmed in 2023.
-76.8861875	38.9810963	NACE_NBSC _SCOUT	North Branch Still Creek	Not wadeable and stagnant flow due to beaver dams. Confirmed in 2023.
-77.4043235	38.5525755	PRWI_JORU _SCOUT	Joplin Run	Access difficult due to remoteness and therefore not selected to be monitored. In 2023, appears perennial and about 1/2–1m wide, 10cm+ deep.
-77.4010984	38.5501452	PRWI_BREC _SCOUT	Breckenridge Run	Access difficult due to remoteness and therefore not selected to be monitored. In 2023, appears perennial and about 1–2m wide with 20cm depth.
-77.402421	38.551132	PRWI_NOCN _SCOUT	North Branch Chopawamsic Creek (north)	Access difficult due to remoteness and therefore not selected to be monitored. In 2023, was found to have intermittent flow
-77.400106	38.549423	PRWI_NOCS _SCOUT	North Branch Chopawamsic Creek (south)	Access difficult due to remoteness and therefore not selected to be monitored. In 2023, it appears to be perennial

Table 4 (continued). Potential monitoring sites that were considered but not included in the protocol. “SCOUT” ending indicates a site was scouted in person, but no monitoring took place.

X	Y	I&M Name	Site Name	Reason
-77.3425669	38.5697957	PRWI_BRRU _SCOUT	Brittany Run	<75 m in park at base of watershed. In 2023, confirmed earlier observations. Upstream reaches have access from the Brittany neighborhood but access to lower reaches of the stream is beyond the reasonable travel time/distance for site access
-77.4121397	38.6069038	PRWI_FFRW _SCOUT	Farms to Forest Run (west)	In 2023, decided that it is the upstream reach of PRWI_FFRU and therefore not selected to be monitored
-77.401323	38.607487	PRWI_FFRE _SCOUT	Farms to Forest Run (east)	In 2023, found to not be long enough to meet criteria and therefore not selected to be monitored
-77.3725333	38.5672064	PRWI_LIRW _SCOUT	Liming Run (west)	In 2023, decided that it is the upstream reach of PRWI_LIRU and therefore not selected to be monitored
-77.2629067	38.9394479	WOTR_WOTS _SCOUT	Wolf Trap Creek (west)	In 2023, decided that it is the upstream reach of WOTR_WOTR and therefore not selected to be monitored

2.5. Sampling Frequency and Replication

Currently, all parameters are measured every two months. The *in-situ* measurements (temperature, pH, DO, specific conductance (including derived salinity and TDS), and turbidity), and water quantity are determined utilizing handheld instrument(s). For ANC and nutrients (nitrogen and phosphorus), grab water samples are collected, and laboratory analysis is conducted. Additional measurements may be taken opportunistically.

2.6. Sampling Frequency History

The protocol was implemented in May of 2005, and streams were sampled on a monthly basis from October 2005 until October 2013, when the decision was made to reduce the sampling frequency to quarterly. At that time, the network decided to add continuous monitoring to get a greater level of detail for many streams. Discrete sampling was reduced to quarterly to achieve that within available resources, while still obtaining seasonal data.

Quarterly sampling continued through the 2017 water year (September 30, 2017). Starting October of 2017, sampling frequency was increased to bi-monthly. NCRN stopped continuous water quality monitoring in 2018.

The history of NCRN water monitoring parameters, sensors, and analytical methods is presented in Table 5.

Table 5. History of NCRN water monitoring parameters, sensors, and analytical methods. “X” indicates sensor (or method) used, “–” indicates sensor (or method) not used.

Parameter	Sensor / Method	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Acid neutralizing capacity	In-house Hach Method 8203	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–
	Hach Method 8203 (Chesapeake Lab)	–	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–
	USGS Alk. & ANC (Chesapeake Lab)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	USGS Alkalinity and Acid Neutralizing Capacity methods (Appalachian Lab)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X
Air temperature	Thermometer	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ammonia ^A	In-house	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–
Discharge	Marsh McBirney Flow-Mate 2000	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	FlowTracker	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	–	–	–	–
	FlowTracker2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X
Dissolved oxygen	YSI 85 (polarographic)	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X
Nitrate / total nitrogen	Nitrate (in-house Hach Methods 8039, 8171, and 8192)	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Nitrate (in-house, Hach Method 10020)	–	–	–	X	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–
	TN (Chesapeake Lab EPA 353.2 Automated Colorimetry)	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–
	TN (Appalachian Lab EPA 353.2 Automated Colorimetry)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X
pH	YSI 100	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI 63	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X

^A Starting in 2011, ammonia no longer monitored.

^B Not monitored (Monitoring proposed to start in 2026).

Table 5 (continued). History of NCRN water monitoring parameters, sensors, and analytical methods. “X” indicates sensor (or method) used, “–” indicates sensor (or method) not used.

Parameter	Sensor / Method	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Phosphate / total phosphorus	TP (in-house Hach Methods 8190 and 8178)	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Orthophosphate (in-house Hach Method 8048)	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	TP (in-house Hach Method 8190)	–	–	–	–	–	X	X	X	X	X	X	–	–	–	–	–	–	–	–
	TP (Chesapeake Lab EPA 365.1 Semi-Automated Colorimetry)	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–
	TP (Appalachian Lab EPA 365.1 Semi-Automated Colorimetry)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X
Salinity	YSI 85	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X
Specific conductance	YSI 85	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X
Total dissolved solids	YSI 85	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X
Turbidity ^B	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Water depth	Wading rod	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water temperature	YSI 100	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI 63	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI 85	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	YSI ProPlus	–	–	–	–	–	X	X	X	X	X	X	X	X	X	–	–	–	–	–
	YSI ProDSS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	X
Wetted width	Measuring tape	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

^A Starting in 2011, ammonia no longer monitored.

^B Not monitored (Monitoring proposed to start in 2026).

3. Field and Laboratory Methods

This section presents Standard Operating Procedures (SOPs) for implementing water chemistry monitoring and stand-alone SOPs for procedures such as permitting and field safety. These SOPs are maintained and updated by the NCRN I&M Program.

3.1. Field Season Preparations and Equipment Setup

Tasks, Project Timeline, and individual responsibilities are described in the following SOP:

- [NCRN WCQ SOP #1: Roles, and Responsibilities, and Project Timeline](#)

Before leaving for the field site, review the following standard operating procedures (SOPs) related to conducting field work and making site visits:

- [NCRN WCQ SOP #2: Safety](#)
- [NCRN WCQ SOP #3: Field and Laboratory Preparation](#)

3.2. Sampling Events and Measurements

At each field site, collect samples and record data following the SOP:

- [NCRN WCQ SOP #4: Field Data Collection](#)

3.3. Post-Sampling and End-of-Season Procedures

Upon completing field work, return data, equipment, and samples to the lab and process water samples according to the following SOPs:

- [NCRN WCQ SOP #5: Post-sampling Duties](#)
- [NCRN WCQ SOP #6: Data Management](#)
- [NCRN WCQ SOP #7: Data Analysis and Reporting](#)
- [NCRN WCQ SOP #8: History of NCRN Measurements and Lab Analyses](#)

4. Data Management, Analysis, and Reporting

4.1. Data Management

The NCRN water monitoring program collects data that are highly valued by parks, NCRN I&M, and the National Capital Region as a whole. These data will be used to justify management actions and inform decision making processes that are ongoing in parks in the NCRN. In order to ensure the long-term usefulness of the data, the NCRN must ensure the data are of high quality and maintained in a secure manner that guarantees that the information will be useable and available long into the future. The data management procedures applied to this protocol are in place to make sure that the NCRN goals of quality, security, and usability are met (Figures 3–4).

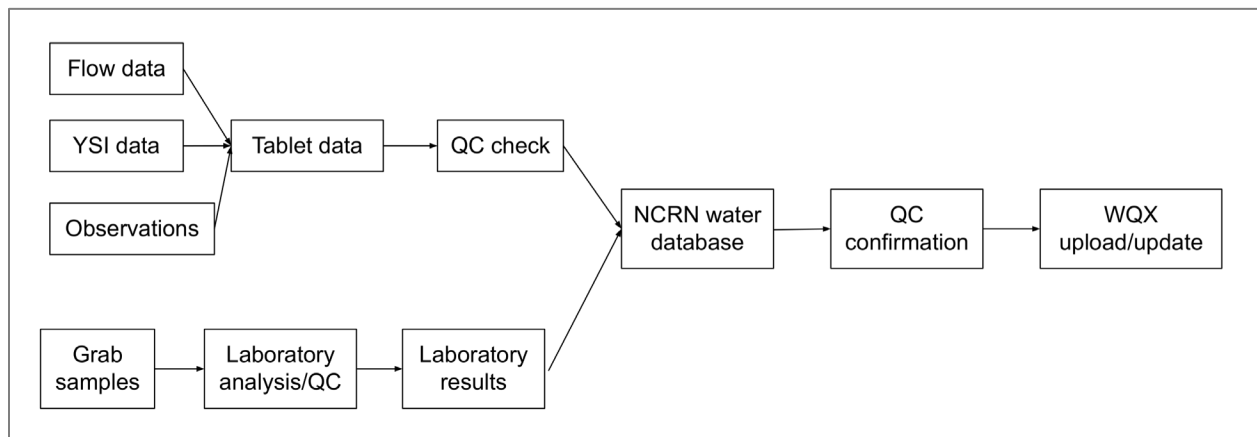


Figure 3. Schematic of NCRN water data workflow.

NPS

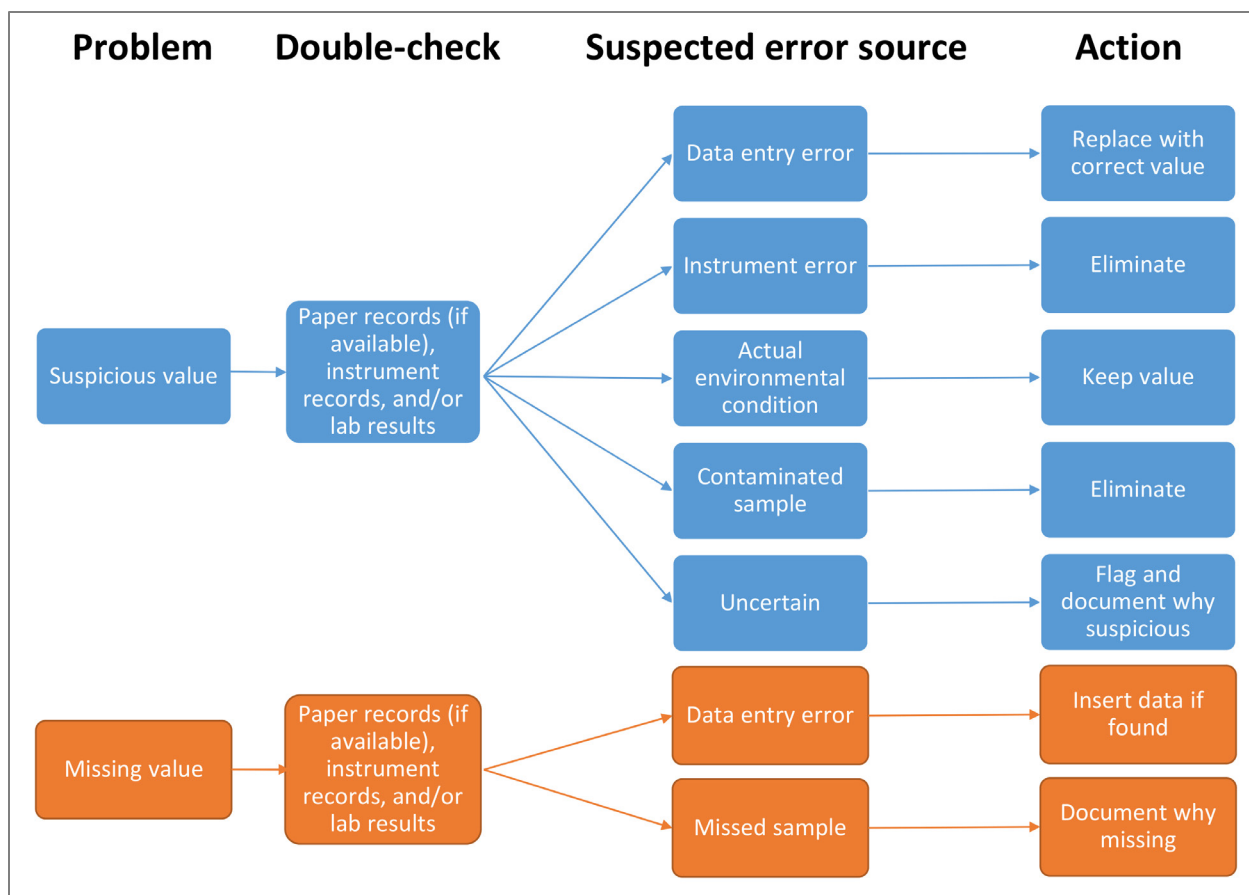


Figure 4. Decision tree for evaluating suspicious or missing data.

NPS

4.2. Data Analysis

The analysis of discrete water monitoring data presents numerous challenges including accounting for measurements that fall below the detection or quantification limits of the chemical test, metrics that are influenced by seasonal changes, and how stream discharge can influence water chemistry. The state of the art for water analysis is constantly evolving and the NCRN will work to stay up to date. Given these complexities of the water data and the potential for changes to analytical methodologies, the specific methods and details of how the NCRN analyzes water data are not addressed in this document. Please refer to [SOP #7: Data Analysis and Reporting](#) for more details.

4.3. Reporting

Two of the primary goals of the I&M Program are to (1) integrate natural resource monitoring data into park planning, management, and decision making; and (2) share NPS accomplishments and information with other organizations. Accomplishing these goals means that I&M Networks need not only analyze the data but also publish and report data and results. Please refer to [SOP #7: Data Analysis and Reporting](#) for more details.

4.4. Protocol Evaluation

The NCRN water monitoring protocol will be evaluated at various levels. See [Protocol Review Guidance](#).

4.4.1. Operational Review

NCRN staff will meet annually following the completion of the annual water year sampling cycle to discuss the past sampling year. This review will typically focus on minor changes to field or safety SOPs and not major changes to the protocol narrative. The outcome of this review may trigger the republishing of SOPs.

4.4.2. Protocol Science Review

The NCRN will review and evaluate this protocol periodically following the latest guidance. This review will focus on ensuring that the protocol and procedures currently in place meet the protocol objectives and are producing data that are useful to park management. The outcome from this review may require republishing of this protocol narrative.

4.5. Data Archival Procedures

NCRN water data are transferred to the Water Quality Portal (<https://www.waterqualitydata.us/>) where they will be publicly available in perpetuity. A diagram of this procedure is shown in Figure 5.

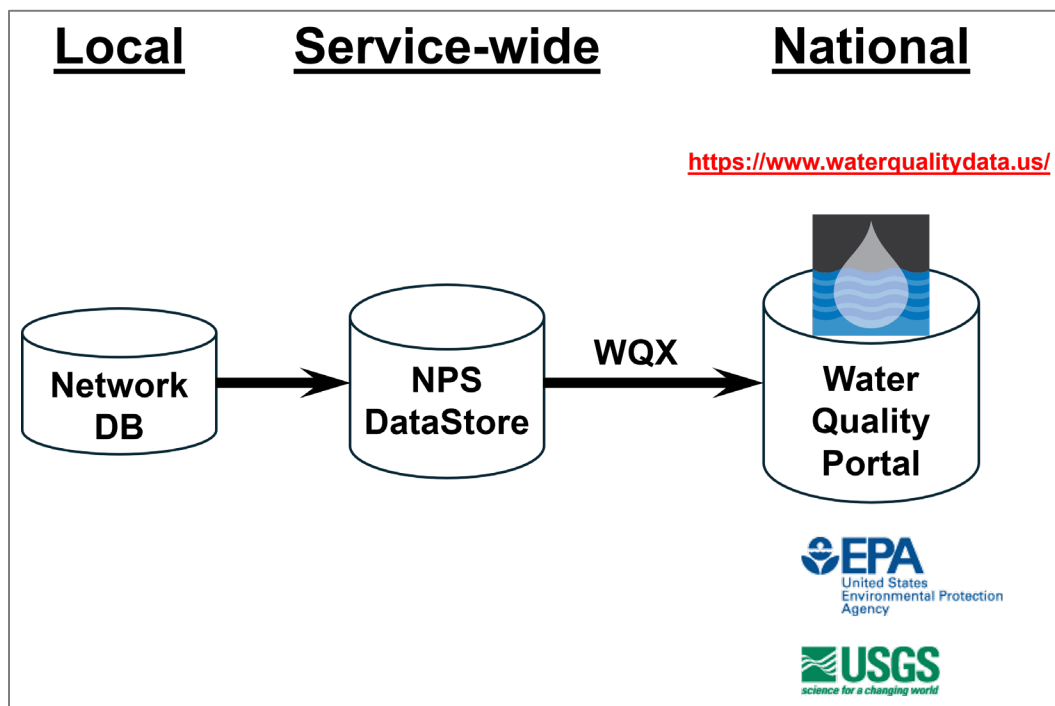


Figure 5. Diagram of the NCRN data distribution procedure.

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5. Personnel Requirements and Training

5.1. Roles and Responsibilities

Procedures for personnel requirements are described in [SOP #1: Roles, Responsibilities, and Project Timeline](#). In summary, the network staff involved with water vital signs may include the Biological Science Technician, Biologist, Data Manager, Regional Program Manager, Geographic Information Science Intern, Ecologist, and Data Scientist.

5.2. Training Procedures

Training procedures are described in [SOP #1: Roles, Responsibilities, and Project Timeline](#). In summary, staff will be trained to calibrate and operate field equipment, implement sampling procedures, safely work in the laboratory, and document data collection.

6. Operational Requirements

6.1. Annual Workload and Field Schedule

The field schedule and workload are described in [SOP #1: Roles, Responsibilities, and Project Timeline](#). In summary, sampling will occur throughout the year, followed by sample handling and data quality control procedures. An operational review and data upload to the Water Resources Division will also occur on an annual basis.

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National Park Service
U.S. Department of the Interior



Science Report NPS/SR—2025/362
<https://doi.org/10.36967/2315848>

Natural Resource Stewardship and Science

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