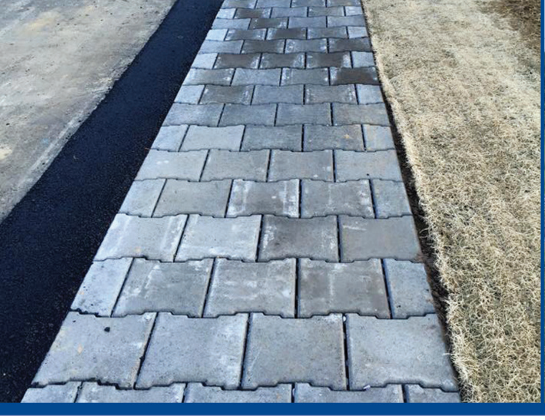

Prince George's County
Countywide Watershed Assessment for MS4 Permit (2014–2019)

December 21, 2018

Prince George's County
DEPARTMENT OF THE
ENVIRONMENT

Prince George's County
Countywide Watershed Assessment for MS4 Permit (2014-2019)

December 21, 2018

Prepared For

Prince George's County, Maryland
Department of the Environment
Stormwater Management Division

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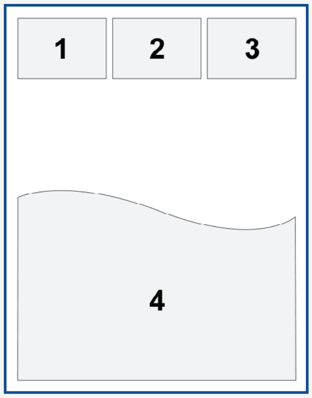

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Contents

Figures

Tables

ABBREVIATIONS AND ACRONYMS

ALT	alternative BMP technique
B-IBI	Benthic Index of Biological Integrity
BANCS	Bank Assessment for Non-Point Source Consequences of Sediment
BEHI	Bank Erosion Hazard Index
BMP	best management practice
BOD	biochemical oxygen demand
CAA	Clean Air Act of 1970
CAST	Chesapeake Assessment Scenario Tool
CWA	Clean Water Act
CWP	Clean Water Partnership
DO	dissolved oxygen
DoE	[Prince George's County] Department of the Environment
E3	everything by everyone everywhere
EPA	U.S. Environmental Protection Agency
IDDE	illicit discharge detection and elimination
LID	low impact development
MBSS	Maryland Biological Stream Survey
MD DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
mg/L	milligrams per liter
MS4	municipal separate storm sewer system
NEB	Northeast Branch
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
R1, R2, R3	round 1, 2, or 3 of countywide biological monitoring
R^2	coefficient of determination
ROW	right-of-way
RR	runoff reduction
SCA	stream corridor assessment
SR3	Sewer Repair, Replacement and Rehabilitation
SSO	sanitary sewer overflow
ST	stormwater treatment
STORET	STOrage and RETrieval
SWPPP	stormwater pollution prevention plan
TMDL	total maximum daily load
TN	total nitrogen

TP	total phosphorus
TS	trash score
TSS	total suspended solids
USGS	U.S. Geological Survey
VDEQ	Virginia Department of Environmental Quality
WIP	Watershed Implementation Plan
WLA	wasteload allocation
WSSC	Washington Suburban Sanitary Commission
WWTP	wastewater treatment plant

1 INTRODUCTION

On January 2, 2014, the Maryland Department of the Environment (MDE) issued Prince George's County (the County) a 5-year National Pollutant Discharge Elimination System (NPDES) permit for its municipal separate storm sewer system (MS4)—the County's fourth MS4 permit since 1993. An MS4 is a series of stormwater sewers owned by a municipal entity (e.g., the County) that discharges the conveyed stormwater runoff into a water body (e.g., the Northeast Branch [NEB]).

The County's MS4 permit states that "By the end of the permit term, Prince George's County shall complete detailed watershed assessments for the entire County." The permit term ends on January 1, 2019.

Specifically, Part IV.E.1 of the permit states the following:

1. Watershed Assessments

> *a. By the end of the permit term, Prince George's County shall complete detailed watershed assessments for the entire County. Watershed assessments conducted during previous permit cycles may be used to comply with this requirement, provided the assessments include all of the items listed in PART IV.E.1.b. below. Assessments shall be performed at an appropriate watershed scale (e.g., Maryland's hierarchical eight or twelve-digit sub-basins) and be based on MDE's TMDL analysis or an equivalent and comparable County water quality analysis.*
>
> *b. Watershed assessments by the County shall:*
>
> > *i. Determine current water quality conditions;*
> > *ii. Include the results of a visual watershed inspection;*
> > *iii. Identify and rank water quality problems;*
> > *iv. Prioritize all structural and nonstructural water quality improvement projects; and*
> > *v. Specify pollutant load reduction benchmarks and deadlines that demonstrate progress toward meeting all applicable stormwater WLAs.*

This watershed assessment report aggregates the findings at the 8-digit watershed scale used by state and federal agencies. As shown in Figure 1-1, all or part of 12 8-digit watersheds lie within the County (Figure 1-1). Figure 1-2 presents the area of each watershed and its percent of the County area.

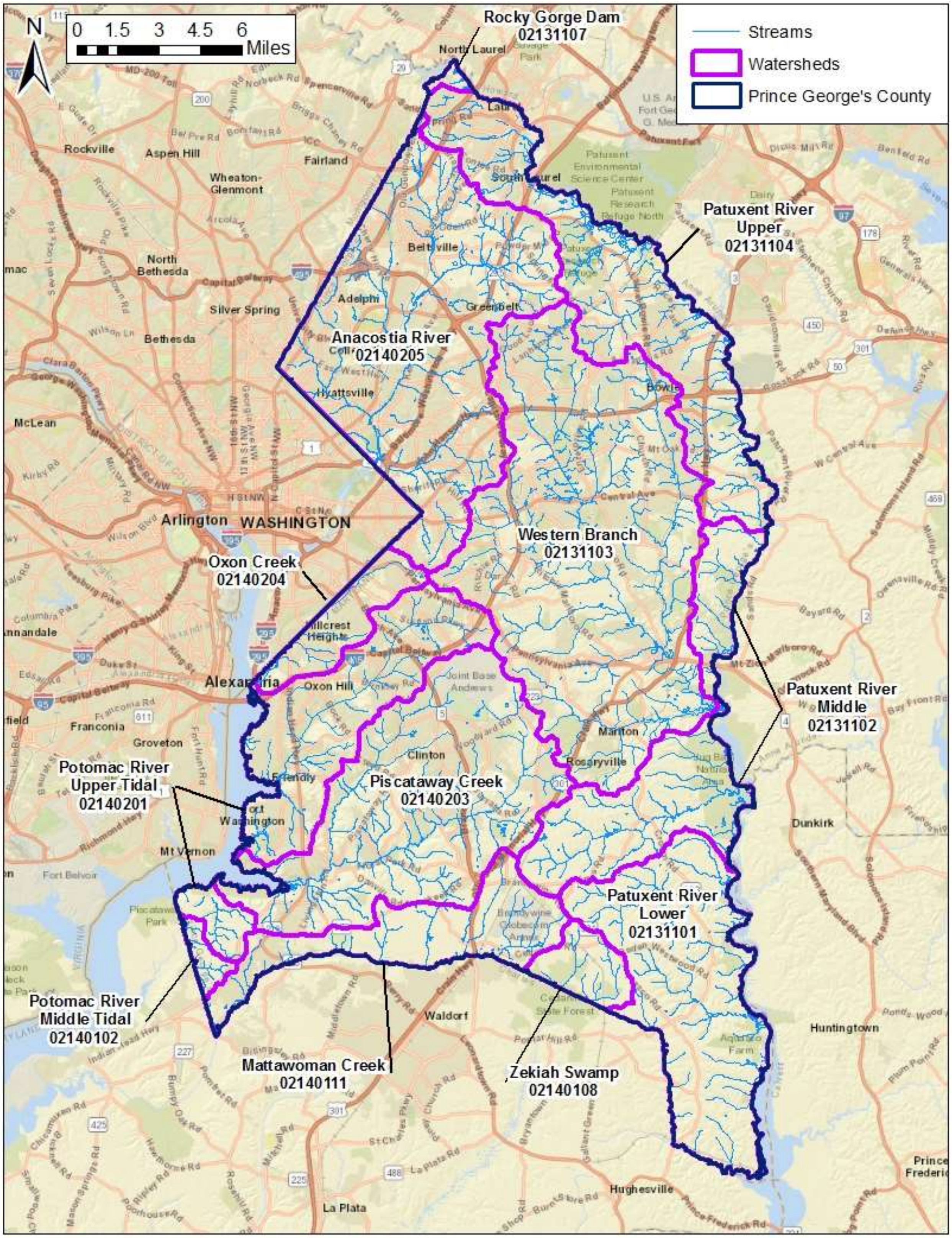

Figure 1-1. Locations of 8-digit watersheds in Prince George's County.

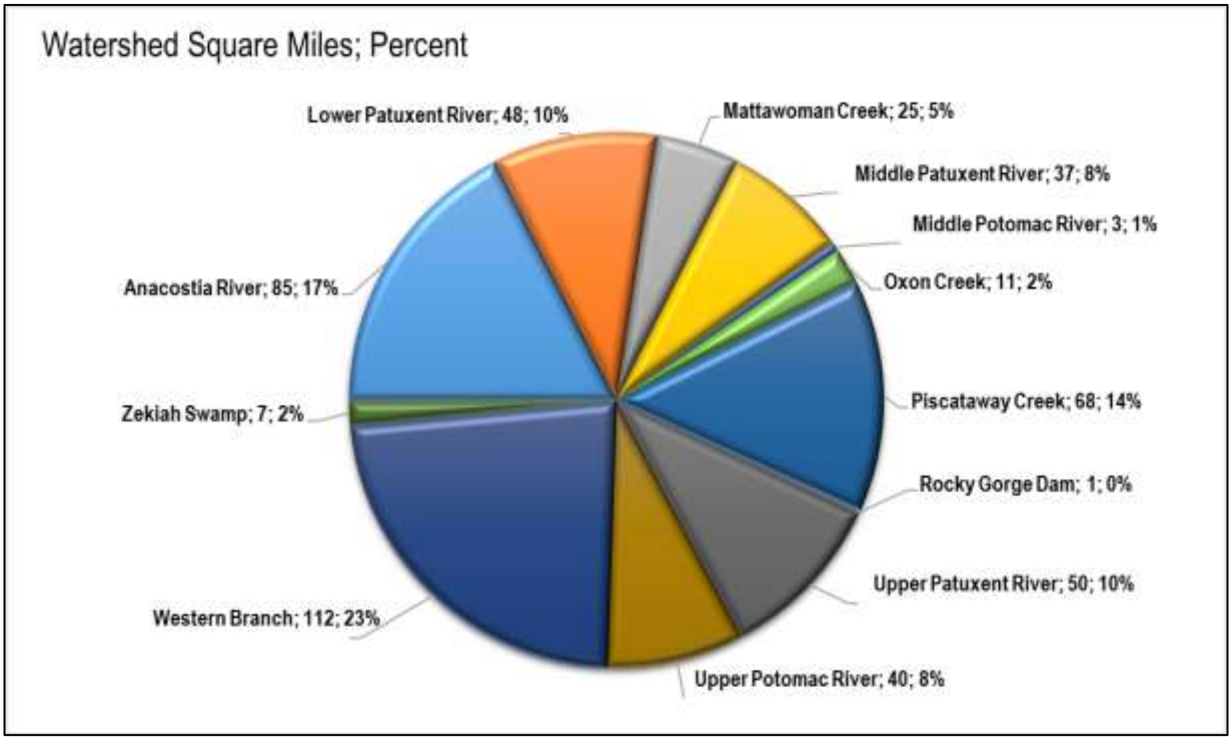

Figure 1-2. Watershed area in Prince George's County.

This report addresses the requirements of the NPDES MS4 permit pertaining to section E.1. The list below indicates the sections and appendices of the report in which section E.1.b items i through v are discussed.

Permit Requirement	Watershed Assessment Report Section(s)
i. Determine current water quality conditions	Section 2.1: Biological Assessment Section 2.2 & Appendix B: Water Quality Plots and Tables
ii. Include the results of a visual watershed inspection	Section 3.1 & Appendix C: Visual Inspection Photograph Comparisons Section 3.2: Trash Assessment Section 3.3: Illicit Discharge Detection and Elimination
iii. Identify and rank water quality problems	Section 4.1: Identifying Water Quality Issues Section 4.2: Ranking Priorities
iv. Prioritize all structural and nonstructural water quality improvement projects	Section 5.1: Water Quality Issues and Their Causes Section 5.3: Prioritizing Water Quality Improvement Practices Section 5.4 & Appendix D: Watershed Maps for the Prioritized BMP Locations
v. Specify pollutant load reduction benchmarks and deadlines that demonstrate progress toward meeting all applicable stormwater WLAs	Section 6: Load Reduction Benchmarks and Deadlines

Section 7 provides the main conclusions of the watershed assessment and the next steps in restoring and continuing assessments of the County's watersheds. In addition, appendix A provides supplemental background information that supports the assessments in the main text but is not part of the assessment. It discusses the sediment processes, a tool used to rank lateral erosion rates in streams, and stream order classification.

1.1 Prince George's County Impaired Waters

Under section 303(d) of the Clean Water Act (CWA), states must develop a list of "water-quality limited segments" or "impaired waters"—waters that will not meet the water quality standards associated with their designated use even after technology-based permits (e.g., industrial or wastewater discharges) are in place (Title 40 of the *Code of Federal Regulations* section 130.7). For each impaired water body, the state is required to either establish a total maximum daily load (TMDL) of the specified substance that the water body can receive without violating water quality standards or demonstrate via a water quality analysis that water quality standards are being met (USEPA 1991). Discharges to state waters are subject to permitting through the NPDES. If any NPDES-permitted facilities that discharge into a 303(d)-listed stream are shown or presumed to contribute a pollutant identified on the 303(d) list for that water body, the TMDL process requires that they be assigned a wasteload allocation (WLA). A WLA both defines and limits the amount of any pollutant that can be associated with the discharge. The 303(d) list provides the initial assessment of the County's waters.

Additional information on the designated uses of the water bodies in Prince George's County can be found on MDE's designated use website.[1] Most of the County's streams are Class I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), while the portions of the Anacostia, Potomac, and Patuxent rivers are Class II (Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting). Similarly, additional information on Maryland's water quality standards can be found MDE's website.[2]

1.1.1 Impaired Water Bodies

The County's MS4 has WLAs for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) from the Chesapeake Bay TMDL, which was developed to address water quality conditions in the Bay. Nutrient and TSS load reductions from County watersheds will be needed to meet water quality standards in the Chesapeake Bay and all County watersheds have target load reductions. These load reductions might not meet water quality standards in County rivers. The County also has WLAs from TMDLs for rivers in the County that address water quality in local streams and rivers. Table 1-1 lists the impaired water bodies in the County and identifies where TMDLs will eventually be developed by MDE or EPA, where and when TMDLs already have been developed, and where and when restoration plans, which lay out a path to improving water quality, have been developed. MDE lists the main water body in a watershed. All tributaries to that water body, impact the main water body.

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[1] https://mde.maryland.gov/programs/water/tmdl/waterqualitystandards/pages/wqs_designated_uses.aspx. Accessed December 6, 2018.

[2] https://mde.maryland.gov/programs/Water/TMDL/WaterQualityStandards/Pages/index.aspx. Accessed December 6, 2018.

Table 1-1a. TMDLs and restoration plans for impaired waters in Prince George's County

MD 8-digit watershed	TN	TP	TSS	Trash	BOD	*E. coli*	Entero-coccus	Fecal coliform	PCBs
Anacostia River	TMDL (2008)/RP (2014)	TMDL (2008)/RP (2014)	TMDL (2007)/RP (2014)	TMDL (2010)/RP (2014)	TMDL (2008)/RP (2014)		TMDL (2008)/RP (2014)		TMDL (2007 & 2011)/RP (2014)
Lower Patuxent River	CB (2010)	CB (2010)	CB/TMDL Needed					TMDL Needed	TMDL Needed
Mattawoman Creek	TMDL (2005)/RP (2014)	TMDL (2005)/RP (2014)							
Middle Patuxent River	CB (2010)	CB (2010)	CB (2010)/ TMDL Needed						TMDL Needed
Middle Potomac River	CB (2010)	CB (2010)	Insufficient Data						
Oxon Creek									TMDL (2007)/RP (2014)
Piscataway Creek	CB (2010)	CB (2010)	CB (2010)/ TMDL Needed			TMDL (2006)/RP (2014)			TMDL Needed
Rocky Gorge Dam		TMDL (2008)/RP (2014)							
Upper Patuxent River			TMDL (2011)/RP (2014)			TMDL (2010)/RP (2014)			
Upper Potomac River									TMDL (2007)/RP (2014)
Western Branch	CB (2010)	CB (2010)	CB (2010)		TMDL (1999)[a]				

Source: MDE 2018.

Notes: BOD = biochemical oxygen demand; CB = included in Chesapeake Bay TMDL, RP = restoration plan developed; *E. coli* = *Escherichia coli*; Insufficient Data = insufficient information is available to assess water quality standards; PCBs = polychlorinated biphenyls.

[a] TMDL did not include WLA for the County MS4; therefore, a stormwater restoration plan is not required.

Table 1-1b. TMDLs and restoration plans for impaired waters in Prince George's County

MD 8-digit watershed	Mercury	Heptachlor epoxide	pH	Chlorides	Sulfates	Channel-ization	Lack of riparian buffer	Oil spill–PAHs	Unknown Cause of Impairment[a]
Anacostia River		TMDL Needed		TMDL Needed	TMDL Needed	Impaired-not due to WQ	Impaired-not due to WQ		
Lower Patuxent River								Impaired, non-TMDL	TMDL Needed

MD 8-digit watershed	Mercury	Heptachlor epoxide	pH	Chlorides	Sulfates	Channelization	Lack of riparian buffer	Oil spill–PAHs	Unknown Cause of Impairment[a]
								pollution controls[b]	
Mattawoman Creek			TMDL Needed	TMDL Needed					
Middle Patuxent River					TMDL Needed				Insufficient Data
Middle Potomac River									
Oxon Creek									Insufficient Data
Piscataway Creek				TMDL Needed					
Rocky Gorge Dam									TMDL Needed
Upper Patuxent River	TMDL (Cash Lake only)[c]			TMDL Needed	TMDL Needed				
Upper Potomac River									TMDL Needed
Western Branch									TMDL Needed

Source: MDE 2018.

Notes: PAHs = polycyclic aromatic hydrocarbons; Insufficient Data = insufficient information is available to assess water quality standards; Impaired-not due to WQ = water body is listed as impaired by factor other than water quality.

[a] The listing is for general biological impairment and does not have a specified cause of impairment (MDE 2017).

[b] Impairment due to the April 7, 2000, oil spill. Only segments that have not met Phase I or Phase II cleanup status are considered impaired.

[c] TMDL did not include WLA for the County MS4; therefore, a stormwater restoration plan is not required.

1.1.2 Causes of Water Body Impairment

This section discusses the background and effects of the main pollutants of concern causing water quality impairments in the County. Identifying the environmental pathways and sources of these pollutants is key to understanding how to correct for water quality issues.

Nitrogen

Nitrogen is a nutrient that can enter surface waters in several ways: via runoff, as leachate from groundwater, as deposition from air pollution, or as a component of eroding stream banks. The nitrogen in fertilizers that stimulates the growth of crops will also stimulate the growth of aquatic vegetation when introduced to surface waters through stormwater runoff. The growth of large algal blooms becomes problematic when the algae die and decompose, depleting the water of dissolved oxygen (DO) and causing eutrophication. Advanced eutrophication can lead to anoxia (absence of oxygen) in which all DO is depleted from the water column and a “kill zone,” which cannot support aquatic life, develops.

Phosphorus

Like nitrogen, phosphorus enters surface water via stormwater runoff during runoff events or as a component of eroding streambanks. Phosphorous also stimulates the growth of aquatic vegetation and can contribute to eutrophication and anoxia. In addition, phosphorus can be adsorbed on sediment particles and carried along with the sediment as it moves downstream.

Total Suspended Solids

TSS are defined as particles carried in water and can be captured by a glass fiber filter that meets the requirements for TSS analysis. A major source of TSS is stream channel erosion, which moves soil particles into the water from both the stream banks and the stream bed. Much of the resulting suspended sediment generated during a runoff event can settle out in deposits as the water slows between events. But that sediment can be lifted into the water again the next time the streamflow increases.

Concentrations of TSS in a water body tend to increase as land is developed. Soil exposed during construction is eroded and can be delivered to receiving waters as fine sediment. After development, new impervious surfaces create more runoff more quickly to local streams and the higher and faster moving water in the streams increase the rate of erosion.

In addition to the erosive effects, excessive settling of sediment on the stream bed and into the gravel blocks the flow of fresh, oxygenated water into the substrate. This situation leads to the destruction of fish spawning beds, a loss of aquatic habitat, and an increase in the mortality rate of macroinvertebrates from damaged or clogged gills and loss of food sources. Suspended sediment blocks light transmission, which limits the growth and survival of submerged aquatic vegetation. Sediment and sediment deposits in tidal reaches can contribute to the demise of aquatic life there as well.

Fecal Bacteria

Fecal bacteria (e.g., Escherichia coli [*E. coli*], fecal streptococci, and enterococci) are single-celled pathogens found in the waste of warm-blooded animals, including humans. Pathogens are microscopic organisms known to cause disease or sickness in humans. Fecal bacteria can enter surface waters through leaking sewage and septic systems, stormwater runoff carrying pet waste, or direct deposit into the water. *E. coli* and enterococci are the most commonly monitored forms of fecal bacteria because they indicate the presence of untreated sewage, which often carries pathogens. Excessive amounts of fecal bacteria in surface waters indicate an increased risk of pathogen-induced illness to humans. These illnesses include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (USDA 1986). Pathogen-induced diseases are easily transmitted to humans through contact with contaminated surface waters, often through recreational contact or ingestion.

Biochemical Oxygen Demand and Dissolved Oxygen

DO is necessary to sustain many forms of aquatic life, including fish, invertebrates, and plants. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen needed to completely break down the amount of organic material in the water. Nutrients entering a natural water body will stimulate the production of organic material in the water body (e.g., algae and aquatic plants), and the increase in BOD will result in a reduction in DO unless mechanisms are at work to keep the water oxygenated (e.g., mechanical aerators or a high degree of natural turbulence).

Sulfates

Sulfates are mineral salts that occur when a mineral bonds with a sulfate ion. Sulfate is released into water when those mineral salts dissolve, and it gets into surface waters through both natural and anthropogenic processes. Natural sulfates result from the breakdown of rock formations and soils during interactions with water. Natural sulfates enter waterways through groundwater seepage. Anthropogenic processes that contribute sulfates to waterways include industrial and sewage treatment plant discharges and field fertilizer applications. In high amounts, sulfates in water can form acids and increase the solubility of metals (e.g., aluminum) and negatively affect fish health. Sulfates in low concentrations pose no risk to human health but at high concentrations can cause digestive problems that are reversible.

Chlorides

Chlorides are a family of compounds that each consists of a mineral bonded with a chloride ion and are soluble compounds that enter waterways through groundwater seepage. Chlorides are the result of interactions between water and rock and soils. Chlorides are also found in septic systems and can enter waterways as the result of leakage from a compromised septic system or softening agents entering the leachfield. In the winter chlorides might enter the waterways from deicing applications on the roadways. High chloride concentrations in freshwater systems interfere with the ability of aquatic organisms to retain an adequate amount of water in their tissues.

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are organic chlorine compounds once widely used in various industrial applications. Although domestic production was banned by Congress in 1979 through the implementation of the Toxic Substances Control Act, the widespread use of PCBs resulted in the legacy contamination of soils that still release the compounds into waterways today and the possibility that they might be found in materials produced before 1979. PCBs are released into the environment through sources such as poorly maintained hazardous waste sites that contain them, leaks or releases from electrical transformers containing them, and disposal of PCB-containing consumer products into municipal landfills not designed for hazardous waste. PCBs do not readily decompose once in the environment and accumulate in leaves, plants, small organisms, and fish. EPA regards PCBs as probable carcinogens in humans, and they have been proven to cause cancer in animals.

Heptachlor Epoxide

Heptachlor is a chemical once found in insecticides used in agriculture, especially on corn fields, or in industrial and household applications. Heptachlor epoxide is a chemical compound that results from the oxidation of heptachlor and is toxic to humans and animals. The sale, distribution, and shipment of heptachlor was prohibited in 1988 in the United States, but it still could be present in some soils as a legacy contaminant. Consequently, heptachlor can still enter waterways through bank erosion or in stormwater runoff.

1.2 Prince George's County Restoration Plans

As shown in Table 1-1, the County has developed restoration plans for all TMDLs in the County for which it received a WLA from MDE. These plans identify efforts to improve water quality in watersheds with impaired waters. Following is a list of these restoration plans

- Implementation Plan for the Anacostia River Watershed Trash Total Maximum Daily Load in Prince George's County. (EA 2015)
- Prince George's County, Maryland—Phase II Watershed Implementation Plan. (PGC DER 2012)
- Restoration Plan for the Anacostia River Watershed in Prince George's County. (Tetra Tech 2015a)
- Restoration Plan for the Mattawoman Creek Watershed in Prince George's County. (Tetra Tech 2015b)
- Restoration Plan for the PCB-Impacted Water Bodies in Prince George's County. (Tetra Tech 2015c)
- Restoration Plan for the Piscataway Creek Watershed in Prince George's County. (Tetra Tech 2015d)
- Restoration Plan for the Upper Patuxent River and Rocky Gorge Reservoir Watersheds in Prince George's County. (Tetra Tech 2015e)

October 31, 2014
DRAFT
Restoration Plan for the Upper Patuxent River and Rocky Gorge Reservoir Watersheds in Prince George's County

October 31, 2014
DRAFT
Restoration Plan for PCB-Impacted Water Bodies in Prince George's County

October 31, 2014
DRAFT
Restoration Plan for the Piscataway Creek Watershed in Prince George's County

October 31, 2014
DRAFT
Restoration Plan for the Mattawoman Creek Watershed in Prince George's County

October 31, 2014
DRAFT
Restoration Plan for the Anacostia River Watershed in Prince George's County

2 CURRENT WATER QUALITY CONDITIONS

For this watershed assessment, biological and water chemistry data from various sources were analyzed to determine the current water quality conditions in the County. The County conducts biological monitoring not only as part of its MS4 permit compliance, but also in a voluntary countywide monitoring program, which is discussed in this section. While the County also monitors water chemistry as part of complying with MS4 permit requirements, other organizations such as the MDE conduct additional water quality monitoring throughout the County. Data from both the County and other organizations also are discussed in this section.

2.1 Biological Assessment

2.1.1 *Assessment Methodology*

The Prince George’s County Department of the Environment (DoE) began its countywide, watershed-scale biological monitoring and assessment program in 1999. Since the initiation of the program, three rounds of assessments have provided biological data from more than 770 stream locations (Table 2-1 and Figure 2-1). Round 1 (R1) was carried out between 1999 and 2003, Round 2 (R2) between 2010 and 2013, and Round 3 (R3) between 2015 and 2017.

Table 2-1. Number of stream sites sampled by biological assessment round

MD 8-digit watershed	Number of sites assessed		
	R1	R2	R3
Anacostia River	64	44	45
Mattawoman Creek	13	15	15
Oxon Creek	4	5	5
Patuxent River lower	24	46	46
Patuxent River middle	17	10	10
Patuxent River upper	31	29	28
Piscataway Creek	29	31	34
Potomac River middle tidal	3	1	1
Potomac River upper tidal	25	18	18
Rocky Gorge	0	0	0
Western Branch	44	55	56
Zekiah Swamp	3	4	4
TOTAL	**257**	**258**	**262**

The County employs field sampling and data analysis protocols in the program that are comparable to the protocols used in the Maryland Department of Natural Resources (MD DNR) Maryland Biological Stream Survey (MBSS). Streams assessed are wadeable and generally first through third order, according to the Strahler (1957) system. The stream order designation uses the National Hydrography Dataset map scale of 1:100,000. The number of streams sampled in each watershed is proportional to the size of the watershed (Table 2-1). Sampling sites were selected along first through third order streams with a larger number of sites on smaller streams (e.g., first order); in addition to the 8-digit watersheds, sites are also stratified by subwatersheds.

Sampling sites are selected at the beginning of each 3-year assessment round. Appendix A provides more information about how the stream order is determined.

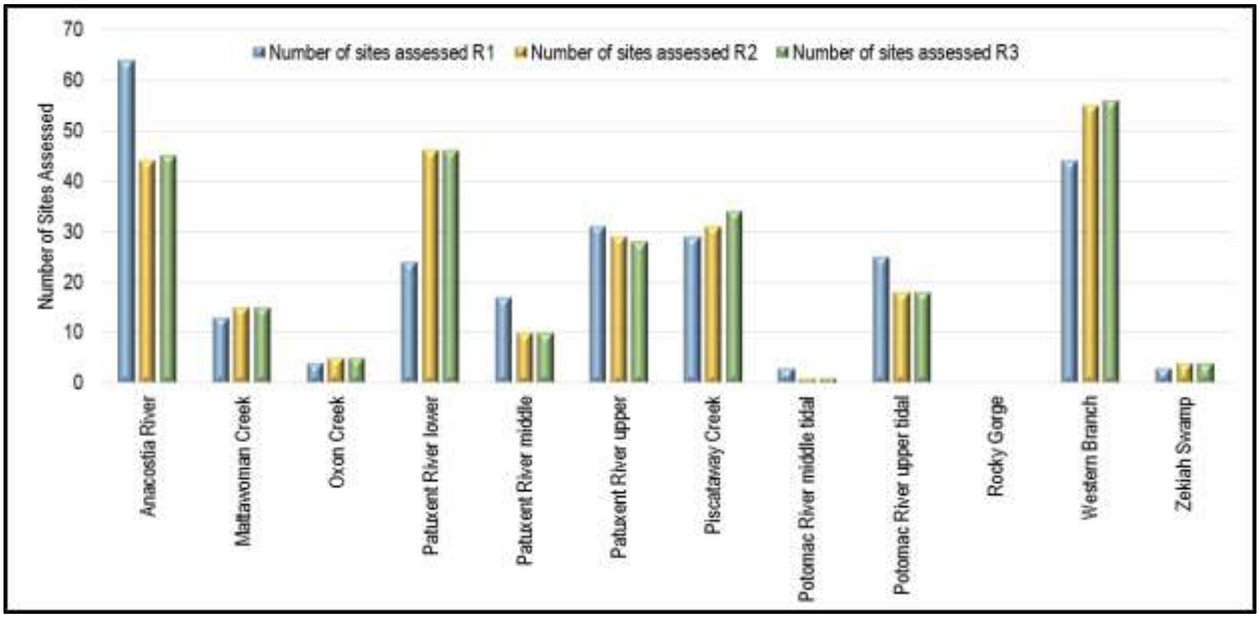


Figure 2-1. Number of stream sites sampled by biological assessment round.

At each location, samples and data were collected for benthic macroinvertebrates, visually evaluated physical habitat quality, substrate particle size distribution, and field chemistry (DO, conductivity, pH, and water temperature). Photographs were also taken facing upstream, downstream, and at each bank. The photographs document several features pertaining to stream conditions, including channel stability, riparian vegetation, visible flow characteristics (e.g., smooth or turbulent), and the presence of trash and other debris.

The primary measure of stream health is the Benthic Index of Biological Integrity (B-IBI) (Southerland et al. 2007). Because different stream conditions support different types of bottom-dwelling—or "benthic"—organisms, analyzing the benthic organisms collected along a stream reach can provide a good indication of the health of that reach. Other data on habitat and water quality are used to help describe the environment in which the benthic organisms are living.

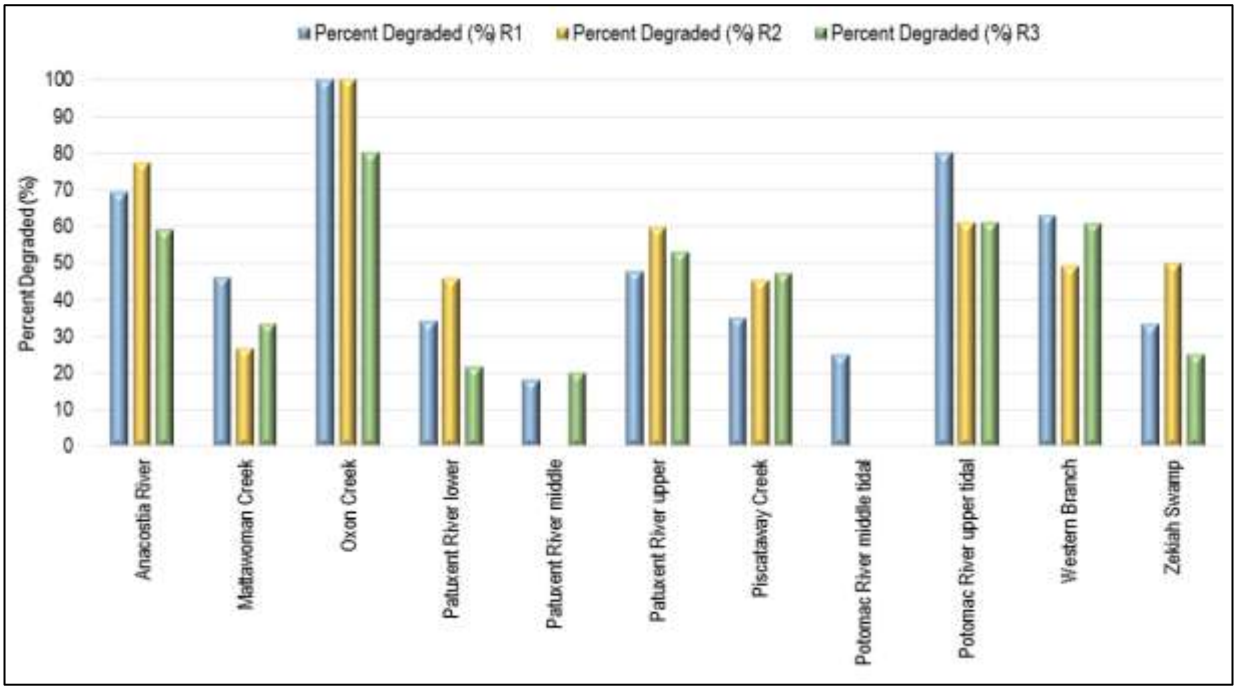
For the County's biological monitoring assessment, the field survey team sampled a 100-meter reach at each selected site. Laboratory technicians identified the samples each to a target taxonomic level, usually genus. The numbers of the different kinds of organisms found were used to calculate the B-IBI numeric value or score. Based on that score, the biological integrity was rated as Good, Fair, Poor, or Very Poor. Stream reaches rated as Poor or Very Poor are considered degraded. Physical habitat quality scores were rated as Optimal, Suboptimal, Marginal, or Poor based on cumulative scores along a 200-point scale.

2.1.2 Biological Assessment Results

Figure 2-2 shows the percentage of assessment locations considered degraded in each watershed, while Figure 2-3 and Figure 2-4 show the B-IBI ratings for each monitoring location and the percent of sites characterized as degraded in each watershed. Individual stream assessments for the County are available in a series of reports that can be obtained from the DoE Stormwater Management Division upon request.

Three of the 8-digit watersheds—Anacostia River, Western Branch, and Potomac River upper tidal—consistently had high percentages of degraded sites through all three assessment rounds (Figure 2-2). The relatively small Oxon Creek watershed consistently showed the highest percentages of degraded sites. There were no biological assessment locations in the Rocky Gorge watershed. The watersheds with lower percentages of degraded sites were generally in the eastern and southeastern parts of the County.

The relative amount of biological degradation observed across the County has been generally consistent through the three rounds of monitoring and assessment. The greatest amount of degradation is seen in the western "Beltway watersheds" and in the County's northern areas because of their more urbanized areas, while the areas with the least degradation are seen in the south and southeast. Table 2-2 ranks the watersheds by percent degradation from lowest to highest, by round. The rank order of the watersheds has not changed much, usually varying by only one or two rank positions between rounds. Summing the ranks across the rounds provides an overall indication of each watershed's position relative to the others. The Patuxent River middle and Potomac River middle tidal watersheds had the lowest percentage of degraded assessment sites. The Anacostia River, Potomac River upper tidal, and Oxon Creek watersheds had the highest percentage of degraded assessment sites.



Notes: Where bars for individual rounds are missing, assessments were 0% degradation (e.g., Patuxent River middle for R2). There were no assessment locations in the Rocky Gorge watershed.

Figure 2-2. Percent degradation per watershed by biological assessment round.

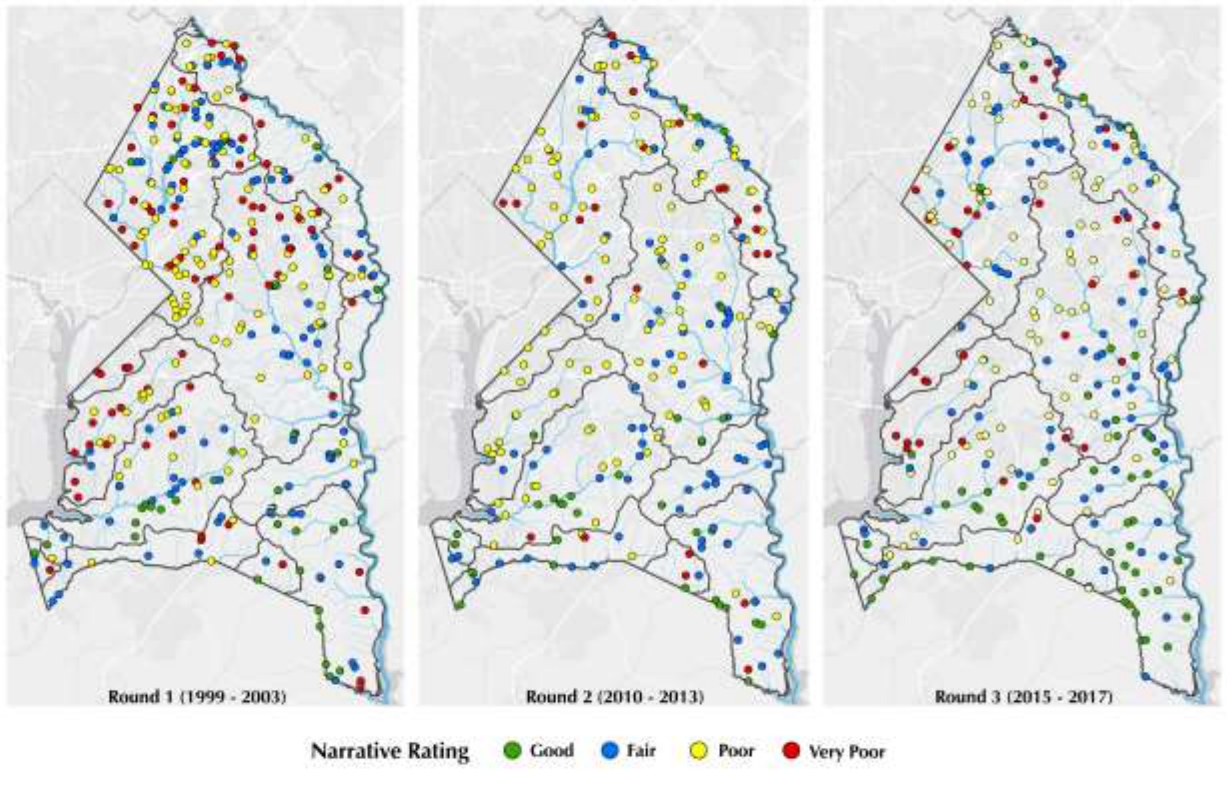


Figure 2-3. Biological assessment ratings by monitoring location.

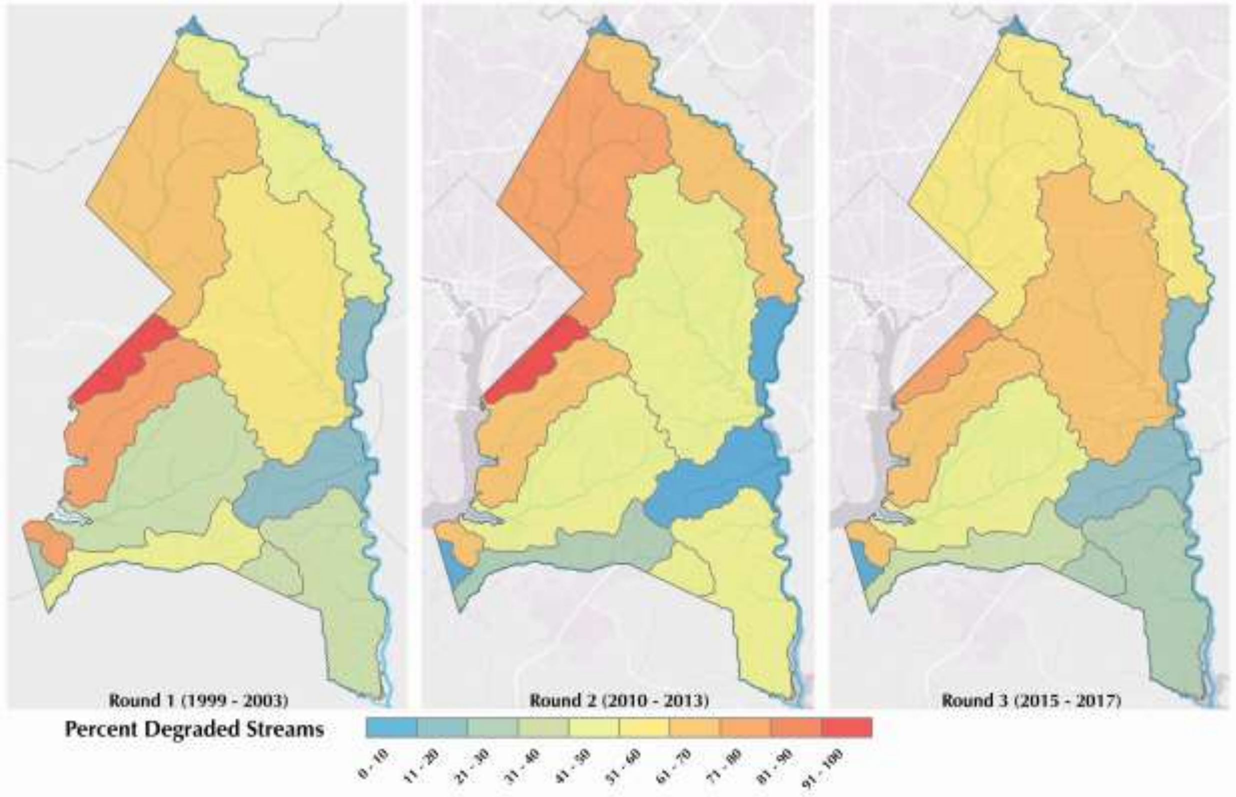


Figure 2-4. Biological assessment results (percent degraded) by major watershed.

Table 2-2. Rank orders per watershed by biological assessment round

MD 8-digit watershed	Rank			
	R1	R2	R3	Sum
Patuxent River middle	1	1	2	4
Potomac River middle tidal	2	2	1	5
Patuxent River lower	4	5	3	12
Mattawoman Creek	6	3	5	14
Zekiah Swamp	3	7	4	14
Piscataway Creek	5	4	6	15
Patuxent River upper	7	8	7	22
Western Branch	8	6	9	23
Anacostia River	9	10	8	27
Potomac River upper tidal	10	9	10	29
Oxon Creek	11	11	11	33
Rocky Gorge Dam	n/a	n/a	n/a	n/a

Notes: n/a = not applicable; there were no assessment locations in the Rocky Gorge Dam watershed.
Ranked by percent degradation from lowest to highest.

2.2 Water Quality Monitoring Data

Water quality data has been collected at various locations throughout the County. The water quality data provide insight into the health of the County's waterways and reflect progress toward reducing sources of impairment. The County currently measures water quality for concentrations of DO, TN, TP, and TSS as part of complying with its MS4 permit. MDE and the U.S. Geological Survey (USGS) also monitor water quality in the County. Figure 2-5 shows the locations of all known water quality monitoring stations.

Water quality monitoring data for each watershed were compiled from files maintained by the USGS, the U.S. Environmental Protection Agency (EPA) STORET (STOrage and RETrieval Data) Warehouse, and MDE. The initial compilation of data yielded over 104,000 records, which were then processed to remove duplicates and any records containing no parameter data or no data for the period from 2007 to 2018. Data from stations where the period of record was exceptionally short (e.g., < 10 records) were also removed. The resulting dataset provided measures of DO, *E. coli*, PCBs, TN, TP, and TSS.

Appendix B presents the data summaries for each watershed. The data come from both dry- and wet-weather monitoring events. It also includes maps that show the mean values of the measured concentrations of TN, TP, and TSS. Those maps are useful for determining which waterways have been historically problematic, especially if all three parameters have high mean values.

2.2.1 Trend Analysis

The monitoring data presented in appendix B were analyzed to identify any clear trends in water quality. The data meeting those criteria for each parameter and watershed were analyzed using a simple linear regression. This section discusses only stations with recent water quality data (i.e., after 2007) and at least 10 years of data.

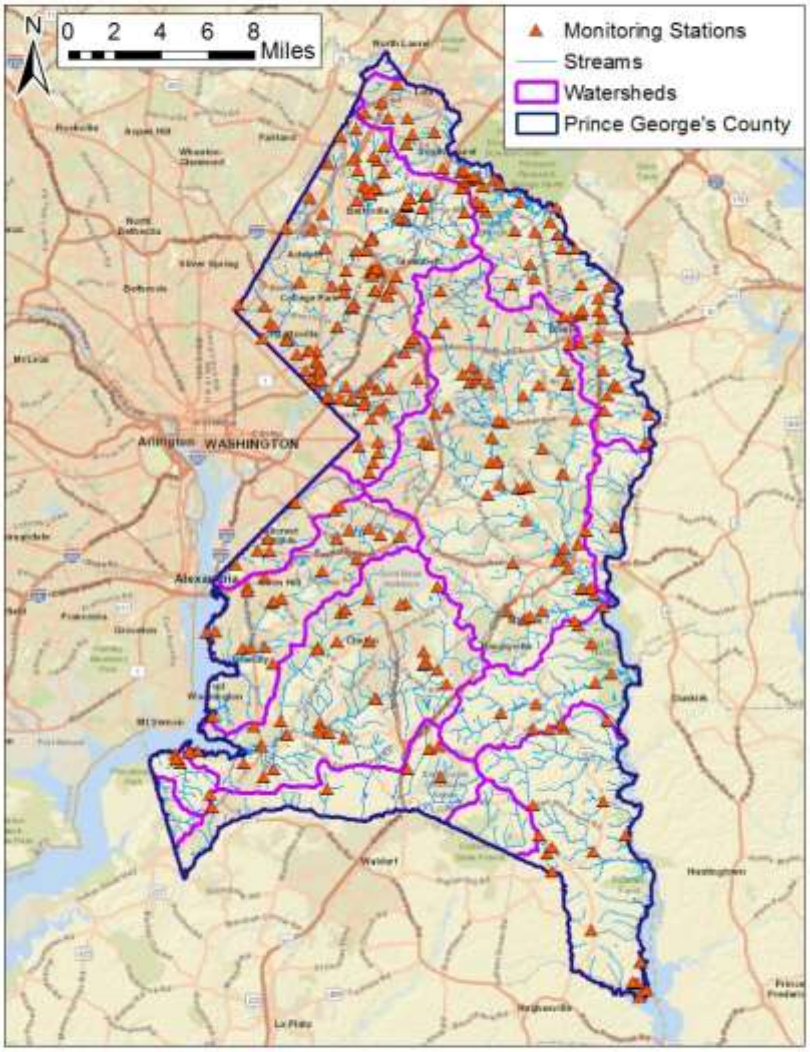


Figure 2-5. Locations of water quality monitoring stations.

The plots in appendix B display the value of the coefficient of determination (R^2) derived from the simple linear regression as a standard approach to describing the strength of any apparent trend. The R^2 value is a measure of how well the regression line represents the collection of data points. An R^2 value of 1.0 represents a perfect fit, meaning the line goes through all the data points. An R^2 value of 0.41 indicates a high degree of variability, or “scatter,” in the data, with only 41 percent of the variation explained by the trend line, while 59 percent is unexplained. The R^2 values in the graphs in appendix B range from 0.00007 (Figure 2-6) to 0.4158 (Figure 2-7).

Appendix B also contains maps that display the average of each water quality parameter by monitoring station. Analysis of the average of water quality data reveals no correlation between water quality and location along the waterway, similar to the results of the analysis of water quality data over time. This result reflects the complexity of water quality analysis and the variability of water quality data at each station.

Water quality in waterways is in a constant state of flux, as reflected in the scattering of observed TN, TP, and TSS concentrations. Water quality also changes significantly along the length of a stream because of the different kinds of pollutant releases from point sources and nonpoint sources, and as a result of various mechanisms that cause dilution, settling, and changes in chemical composition, point source discharges, and nonpoint sources.

A review of the data plots in Appendix B shows that nutrient concentrations are decreasing, and recent data shows less scatter than in previous years. For bacteria and TSS, concentrations are slightly increasing at some stations, and slightly decreasing at others, with little change in concentration scatter. Over the past 10 years, there has been efforts from multiple entities to reduce nutrients and sediment discharged into the Chesapeake Bay. These efforts have had positive effects on the County’s local water bodies. Wastewater treatment plants (WWTPs) have increased their level of treatment, thus reducing nutrients. There have been phosphorus bans in detergents and new fertilizer guidance. Additionally, the County and developers have installed a significant number of stormwater best management practices (BMPs) in recent decades.

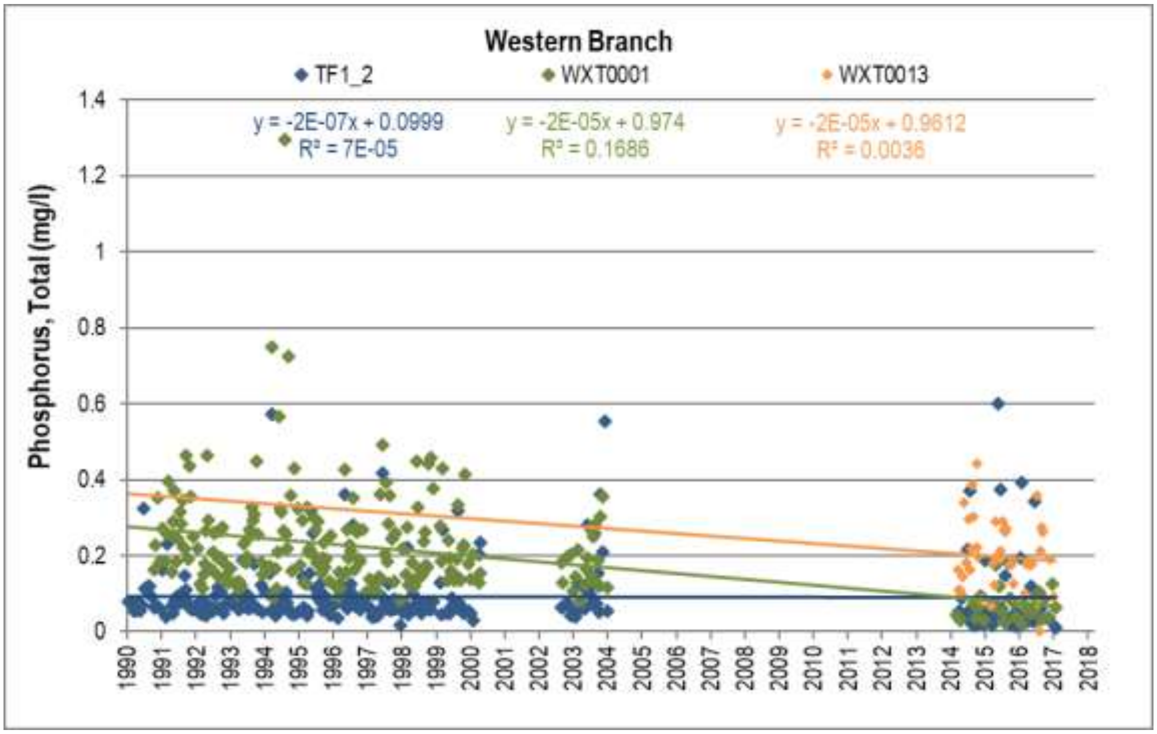


Figure 2-6. Plot of TP over time in the Western Branch watershed.

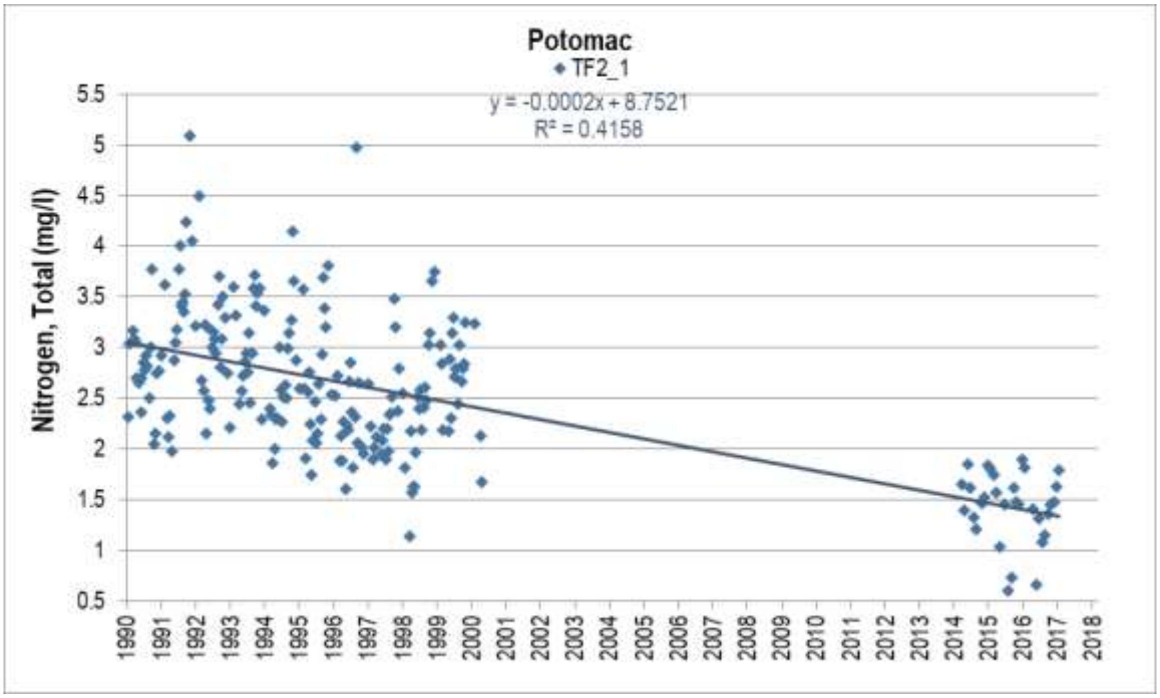


Figure 2-7. Plot of TN over time in the Potomac River watershed.

The high variance in the parametric data (i.e., data scatter) reflects the complexity of the processes that can affect the water quality at a monitoring point. As water flows downstream, its physical and chemical composition changes because of inputs that vary in space and time. Precipitation events can quickly affect the concentrations of DO, nutrients, TSS, and bacteria. Even when flows are stable, those concentrations can vary along different reaches of the stream and at different depths. High sediment inputs can be localized where land disturbance or erosion has occurred, but then the sediments can be carried a considerable distance downstream when flow rates are high. The rate, volume, and quality of runoff also varies with land use and land cover: Impervious surface runoff increases water volume and alters the concentration levels of water quality parameters; agricultural runoff increases nutrient and sediment inputs, which might result in a decrease in DO, and so forth. All the interactions between the waterway, terrain, and climate contribute to the scatter of the data points.

Nitrogen and Phosphorus

Nitrogen and phosphorus concentrations measured in all watersheds in this assessment appear to be trending downward in the plots in appendix B. Overall, the largest declines in nitrogen concentrations were observed in the Potomac River and Upper Patuxent River watersheds. The largest declines in phosphorus were in the Upper Patuxent River watershed. The highest overall concentrations were found in the Anacostia River watershed, which needs the largest percent reduction to nutrient loads.

Total Suspended Solids

Monitoring data in the Anacostia River watershed are showing an upward trend in TSS concentrations in the plots in appendix B. Station USGS-1649500 (see map in appendix B), located on the NEB in Riverdale, has a high mean TSS value of 186 milligrams per liter (mg/L). The NEB conveys runoff from developed areas characterized by a high percentage (more than 25 percent) of imperviousness. Impervious surfaces increase runoff and can lead to significant channel erosion, which is a major source of sediment throughout the County.

Data from the two Bear Branch stations in the Upper Patuxent River watershed show that TSS concentrations have been declining in that area. Station PG005, upstream of Laurel Lake, however, has a high mean value of 140 mg/L, which might be explained by the increase in the amount of impervious area contributing runoff to Bear Branch from station PG003 to PG005 (see map in appendix B). There is a TSS increase at station TF1.0 in the Upper Patuxent River watershed on the main stem of the Patuxent River at the U.S. Route 50 overpass. The TSS concentrations at stations TF1.5 and TF1.7 trend downward, while the readings at station TF1.6 have shown no significant change.

In the Western Branch watershed, TSS concentrations have been recorded by three monitoring stations. TSS concentrations at stations TF1.2 and WXT0013 appear to be increasing slightly. Station WXT0013 is just downstream of the Washington Suburban Sanitary Commission (WSSC) Upper Marlboro Treatment Plant. Station WXT0001, which is in an estuary upstream of the confluence between Western Branch and the Patuxent River, shows only a very slight decreasing trend in TSS. The lower flow velocity causes some of the TSS to settle out. At station TF1.2 in Upper Marlboro, water quality is affected by the relatively large percentage of impervious surface in the drainage area.

Bacteria

In the Anacostia River watershed, data from station USGS-1649500 show an upward trend in the concentration of *E. coli*. That station is located on the NEB of the Anacostia River in the community of West Riverdale.

In the Upper Patuxent River watershed, *E. coli* concentrations measured at station PG003 exhibit an upward trend, while concentrations at station PG005 exhibit a downward trend. Those two stations are located approximately 0.8 miles apart on Bear Branch. Station PG003 is located downstream of Contee Road and includes drainage from a wetland. Station PG005 is located upstream of Laurel Lake.

Biochemical Oxygen Demand and Dissolved Oxygen

Available records of BOD data were not collected over a period long enough to use for trend analysis for any of the County's watersheds. Monitoring for BOD began in 2013 at eight monitoring stations in four major waterways—the Potomac River, the Upper Patuxent River, the Anacostia River, and Piscataway Creek. Furthermore, the data records are inconsistent in both the period of data collection and the methods used to derive the concentrations.

Records of DO data are available that were collected over a period long enough to support trend analysis for most of the watersheds. The amount of oxygen that can be dissolved in water is sensitive to the water temperature, so identifying trends is difficult. The concentration of oxygen that can be dissolved in water decreases as water temperature increases. Consequently, DO as a percentage of saturation at the measured temperature was used for these trend analyses.

- DO data within the Anacostia River watershed was collected at two stations. Station ANA0082 shows a downward, or impairing, trend. Station NCRN_NACE_STCK, in Still Creek, shows an upward, or improving, trend. Still Creek runs through Greenbelt Park, a 1,100-acre park managed by the National Park Service and dominated by forest.
- In the Lower Patuxent River watershed, the DO levels at stations TF1.5 and TF1.6 exhibit a slight downward trend.
- DO data from both stations in the Western Branch watershed, TF1.2 and WXT0001, show a slight downward trend.
- DO data from station NCRN_NACE_HECR on Henson Creek and Station NCRN_NACE_OXRU on Oxon Run show an upward trend. No DO data after 2016, however, is available.

Chloride

Chloride data was available for monitoring stations in the Anacostia River and Piscataway Creek watersheds. No trends were observed in the limited data—only available for summer and fall—in the Piscataway Creek watershed. There were seven monitoring stations in the Anacostia River watershed with long term chloride data. Chloride concentrations were relatively low throughout most of the monitoring period, except for several spikes of chloride concentration in the winter months. For example, chloride monitoring data shows a spike in concentrations on January 31, 2013. There was 1.22 inches of rain recorded at Baltimore internal Airport on January 30, 2013, with an additional 0.73 inches on January 31, 2013. This rain likely washed salt of the roads, which would have been applied to roads before and during a snow event on January 24, 2013. Similar circumstances were observed in 2014, 2015, and 2016.

Sulfate

There were four monitoring stations with only a few sulfate data points. There were not enough data points to determine a trend. Based on the limited data, sulfate concentrations appear higher in the winter.

Heptachlor Epoxide

There is only 1 data point available for heptachlor epoxide. The monitoring result is from 1988 in the Potomac river and it was below the detection point.

Polychlorinated Biphenyls

Total PCB data were available for only two stations in the Anacostia River watershed over a 1.5-year period in 2004 and 2005. No trends could be determined because of the short period of time over which the data were collected. In addition, the data were scattered, with both high and low concentrations throughout the period of record.

The USGS has been conducting sediment monitoring for PCBs along the Anacostia River in Washington D.C. and Maryland. Some of these samples have been collected in Lower Beaverdam Creek. Preliminary unpublished data show that concentrations are highest in Lower Beaverdam Creek. PCBs found in sediment, which will affect water column concentrations, which will impact aquatic life, and create human health threats.

pH

The pH levels remain fairly constant over the monitoring periods for all watersheds. The pH of most water bodies ranged from 7.0 to 7.5. There are a few outlier data points that could be attributed to probe malfunction.

2.2.2 Data Gaps

Spatial Gaps

A spatial analysis was completed to identify locations in the County where sufficiently representative water quality data are not yet available. It is optimal to have water quality data from as many locations as possible to most accurately determine sources of nutrient, sediment, and bacteria inputs. Spatial gaps in water monitoring data can generate uncertainty in determining the best locations for remediation or restoration efforts.

The spatial analysis showed a scarcity of sampling stations in headwaters. Sampling stations in smaller, headwater reaches could show load reductions from BMPs are installed their drainage areas. This spatial approach of placing BMPs closer to the headwaters would allow fewer BMPs to show a greater change in measured water quality parameters. As an example, a BMP with the capacity to treat 20 acres would have a more measurable effect at a point in the watershed that drains 200 acres than if the same BMP was installed at a point in the watershed that drains 2,560 acres.

While it is advantageous to have monitoring stations throughout the County, it is not practicable with limited resources. The County will look at areas with known issues or that have the potential to have high impacts to water quality. For instance, USGS and the District of Columbia Department of Environment and Energy (DC DOEE) will complete sediment monitoring in Anacostia River watershed. From this sampling, elevated levels of PCBs were found in Lower

Beaverdam Creek. Because of this, the County will conduct additional monitoring to this watershed.

There are no water monitoring stations operating along the smaller streams bulleted below and indicated in Figure 2-8. The following water bodies have the indicated gaps in placement of water monitoring stations:

Anacostia River

- Beaverdam Creek upstream of the confluence with Beck Branch
- Beck Branch
- Little Paint Branch upstream of the confluence with Paint Branch
- Northwest Branch upstream of the confluence with Sligo Creek
- Paint Branch upstream of the confluence with Little Paint Branch

Lower Patuxent River

- No water monitoring stations on interior waterways; only County Line Creek and the Patuxent River are currently monitored

Lower Potomac River

- Mattawoman Creek
- Timothy Creek

Middle Patuxent River

- Charles Branch upstream of Horse Tavern Branch
- Black Walnut Creek
- District Branch
- Hennesey Creek
- Horse Tavern Branch
- Kings Creek
- Old House Creek
- Wyvil Branch

Middle Potomac River

- Swan Creek

Oxon Creek

- Oxon Run upstream of Oxon Run Park

Piscataway Creek

- Birch Branch
- Butler Branch
- Dower House Pond Branch
- Meetinghouse Branch
- Paynes Branch
- Piscataway Creek upstream of confluence with Dower House Pond Branch

Upper Patuxent River

- Crow Branch
- Green Branch
- Honey Branch upstream of confluence with Mount Nebo Branch
- Horsepen Branch upstream of confluence with Newstop Branch
- Mount Nebo Branch
- Newstop Branch
- Walker Branch

Western Branch

- Cabin Branch upstream of confluence with Back Branch
- Charles Branch upstream of confluence with Southwest Branch
- Federal Spring Branch
- Folly Branch
- Lottsford Branch
- Ritchie Branch
- Southwest Branch upstream of confluence with Ritchie Branch
- Thersea Creek

Zekiah Swamp

- No water monitoring stations in this watershed

Temporal Gaps

Gaps in time series data limit the quality of the conclusions that can be drawn from analyzing the data, particularly in trend analysis. Records that do not continue beyond 2007 or cover a period of more than 10 years were not included in the water quality data analyzed in this assessment. The remaining data were then plotted and analyzed for gaps in the records. The lack of continuous records affects the County's ability to determine the locations contributing loadings. It also limits the County's ability to determine if water quality trends. Data gaps can hide the effects of extreme weather events on water quality and the potential for distinct pollutant spills or discharges.

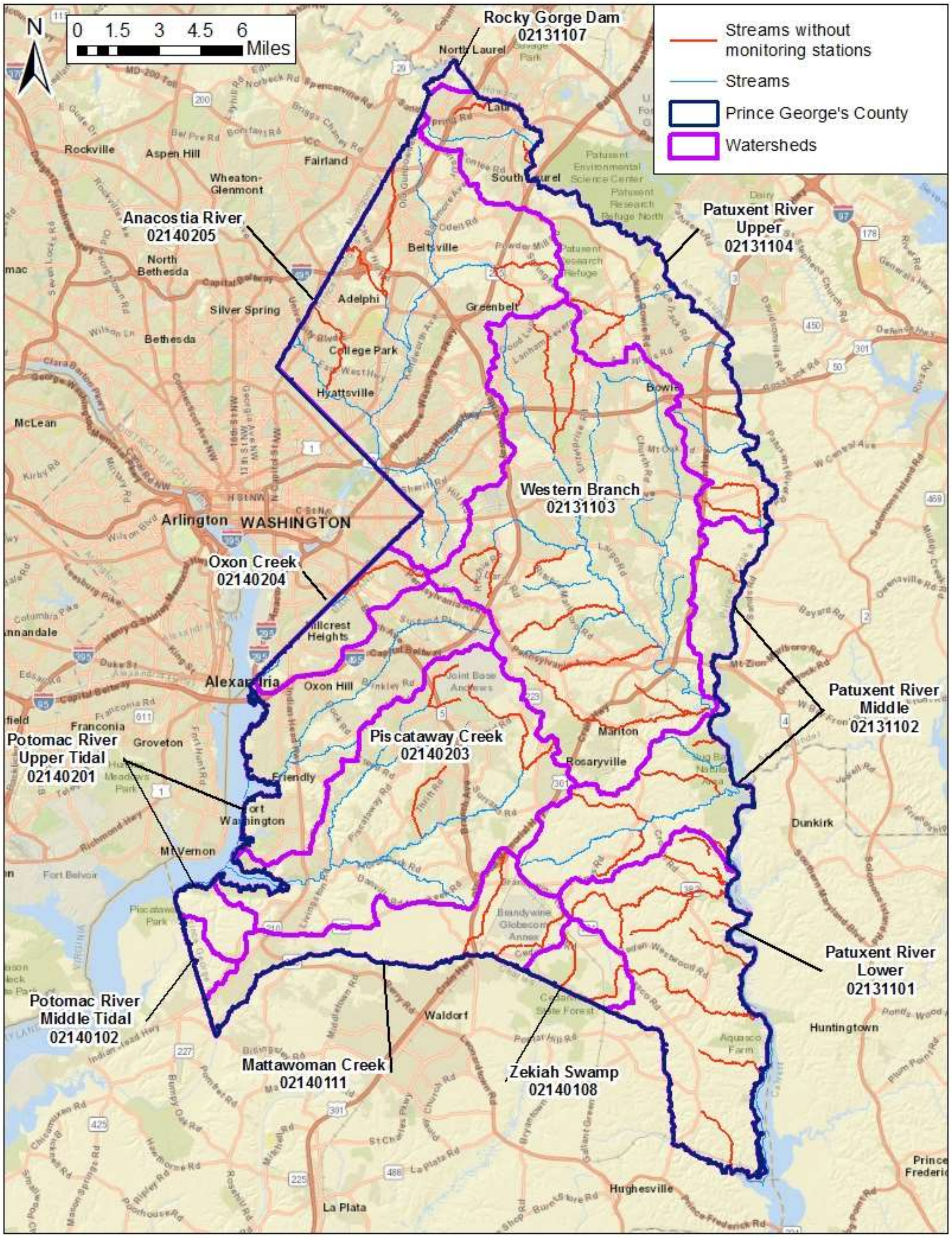


Figure 2-8. Locations without water quality monitoring stations.

3 VISUAL WATERSHED INSPECTION

For the visual watershed inspection, the County used three sources of information: stream corridor assessments (SCAs); a photographic trash assessment; and results from the County's illicit discharge detection and elimination (IDDE) program.

3.1 Stream Corridor Assessments

The MD DNR conducted SCAs of all County watersheds in the 2000s. The SCAs included photographs of stream bank erosion and head cutting, among other erosion problems. For this watershed assessment, the previous SCA findings were reviewed and 78 sites were selected, including 34 head cuts and 44 areas of severe erosion, as an initial basis for the visual inspection. The photographs and locations of the head cuts and erosion points were reviewed and a subset of each was selected for site visits to assess current conditions compared to the original assessment. Sites were selected if their head cuts or erosion was categorized as severe. The severe erosion sites were distributed throughout the County (Figure 3-1). Site visits were conducted at the 24 selected sites in early 2018 to assess changes since the original SCA in 2009 and 2010.

Appendix C shows the location of the 24 sites that were visited, photographs of the sites from the original SCA, and comparable digital photographs from early 2018 taken for this assessment. The recent site visits revealed that the sites are not recovering from past degradation and disequilibrium. Most are in worse condition than they were in the original SCA. The 2018 site visits showed that many County streams are still experiencing erosion issues. Much of this erosion occurred prior to urbanization, when forests were converted to agriculture fields. Trees that stabilized soils and soaked up rainfall were removed, increasing rainfall runoff and stream erosion. The streams will continue to erode until they reach a point of stable equilibrium.

Removing forest cover and conversion to other land uses (e.g., residential or agricultural) have adverse effects on stream channels (MDE 2009). While the exact land use and stream erosion history of the entire County is unknown, it is likely that, after the initial deforestation occurred, agricultural activities were established and have continued in the County for the past 250 years. Some county streams are still adjusting to the land use change from forest to agriculture, which degraded watershed streams through incision and increasing the cross sections. Stream bank erosion will occur as the incised banks are oversteepened and fail. The oversteepened banks are unstable because of the high bank angle resulting in rock and soil slides. Although the failure mechanism is complex, it typically involves undermining of the toe (i.e., bottom) of the steepened bank and subsequent failure of the bank. This failure will continue over time until the angle of the bank is reduced to a stable angle of repose. Many County streams are already degraded and will not return to a stable condition without stream restoration efforts and additional upstream runoff control through BMPs. Appendix A describes the process.

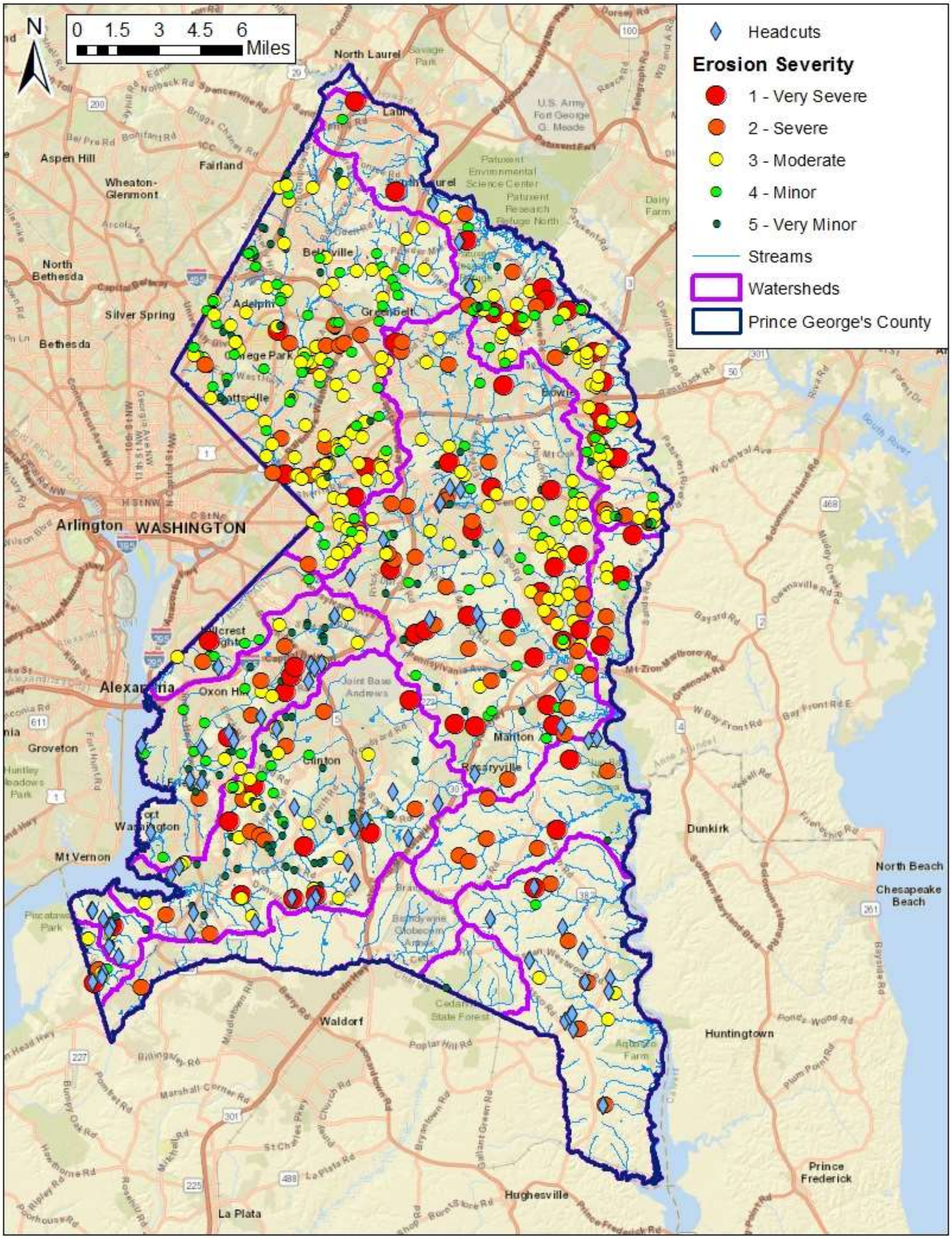


Figure 3-1. Locations of SCA erosion points (with severity) and head cuts.

Maryland Biological Stream Survey

The MBSS rating methodology incorporates factors that reflect channel stability, morphology, and sediment problems. That makes the methodology appropriate as a surrogate for sediment and stability conditions. The latest statewide MBSS results by county are from the 1997–1999 report, which showed 576 miles of first-, second-, and third-order streams in the County. Those historic data are important as the extent of degradation has not improved since the report was published. The visual inspection during this watershed assessment shows that most of the streams have gotten worse. The MBSS assessment showed that 88 percent of first-, second-, and third-order streams in Prince George’s County were degraded at the following levels:

- Severely degraded: 69 miles (12 percent)
- Degraded: 172 miles (30 percent)
- Partly degraded: 265 miles (46 percent)

3.2 Photographic Trash Assessment

3.2.1 Trash Rating Protocol

The digital photographs taken during the biological assessments (section 2) were also used to assess the amount of trash at those locations. A total of 3,404 digital photos taken at 834 different stream sites were used in the trash assessment. A minimum of four photographs was taken at each sampled reach during biological monitoring, capturing upstream, downstream, left bank, and right bank views of the location—effectively providing a 360° view. More than 96 percent of the sites are represented by four or more photos.

The types of trash observed ranged from paper and small plastic items to shopping carts, tires, discarded building materials, and dislodged corrugated sewer pipes or culverts. Although the smaller items might not be visible in the photos because of their size or the water depth, the diversity, magnitude, and abundance of stream trash are often apparent. The team used a simple rating scale—or “trash score” (TS)—to represent the amount of trash visible in each photograph (Table 3-1).

Table 3-1. Rating criteria for the occurrence and amount of solid trash in streams

Trash score	Descriptive rating	Number of items
0	None	None
1	Light	1–5
2	Moderate	6–10
3	Abundant/heavy	>10

Figure 3-2 shows four photographs that illustrate each major level on the rating scale. After each photo from a site was rated, a combined score for all the photos taken at the site was calculated. The TS for a single site ranged from 0 (no trash) to 12 (abundant or heavy trash).

Figure 3-2. Streams illustrating different amounts of trash and corresponding trash scores.

3.2.2 Results of Trash Assessment

Throughout the County, about half the assessed sites were trash free (Figure 3-3); the majority of sites with the highest TSs (i.e., that had the most trash) were found in western portions of the County (Figure 3-4), largely inside the Beltway and immediately to the north and south of the Beltway. Trash levels in the Anacostia River, Patuxent River upper, and Potomac River upper watersheds appear to have decreased over time, while levels in the Piscataway Creek watershed might have increased.

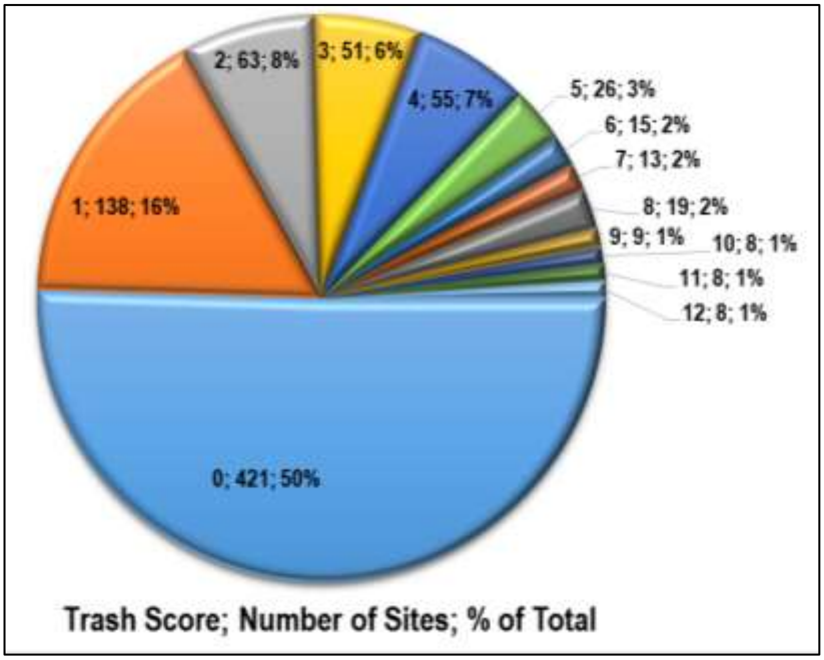


Figure 3-3. Trash score distribution throughout the County.

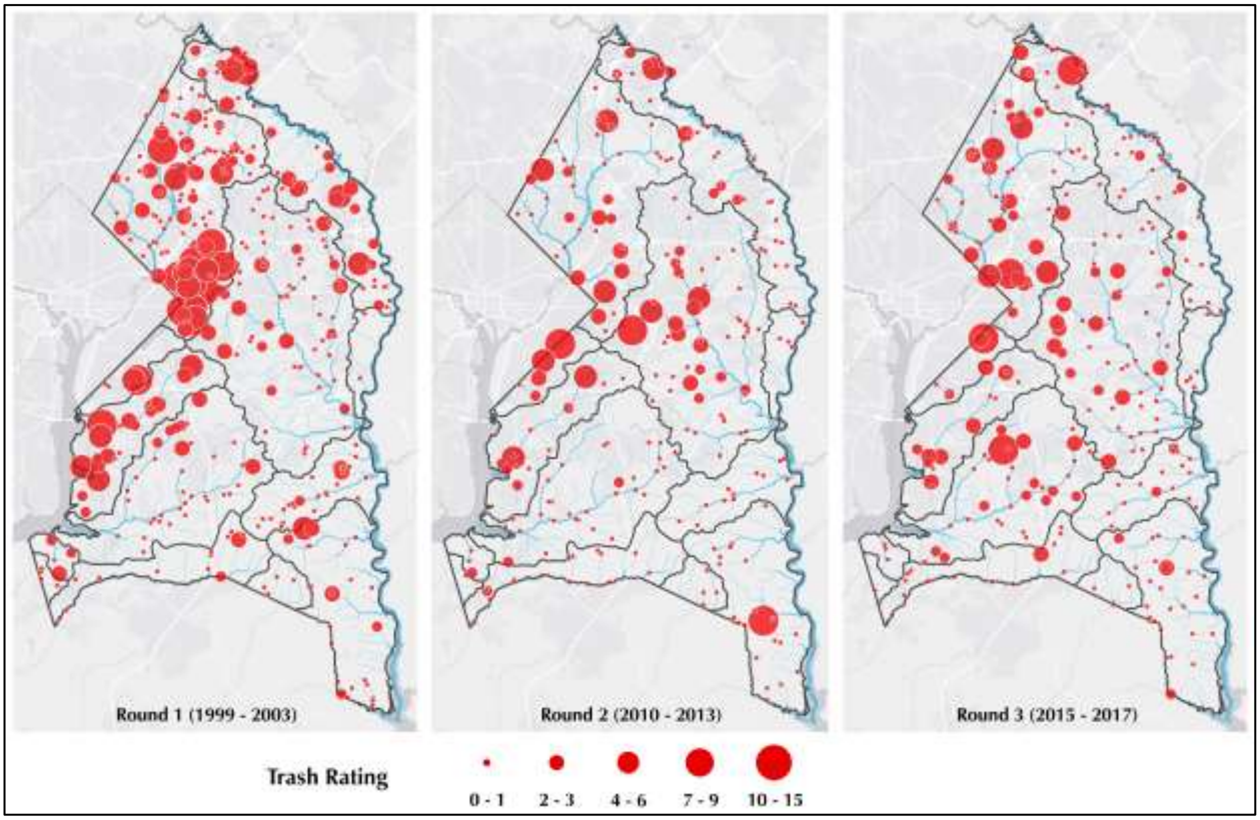


Figure 3-4. Amount and concentration of trash at assessment locations.

The Zekiah Swamp, Mattawoman Creek, and Patuxent River (lower, middle, and upper) watersheds had the most trash-free sites (i.e., highest proportions of trash-free sampling locations) (Table 3-2). The Potomac River upper tidal, Oxon Creek, and Anacostia River watersheds had the lowest proportions of trash-free sites, ranging from 23.8 percent to 41.8 percent. The Oxon Creek watershed had the highest mean TS of all the County watersheds.

Table 3-2. Trash assessment results by watershed

MD 8-digit watershed	Number of sites	Trash score			Sites with *no visible trash*	
		Min	Mean	Max	Number	Percent
Anacostia River	219	0	2.4	12	87	41.8%
Mattawoman Creek	43	0	0.5	5	31	72.1%
Oxon Creek	15	0	4.4	12	4	26.7%
Patuxent River lower	134	0	0.8	11	93	69.4%
Patuxent River middle	31	0	0.5	4	12	60.0%
Patuxent River upper	88	0	1.5	12	49	55.7%
Piscataway Creek	77	0	1.3	10	34	44.2%
Potomac River middle tidal	2	0	0.5	1	1	50.0%
Potomac River upper tidal	63	0	2.8	11	15	23.8%
Rocky Gorge Dam	n/a	n/a	n/a	n/a	n/a	n/a
Western Branch	154	0	1.4	10	73	47.4%
Zekiah Swamp	8	0	0.1	1	7	87.5%

Note: n/a = not applicable; there were no assessment locations in the Rocky Gorge Dam watershed.

The watersheds with the least amounts of solid trash were the Mattawoman Creek, Patuxent River (lower, middle, and upper), Piscataway Creek, Potomac River upper tidal, Potomac River middle tidal, and Zekiah Swamp watersheds (Figure 3-5). Figure 3-6 presents the average and maximum TS per each biological monitoring year. Overall, the levels of solid trash have decreased over approximately 18 years, with a slight recent increase. The decreases are likely to the result of the County's trash initiatives such as cleanups, outreach, and the PGCLitterTRAK smartphone application.

Most of the trash items seen were small enough that they could easily have been transported via stormwater conveyances. Some materials (e.g., rusty barrels, and a large pile of bricks and lumber) were obviously dumped because it was easier than disposing of them properly. Unique and unusual items (e.g., shopping carts) were found in all watersheds, except Oxon Creek, Patuxent River middle, Potomac River middle tidal, and Rocky Gorge Dam (which had no monitoring locations). Table 3-3 lists the items found in each watershed.

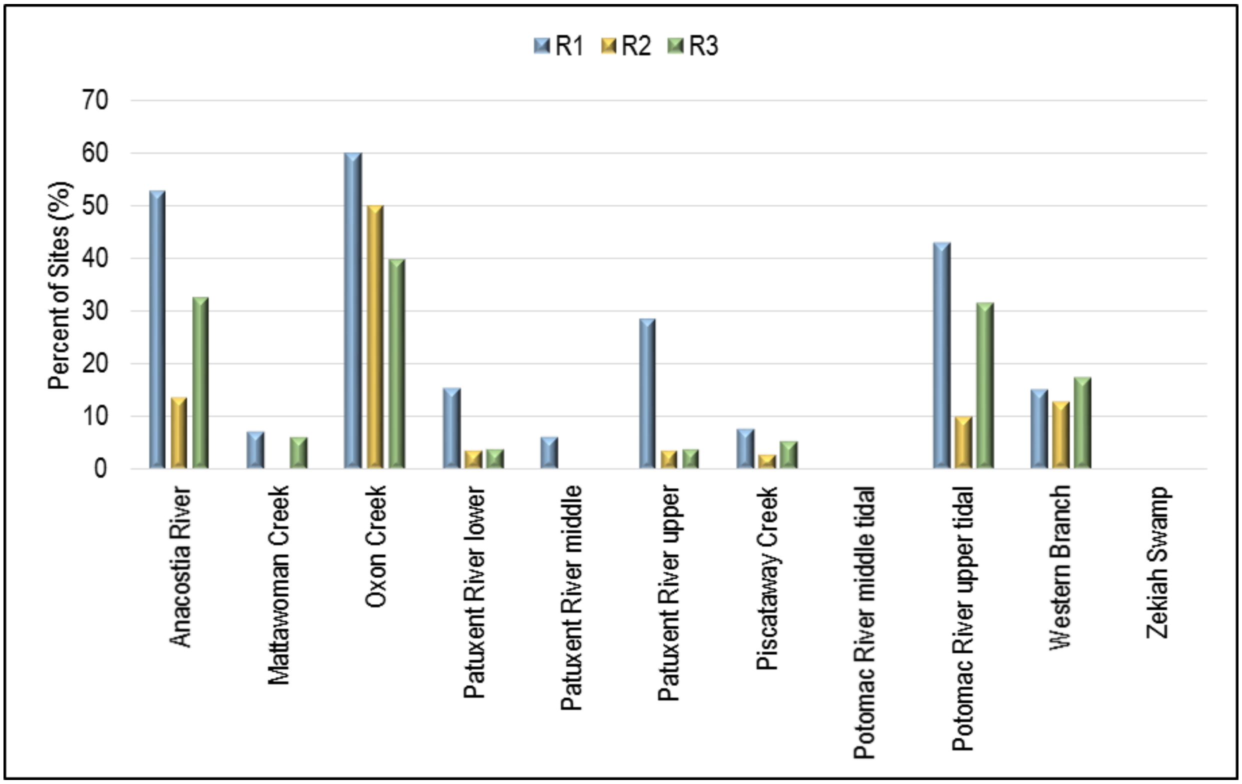


Figure 3-5. Percent of sites with trash scores higher than 4 by assessment round.

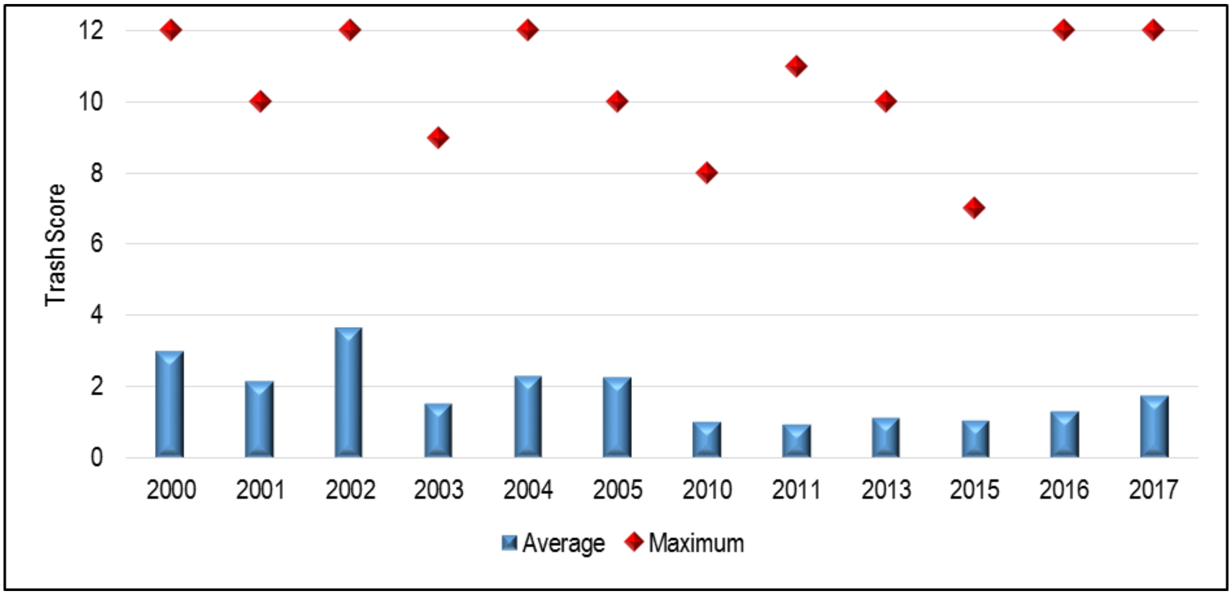


Figure 3-6. Average and maximum site trash scores by year of assessment.

Table 3-3. Observations of unique and unusual items found at biological monitoring locations

Observation/items	Anacostia River	Mattawoman Creek	Oxon Creek	Patuxent River lower	Patuxent River middle	Patuxent River upper	Piscataway Creek	Potomac River middle tidal	Potomac River upper tidal	Rocky Gorge Dam	Western Branch	Zekiah Swamp
Cattle										n/a	X	
Discarded construction materials				X					X	n/a		
Exposed sewer stack/manhole									X	n/a		
Fallen trees	X								X	n/a		
Heavy algal growth										n/a	X	X
Exposed manhole/ sewer stack							X			n/a		
Pipes (concrete)	X					X			X	n/a		
Pipes (metal)		X							X	n/a		
Pipes (plastic)	X					X				n/a		
Plastic toys							X			n/a		
Plastic tarpaulin		X								n/a		
Rip-rap armor	X									n/a		
Rusted barrel	X									n/a		
Shopping cart	X					X				n/a		
Tires	X			X		X	X		X	n/a	X	
Toys/tricycle						X	X			n/a	X	
Trash can	X					X				n/a		

Notes: Empty cell = the item was not seen in any of the available photographs; it might have been found elsewhere in the watershed. n/a = not applicable; there were no assessment locations in the Rocky Gorge Dam watershed. X = at least one occurrence at the sites visited.

3.3 IDDE Program Results

Since 2015, the County has conducted the IDDE program, through which inspectors examine major stormwater outfalls and test the water for unusual levels of pollutants that must be controlled upstream because of the stormwater system's inability to handle them. Major outfalls are defined as the ends of stormwater pipes that release runoff from commercial and industrial land into a body of water.

County inspectors also investigate water quality complaints from citizens about potential illicit discharges. If flow is present, the inspectors record any evidence of possible secondary sources of pollution, including water color, clarity, floatables (e.g., trash/debris and oil sheen), odor, and deposits. They take a sample when possible and test for water quality indicators, including ammonia, chlorine, copper, detergents, phenols, turbidity, and pH level. Readings above certain thresholds indicate an illicit discharge. Samples giving pH readings below 6.5 and above 8.5 are considered to contain illicit discharges. The following are concentrate limits for some of the pollutants:

- Chlorine—0.4 mg/L
- Copper—0.21 mg/L
- Detergents—0.5 mg/L
- Phenol—0.17 mg/L

County inspectors have conducted almost 500 outfall inspections since 2015, of which only 19 (4 percent) discovered illicit discharges. Table 3-4 indicates the pollutant(s) for which each outfall failed. The Anacostia River and Western Branch watersheds had the highest number of illicit discharges. Table 3-5 provides more details on the 19 outfalls with illicit discharges. Secondary indicators of pollutants were found in 323 of the outfall inspections (Table 3-6 and Figure 3-7). Of those, 59 were removed from consideration because the secondary indicators found were iron flocculent and bacterial sheen (often in combination), which can be the result of natural bacterial action.

Table 3-4. Number of failing inspections per pollutant and watershed

MD 8-digit watershed	Total number of inspections	Number of failing sites				
		Ammonia	Detergents	Chlorine	pH	All illicit[a]
Anacostia River	173	5	1	1	3	8
Mattawoman Creek	16	0	0	1	0	1
Oxon Creek	15	0	0	0	0	0
Patuxent River Lower	0	0	0	0	0	0
Patuxent River Middle	6	0	0	0	0	0
Patuxent River Upper	51	0	0	1	1	2
Piscataway Creek	25	0	0	1	0	1
Potomac River U Tidal	44	1	1	0	1	2
Rocky Gorge Dam	0	0	0	0	0	0
Western Branch	123	4	0	1	0	5
Total	453	10	2	5	5	19

Note:

[a] Might not equal the sum of failing sites as many outfalls failed more than one criterion.

Table 3-5. Failed inspections by watershed and pollutant

Map ID #	MD 8-digit watershed	Ammonia	Detergents	Chlorine	pH	Illicit flow	Inspector comment
1	Patuxent River Upper				Fail	Fail	
2	Anacostia River			Fail		Fail	Standing water in outfall. Visible suds on water at outfall. Strong smell of bleach at outfall and in sample. Sample collected at first upstream structure.
				Fail		Fail	Visible suds much reduced. Chlorine smell still present but faint. Flow arises above third upstream

Map ID #	MD 8-digit watershed	Ammonia	Detergents	Chlorine	pH	Illicit flow	Inspector comment
							structure. Active repairs of water main occurring at southwest corner of property.
3	Western Branch	Fail				Fail	Outfall is half submerged. Sample taken from first upstream structure. Flow is red presumably from active construction site upstream.
3	Western Branch	Fail				Fail	No upstream structures visible except headwall inlet with standing water and no flow and collapsed fifth upstream structure. No source of flow seen. Could not collect pristine bacterial sample.
4	Patuxent River Upper			Fail		Fail	Flow appears to come from building in a sewage treatment plant. If flow is treated sewage, it may or may not be illicit.
4	Patuxent River Upper			Fail		Fail	Outfall half buried by sediment. Standing water in outfall. Sample taken from first upstream structure.
5	Western Branch	Fail				Fail	Standing water in outfall. Milky water discharging from outfall. Intermittent flow in first upstream structure.
6	Anacostia River				Fail	Fail	
7	Potomac River U Tidal	Fail	Fail			Fail	Strong smell of sewage. Sign indicates sewage overflow. Red and gray deposits.
7	Potomac River U Tidal	Fail	Fail			Fail	Flow originates between outfall and first upstream structure. No obvious source of flow was found.
8	Western Branch	Fail				Fail	Flow less today than at time of first inspection. Flow arises from a pipe in curb on Chrysler Way and flows into southern third upstream structure. Could not collect bacterial sample directly.
9	Anacostia River	Fail			Fail	Fail	Some sediment deposition observed.
9	Anacostia River	Fail			Fail	Fail	Yellow deposits below outfall. Minor erosion downstream.
10	Potomac River U Tidal				Fail	Fail	Low pH flow arises between second upstream structure and southern third upstream structure. No obvious source of low pH.
10	Potomac River U Tidal				Fail	Fail	Outfall is half submerged.
11	Anacostia River	Fail				Fail	Samples taken to lab.
11	Anacostia River	Fail				Fail	Drainage area is an active construction site. Inlet protection is installed. No obvious source of pollution was observed.
12	Piscataway Creek			Fail		Fail	Standing water in outfall. Sample taken from flowing point downstream.
12	Piscataway Creek			Fail		Fail	Standing water at outfall. Collected sample at flowing point downstream. Flow originates between the southern third and fourth upstream structures behind Tai Jung Restaurant.
13	Anacostia River				Fail	Fail	Pipe sections are separated. Sinkholes forming above pipe. Outfall is being undermined by flow beneath pipe.
14		Fail				Fail	Iron flocculent present.

Map ID #	MD 8-digit watershed	Ammonia	Detergents	Chlorine	pH	Illicit flow	Inspector comment
	Anacostia River	Fail				Fail	Follow up. Iron flocculent present. Flow originates between the third and fourth upstream structure. No apparent source of pollution.
15	Anacostia River	Fail	Fail			Fail	No sign of flow in either third upstream structure. Adjacent sanitary sewer manhole is bolted shut. Report remade due to loss of data.
15	Anacostia River	Fail	Fail			Fail	Outfall is fenced off. Sample was taken from first upstream structure. Strong smell of sewage. Report remade due to loss of data.
16	Western Branch			Fail		Fail	Outfall is partially submerged. Sample taken from first upstream structure.
17	Mattawoman Creek			Fail		Fail	Standing water in outfall. Could not locate first upstream structure. Sample taken from second upstream structure. Damage to second upstream structure seems to bypass flow from outfall.
18	Western Branch	Fail				Fail	Spalling on concrete apron. General smell of sewage around the outfall. No smell detected on water.
18	Western Branch	Fail				Fail	Iron flocculent in upstream structures. Flow arises between Buena Vista Ave and Washington Blvd. Flow is likely groundwater. Spalling on outfall apron.
19	Anacostia River	Fail				Fail	Could not access outfall. Outfall hidden by vegetation. Could not locate next 4 upstream structures. Took sample from inlet 61135.
19	Anacostia River	Fail				Fail	Flow originates between the third and fourth structures on Kilmer Place. Investigation could not locate source of flow. Samples were taken for laboratory.

Table 3-6. Number of inspections with secondary indicators per watershed

MD 8-digit watershed	Total secondary indicators	Odor	Deposits	Floatables	Color	Clarity	Erosion
Anacostia River	118	18	88	60	5	14	18
Mattawoman Creek	9	0	5	7	0	0	0
Oxon Creek	6	0	3	5	0	1	1
Patuxent River Upper	19	0	14	8	0	2	1
Piscataway Creek	14	0	12	8	0	0	1
Potomac River U Tidal	29	3	24	16	0	2	3
Western Branch	69	2	53	30	3	7	8
Total	264	23	199	134	8	26	32

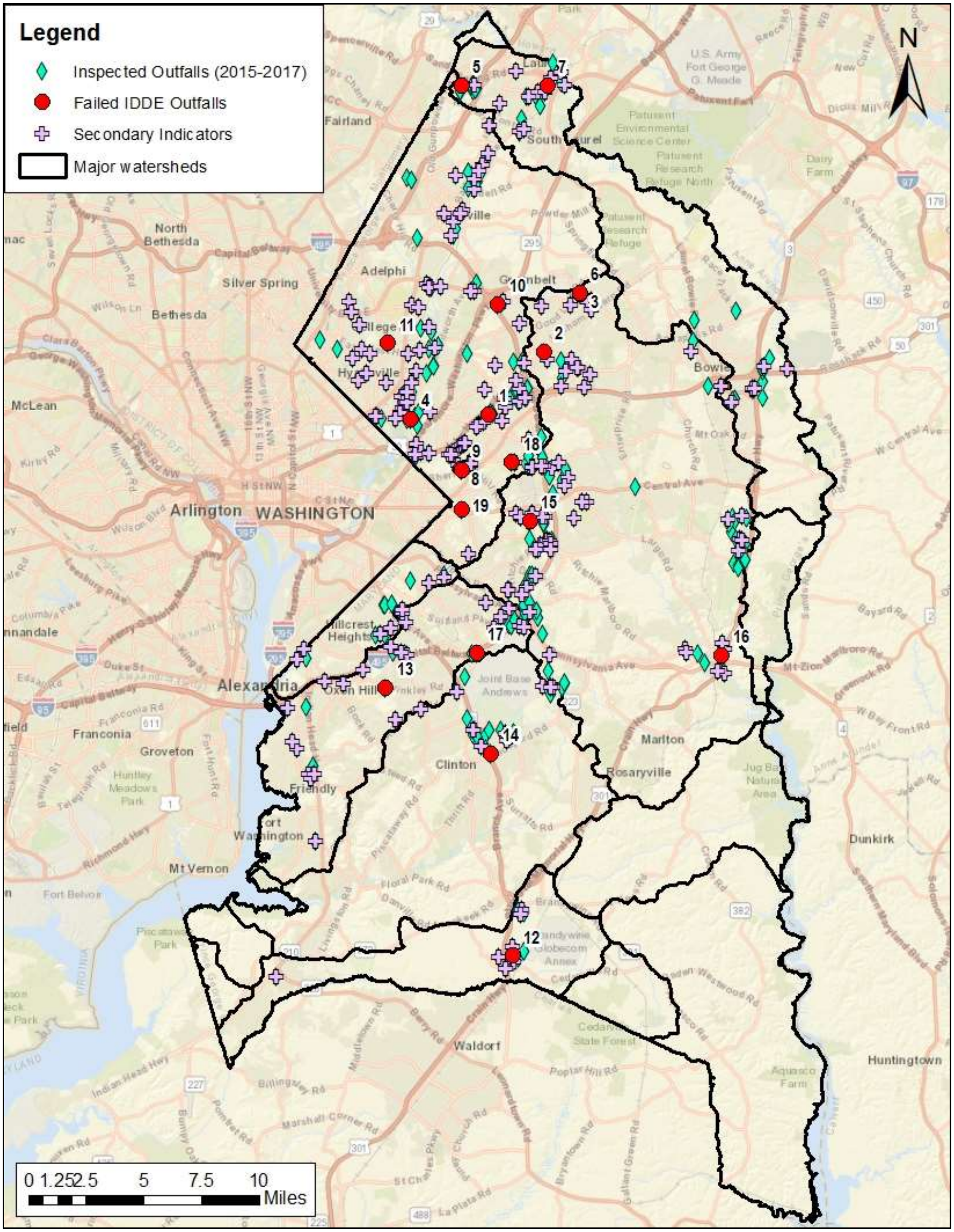


Figure 3-7. Failed IDDE outfalls and outfalls with secondary indicators.

4 IDENTIFYING AND RANKING WATER QUALITY ISSUES

4.1 Identifying Water Quality Issues (or Problems)

Table 4-1 lists the potential water quality issues in each of the watersheds, which were identified by using the following information:

- The list of impaired water bodies previously developed by the state to comply with CWA section 303(d) (Table 1-1)
- Water quality data (section 2.2)
- Professional knowledge of the County and its watersheds, drawn from the prior experience of County staff and outside expertise

The three parameters from the Chesapeake Bay TMDL (TN, TP, and TSS), along with bacteria, were identified as issues across all 12 watersheds. The Anacostia River watershed was identified as having the highest number of water quality issues (ten), and the Zekiah Swamp and Rocky Gorge Dam watersheds as having the lowest number of water quality issues (four).

Table 4-1. Identified water quality issues by watershed

Water quality issue	Anacostia River	Mattawoman Creek	Piscataway Creek	Potomac River Basin			Patuxent River Basin					
				Oxon Creek	Potomac River middle tidal	Potomac River upper tidal	Patuxent River lower	Zekiah Swamp	Patuxent River middle	Patuxent River upper	Rocky Gorge Dam	Western Branch
Bacteria[a]	X	X	X	X	X	X	X	X	X	X	X	X
BOD	X											X
Chlorides	X	X	X							X		
Nitrogen	X	X	X	X	X	X	X	X	X	X	X	X
Pesticides/Herbicides	X	X	X			X	X		X	X		X
Phosphorus	X	X	X	X	X	X	X	X	X	X	X	X
pH		X										
Sediment[b]	X	X	X	X	X	X	X	X	X	X	X	X
Sulfates	X								X	X		
Toxics (e.g., PCBs)	X		X	X	X	X	X		X			X
Trash	X		X	X						X		X

Notes:
[a] Includes fecal coliform bacteria, *E. coli*, and enterococcus.
[b] Includes TSS.

Table 4-2 lists the potential causes of the water quality issues identified for each watershed. This list of causes was produced in consultation with local experts in restoration planning, geomorphology, local biological conditions, and natural habitats. The experts drew upon their knowledge of the County and its streams, along with geospatial data (e.g., land use and land cover, and landfill locations) to determine the most likely and potential causes in each watershed.

Agricultural processes and historical agriculture, land-use and land-cover changes, stream channelization, industrial facilities exceeding their discharge limits, and inadequate stormwater infrastructure are the likely sources of water quality issues across all watersheds.

Table 4-2. Identified potential causes of water quality issues by watershed

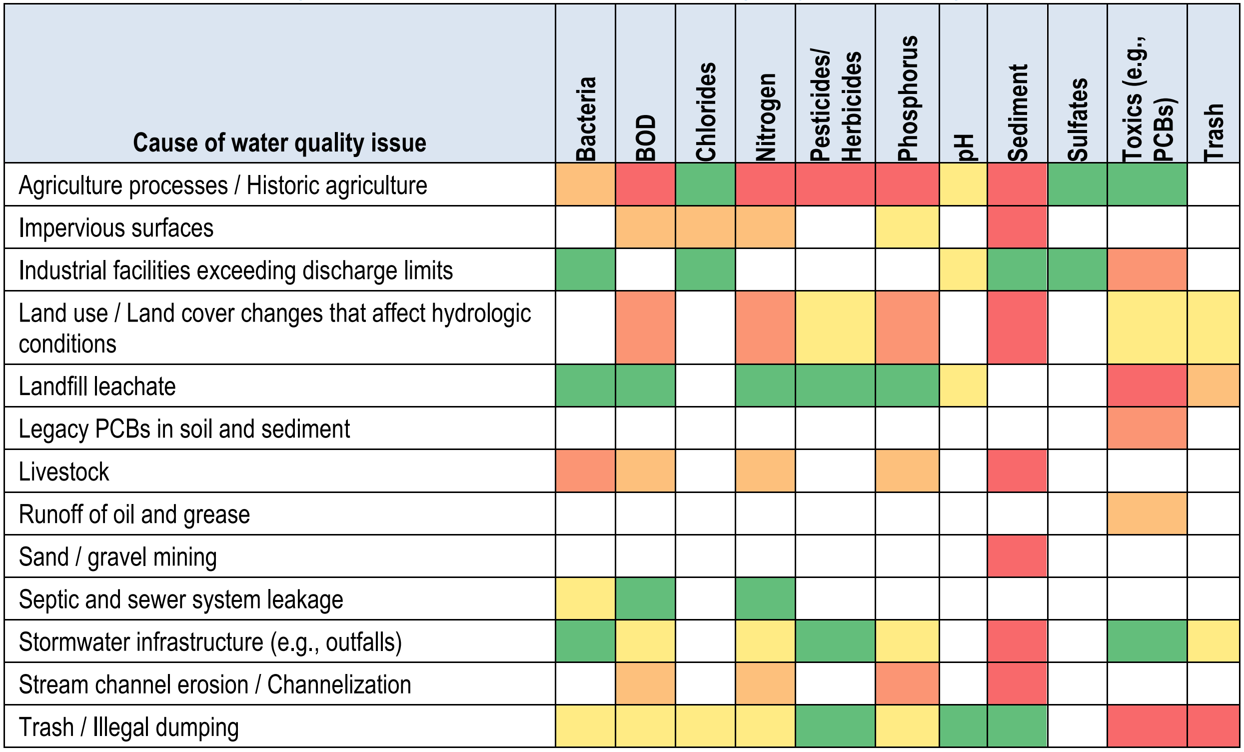
				Potomac River Basin			Patuxent River Basin					
Potential cause of issues	**Anacostia River**	**Mattawoman Creek**	**Piscataway Creek**	**Oxon Creek**	**Potomac River middle tidal**	**Potomac River upper tidal**	**Patuxent River lower**	**Zekiah Swamp**	**Patuxent River middle**	**Patuxent River upper**	**Rocky Gorge Dam**	**Western Branch**
Agricultural processes / Historical agriculture	X	X	X	X	X	X	X	X	X	X	X	X
Impervious surfaces	X		X	X	X	X	X		X	X	X	X
Industrial facilities exceeding discharge limits	X	X	X	X	X	X	X	X	X	X	X	X
Land use / Land cover changes that affect hydrologic conditions	X	X	X	X	X	X	X	X	X	X	X	X
Landfill leachate												X
Legacy PCBs in soil and sediment[a]	X		X	X	X	X				X	X	
Livestock	X		X		X							
Runoff of oil and grease	X		X	X	X	X	X		X	X		X
Sand / gravel mining	X	X	X				X		X	X		
Septic and sewer system leakage	X	X	X	X	X	X	X	X	X	X	X	X
Stormwater infrastructure (e.g., outfalls)	X	X	X	X	X	X	X	X	X	X	X	X
Stream channel erosion / Channelization	X	X	X	X	X	X	X	X	X	X		X
Trash / Illegal dumping	X	X	X	X	X	X				X		X

Note:

[a] Multiple potential sources of legacy PCBs exist in soils and sediment, including old electrical transformers (e.g., fires and illegal dumping), industrial activities, and oil spills. PCBs sprayed as a dust suppressant on County dirt roads is another potential source for all watersheds; however, no documentation of this practice exists, either of quantity sprayed or geographic locations.

Table 4-3 presents qualitative ratings of the strength of the association between the water quality issues and their potential causes. In the table, red indicates a relatively strong association and green indicates a relatively weak association, with dark orange, light orange, and yellow representing intermediate ratings from stronger (oranges) to weaker (yellow) associations. White cells indicate that no causal association exists. For example, agricultural practices are well known to be a potential source of pollutants such as nitrogen, pesticides, herbicides, phosphorus, and sediment; they are associated less with the presence of PCBs, chlorides, and sulfates in the water; and they are not directly a source of the trash found in and along local streams.

Table 4-3. Relative strength of the association between water quality issues and potential causes



Cause of water quality issue	Bacteria	BOD	Chlorides	Nitrogen	Pesticides/ Herbicides	Phosphorus	pH	Sediment	Sulfates	Toxics (e.g., PCBs)	Trash
Agriculture processes / Historic agriculture	🟠	🟥	🟩	🟥	🟥	🟥	🟨	🟥	🟩	🟩	
Impervious surfaces		🟠	🟠	🟠		🟨		🟥			
Industrial facilities exceeding discharge limits	🟩		🟩				🟨	🟩	🟩	🟧	
Land use / Land cover changes that affect hydrologic conditions		🟧		🟧	🟨	🟧		🟥		🟨	🟨
Landfill leachate	🟩	🟩		🟩	🟩	🟩	🟨			🟥	🟠
Legacy PCBs in soil and sediment										🟧	
Livestock	🟧	🟠		🟠		🟠		🟥			
Runoff of oil and grease										🟠	
Sand / gravel mining								🟥			
Septic and sewer system leakage	🟨	🟩		🟩							
Stormwater infrastructure (e.g., outfalls)	🟩	🟨		🟨	🟩	🟨		🟥		🟩	🟨
Stream channel erosion / Channelization		🟠		🟠		🟧		🟥			
Trash / Illegal dumping	🟨	🟨	🟨	🟨	🟩	🟨	🟩	🟩		🟥	🟥

4.2 Ranking Priorities

The County's water quality improvement priorities will continue to reflect MDE's emphasis on meeting the Chesapeake Bay TMDLs and fulfilling already established restoration plans. While TN, TP, and TSS loading rates that exceed established TMDLs continue to be of significant concern, the County's programs will also help address other water quality issues such as bacteria and BOD.

The County will continue to focus on meeting its MS4 permit requirements with programs that address restoration activities to treat stormwater runoff, placing emphasis in untreated impervious cover, street sweeping, IDDE program, stormwater pollution prevention plans (SWPPPs), stream restoration, outfall repairs, and other stormwater practices deemed important to our local residential communities. The County plans to continue its outreach program strategies (e.g., pet waste disposal, tree planting opportunities, and trash reduction) that help to address water quality causes. Table 4-4 lists current and future County programs and initiatives. These programs each address one or more of the identified water quality issues.

Going forward, the County will also focus on efforts that address a range of important environmental issues, which, if addressed through stormwater BMPs, will increase the practice's cost-effectiveness. For example, the County plans to address toxics (e.g., PCBs) through programs that go beyond the scope and reach of the IDDE and SWPPPs, such as identifying potential sources of PCBs and researching new methods to remove PCBs from the water bodies.

As TMDLs and restoration plans are developed (e.g., for pH, chlorides, and sulfates), the County will create targeted strategies based on the water quality issues and sources identified in the associated restoration plans. The County will also increase the priority (ranking) of the water quality issue based on the impairment of the waterbody.

Table 4-4. Effects of County programs on water quality issues

Program type	County program	Water quality issues (D = Directly addresses issue P = Potentially effects issue)									
		Bacteria	Nitrogen	Pesticides/ Herbicides	Phosphorus	Sediment	Toxics (e.g., PCBs)	Trash	Chlorides	Sulfates	pH
Established programs											
BMP Implementation	Channel and Outfall Restoration Program	P	D		D	D	P	D			
BMP Implementation	Clean Water Partnership	P	D		D	D		P			
BMP Implementation	County CIP	P	D		D	D		P			
BMP Implementation	Green/Complete Streets Program	P	D	P	D	D	P	D			
BMP Implementation	Deficient Pond and Pilot Pond Programs		D		D	D		D			
Community Involvement	Adopt-A-Can	P	P		P	P	P	D			
Community Involvement	Adopt-A-Park	P	P		P	P	P	D			
Community Involvement	Adopt-A-Road/Adopt-A-Median	P	P		P	P	P	D			
Community Involvement	Adopt-A-Stream	P	P		P	P	P	D			
Community Involvement	Adopt-A-Trail	P	P		P	P	P	D			
MS4 Program	Commercial and Industrial Visual Surveys	P					P	P	P		P
MS4 Program	County Facilities SWPPPs			P		P	P	P			
MS4 Program	County Storm Drain Maintenance Division	P	D		D	D	P	D			
MS4 Program	Erosion and Sediment Control Inspections		P		P	D	P				
MS4 Program	Illicit Discharge Detection and Elimination (IDDE)	D					P				P
MS4 Program	Preventative Maintenance Inspection Program		D		D	D					
MS4 Program	Street Sweeping	P	D		D	D	P	D	P	P	
Other	Environmental Engineering / Policy Program	P	P		P		P		P		
Outreach / Education	Community Outreach Promoting Empowerment	D	D	D	D	D	P	D			
Outreach / Education	Pet Waste Outreach	D	P		P			P			
Property Owner	Alternative Compliance Program		D		D	D					
Property Owner	Raincheck Rebate Program		D	P	D	D	P				
Trash / Dumping	Clean Lot Program	P					P	D			

Program type	County program	Water quality issues (D = Directly addresses issue P = Potentially effects issue)									
		Bacteria	Nitrogen	Pesticides/ Herbicides	Phosphorus	Sediment	Toxics (e.g., PCBs)	Trash	Chlorides	Sulfates	pH
Trash / Dumping	Comprehensive Community Cleanup Program						P	D			
Trash / Dumping	County Recycling Program						D	D			
Trash / Dumping	Illegal Dumping Enforcement						P	D			
Trash / Dumping	Trash Outreach (Clean Sweep Initiative)	P	P		P	P		D			
Tree Planting	Right Tree, Right Place Program		D		D						
Tree Planting	Stormwater Stewardship Grant Program		D	P	D	D	P				
Volunteer	Clean Up, Green Up Program	P	P		P			D			
Volunteer	Green Team							D			
Volunteer	Master Gardeners / Bay-Wise Program		D	D	D	D	P				
Volunteer	Master Gardeners Program		D	P	D	P					
Volunteer	Neighborhood Cleanup Program	P					P	D			
Future programs											
Other	Toxics			D			D				
Trash / Dumping	In-Stream Trash Trap Installations							D			

Note: CIP = Capital Improvement Program; D = directly addresses issue; P = potentially effects issue.

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5 WATER QUALITY IMPROVEMENT PROJECTS

This section looks at the steps involved in prioritizing water quality improvement practices, or BMPs, and including BMP types and their locations. These steps involved looking at which BMPs are more effective for treating water quality issues and their causes; reviewing BMP design and placement constraints; identifying the most appropriate BMPs for each County watershed; and identifying preferred BMP locations within watersheds.

5.1 Watershed Restoration Practices

Table 5-1 lists structural BMP types that could be used for restoration and places them into broader categories based on similarity of function. MDE (2014a) further separates BMPs into three broad classes—runoff reduction (RR), stormwater treatment (ST), and alternative BMP technique (ALT)—which also are identified in Table 5-1. RR practices reduce pollutants through infiltration interception by vegetation and adsorption by soil (e.g., bioswales and permeable pavement). ST practices reduce pollutants through filtration or settling (e.g., sand filters and wet ponds). RR practices have a higher level of pollutant removal than ST practices because of their removal mechanisms. ALT practices are restoration activities such as stream restoration.

Table 5-1. BMP types, categories, and classes

Type	Category	Class
Attenuation swale or dry swale	Urban infiltration	RR
Bioretention	Bioretention	RR
Bioswale	Bioswale	RR
Disconnection of nonrooftop runoff	Disconnection	RR
Disconnection of rooftop runoff	Disconnection	RR
Dry well	Urban infiltration	RR
Enhanced filters	Urban filtration	ST
Extended detention–wetland	Wet ponds and wetlands	ST
Extended detention structure, wet	Wet ponds and wetlands	ST
Grass swale	Urban infiltration	RR
Infiltration basin	Urban infiltration	RR
Infiltration trench	Urban infiltration	RR
Infiltration trench–complete exfiltration	Urban infiltration	RR
Infiltration trench–water quality exfiltration	Urban infiltration	RR
Landscape infiltration	Urban infiltration	RR
LID–infiltration system	Urban infiltration	RR
LID–bioretention	Rain gardens	RR
LID–disconnection of impervious areas	Disconnection	RR
LID–grass channel with underdrain	Urban infiltration	RR
LID–grassed channel	Urban infiltration	RR
LID–grid pavers	Permeable pavement	RR
LID–infiltration trench	Urban infiltration	RR
LID–infiltration trench grassed channel	Urban infiltration	RR
LID–porous pavement	Permeable pavement	RR
LID–rain garden	Rain gardens	RR
Microbioretention	Rain gardens	RR
Permeable pavements	Permeable pavement	RR
Pocket sand filter	Urban filtration	ST
Porous paving	Permeable pavement	RR
Retention pond (wet pond)	Wet ponds and wetlands	ST
Sand filter	Urban filtration	ST
Shallow marsh	Wet ponds and wetlands	ST
Sheet flow to buffer	Disconnection	RR
Stream stabilization	Stream restoration	ALT
Submerged gravel wetlands	Wet ponds and wetlands	ST

Note: LID = low impact development.

5.2 BMP Impacts on Water Quality Issues

These broader BMP categories shown in Table 5-1 were compared to the identified water quality issues and their causes (section 4). Table 5-2 and Table 5-3 present the effectiveness of certain BMP categories in addressing water quality issues and causes, respectively. The BMPs were each assigned a relative impact of High, Medium, or Low. Some BMPs will have no impact on a given water quality issue or a cause of a water quality issue. Additionally, for some water quality issues and BMPs, there are not enough data available to determine their impacts.

The information in Table 5-2 is based on actual data. MDE's *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits* (MDE 2014a) contains BMP load reduction efficiencies for TN, TP, and TSS.

MDE (2014a) has provided load reduction efficiencies for each BMP listed. RR practices are designed to capture and infiltrate more stormwater runoff than ST practices, resulting in greater load reductions. Because MDE no longer considers dry ponds to have water quality benefits, upgrades of a dry pond to another BMP do provide water quality benefits and are included in Table 5-2.

Load reduction information was also obtained from the Virginia Department of Environmental Quality (VDEQ) *Guidance Manual for Total Maximum Daily Load Implementation Plans* (VDEQ 2017), *International Stormwater BMP Database: 2016 Summary Statistics* (Clary et al. 2017), and the National Pollutant Removal Performance Database (CWP 2007). Following is the additional load reduction information for the water quality issues:

- **Bacteria:** The VDEQ TMDL implementation guidance included load reductions for bacteria (VDEQ 2017). The *International Stormwater BMP Database* documentation states that most BMPs are unable to reduce bacteria concentrations to primary contact recreation receiving water standards, except for retention ponds in treating *E. coli* (Clary et al. 2017). Several BMPs—bioretention, wetland basins, retention ponds, and dry extended detention basins—however, can reduce levels of fecal coliform bacteria concentrations.
- **BOD:** No single source provides all the available data on the effects of BMPs on BOD concentrations in streams. For RR and ST practices and street sweeping, the values in Table 5-2 were adopted from Harper (1995) and USEPA (2018). Values for alternative BMPs were determined using best professional judgment and known nutrient reductions, based on the understanding that one of the causes of increased BOD in streams is nutrients transported by urban runoff.
- **Chlorides:** No data are available on the chloride load reductions from BMPs. Chlorides come primarily from road-salting operations. Currently, alternative load reduction approaches include using materials other than rock salt for deicing operations and ensuring that runoff from salt storage facilities is prevented from entering water bodies.

Table 5-2. Impact of BMPs on water quality issues

Water quality issue	RR practices				ST practices			MDE-approved ALTs					
	Bioretention / rain gardens	Bioswales	Permeable pavement	Urban infiltration	Urban filtering	Convert dry pond to wet pond	Wet pond / wetland	Street sweeping	Impervious surface elimination	Urban tree planting	Urban stream restoration	Outfall enhancement	Urban forest buffer
Bacteria[a]	H	M	H	H	L	L	M	M	M	M	M	nd	M
BOD	H	H	H	H	M	M	M	L	H	L	L	M	H
Chlorides	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Nitrogen	H	H	H	H	H	H	H	M	H	L	M	M	H
Pesticides/herbicides	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Phosphorus	H	H	H	H	H	H	H	M	H	L	H	M	H
pH	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sediment[b]	H	H	H	H	H	H	H	H	H	L	H	M	H
Sulfates	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Toxics (e.g., PCBs)	H	M	H	H	H	M	M	H	nd	nd	nd	nd	nd
Trash	H	H	0	H	H	H	H	H	nd	0	0	0	nd

Notes: Relative Impact: 0 = no impact; H = high; M = medium; L = low; nd = no data available.

[a] Includes fecal coliform bacteria, *E. coli*, and *Enterococcus*.

[b] Includes TSS.

Table 5-3. Impact of BMPs on causes of water quality issues

Cause of water quality issues	RR practices				ST practices			MDE-approved ALTs					
	Bioretention / rain gardens	**Bioswales**	**Permeable pavement**	**Urban infiltration**	**Urban filtering**	**Convert dry pond to wet pond**	**Wet pond / wetland**	**Street sweeping**	**Impervious surface elimination**	**Urban tree planting**	**Urban stream restoration**	**Outfall enhancement**	**Urban forest buffer**
Agricultural processes / Historical agriculture	n/a	H	n/a	n/a	nd	n/a	H	n/a	n/a	L	H	n/a	H
Livestock	n/a	n/a	n/a	n/a	n/a	n/a	nd	n/a	n/a	n/a	H	n/a	H
Land use / Land cover changes that affect hydrologic conditions	H	H	H	H	M	M	M	n/a	H	H	M, H	n/a	H
Stream channel erosion / Channelization	H	H	H	H	L	n/a	L	n/a	L	n/a	H	H	H
Trash / Illegal dumping	n/a	n/a	n/a	n/a	n/a	n/a	n/a	M	n/a	n/a	n/a	n/a	n/a
Legacy PCBs in soil and sediment	nd	nd	nd	nd	nd	nd	nd	L	n/a	n/a	M	n/a	n/a
Industrial facilities exceeding discharge limits	nd	nd	nd	nd	M	M	M	n/a	n/a	n/a	n/a	n/a	n/a
Landfill leachate	n/a	n/a	n/a	n/a	n/a	n/a	H	n/a	n/a	n/a	L	n/a	n/a
Runoff of oil and grease	H	H	H	H	H	H	H	n/a	L	n/a	n/a	n/a	n/a
Stormwater infrastructure (e.g.,outfalls)	L	L	L	H	n/a	n/a	n/a	n/a	L	n/a	H	H	M
Sand / Gravel mining	n/a	n/a	n/a	n/a	H	H	H	n/a	n/a	n/a	H	n/a	n/a
Septic and sewer system leakage	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Notes: Relative Impact: 0 = no impact; H = high; M = medium; L = low; n/a = practice not applicable; nd = no data available.

- **Pesticides/Herbicides:** No data are available on pesticide/herbicide load reductions from structural BMPs. BMPs for pesticides and herbicides are generally focused on adherence to handling, use, and application guidelines found on regulated container labels. Proper handling and use can minimize discharges into surface and subsurface waterways, thus limiting exposure of nontarget organisms. Alternative pest control techniques such as biological and cultural control can help reduce or eliminate the need for pesticides and herbicides and are relevant to both agricultural and homeowner/lawn care uses.
- **pH:** No data are available on how BMPs directly improve pH conditions in streams. Successful BMPs would treat water at the sources of the increased acidity or alkalinity before it enters water bodies and not treat the water bodies themselves. Depending on site conditions, cement used in concrete at construction sites could be a source of increased pH. Low pH can be caused by untreated industrial discharges.
- **Sulfates:** No data are available on the sulfate load reductions from BMPs.
- **Toxics (e.g., PCBs):** No data are available on the load reductions for toxics from BMPs. Current management activities to specifically address PCB loadings do not exist. Current upland practices for sediment management can be considered to contribute to PCB removal, as PCBs are often associated with sediment (MDE 2014b).
- **Trash:** No data are available on how BMPs directly prevent trash from entering streams or remove trash from streams. The values in Table 5-2 are based on professional knowledge of the design, operation, and maintenance of structural BMPs. The BMPs that would have the greatest effect are those that trap trash, which is then removed through routine maintenance. Other practices that prevent trash from entering water bodies are volunteer cleanup, trash nets on stormwater outfalls, and education/outreach.

The information in Table 5-3 is based on published information on BMP pollutant removal performance and supplemented by professional experience with various BMP types and different causes of water quality issues.

5.3 BMP Site, Placement, and Design Constraints

Because BMPs have certain site, placement, and design constraints, they cannot all be placed everywhere. MDE (2009) has identified the following potential site location factors or constraints that influence the suitability of a BMP type at specific locations:

- **Drainage Area:** The size of drainage areas contributing runoff to various BMPs can vary widely. In general, the maximum drainage areas for RR practices are limited to smaller areas, ranging from 10,000 square feet for a rain garden to 10 acres for infiltration basins. ST practices can handle larger drainage areas and often have a minimum size requirement for their drainages.
- **Topography/Slope:** Site and drainage area topography (i.e., slope) do not typically constrain BMPs with a few notable exceptions, including infiltration practices and bioswales.
- **Soils:** Soil conditions are an important consideration for RR practices, especially those that rely on infiltration. These practices function best when soil permeability is high, as in sandy soils. ST practices, on the other hand, require soils of low permeability or, if

their permeability is not sufficiently low, the use of an impermeable geotextile liner to reduce or eliminate soil infiltration.

- **Water Table:** The depth to the water table is an important consideration for RR practices that rely on soil infiltration. The probability of failure for certain practices increases if the water table is too high and they intercept the flow of groundwater.
- **Space:** Space considerations include the surface area footprint required for the BMP to function. The footprint for many BMPs depends on the size of the impervious drainage area contributing runoff. ST practices typically control larger drainage areas and must have sufficient space available at their location.
- **Infrastructure:** The location of existing and proposed buildings and utilities (e.g., water supply wells, sewer pipes, storm drains, electricity, and overhead power / communication lines) influence the design and construction of both RR and ST practices.
- **Hot Spot Runoff:** Hot spots are areas of increased concentration of pollutants. Runoff from hot spot areas is an important consideration for RR practices that rely on infiltration. These practices should not be used to treat hot spots that generate higher concentrations of hydrocarbons, trace metals, or toxicants than are typically found in stormwater runoff.

In addition to location constraints, MDE (2009) identified community and environmental factors that influence the suitability of a BMP for its intended use. These factors include the following:

- **Ease-of-Maintenance:** All BMPs require routine inspection and maintenance. The level of effort needed to maintain a BMP varies depending on the frequency of scheduled maintenance, chronic maintenance problems (e.g., clogging), and its failure rate.
- **Community Acceptance:** This factor is measured by market and preference surveys, reported nuisance problems, and visual aesthetics.
- **Construction Cost:** This factor is identified as the relative construction cost per impervious acre treated as determined from cost surveys and local experience.
- **Habitat Quality:** BMPs were rated on their ability to provide wildlife or wetland habitat, if appropriately designed. Selected objective criteria include size, water features, wetland features, physical complexity, and vegetative cover of the BMP and its surrounding area.

Table 5-4 looks at how these factors affect BMP suitability. Each factor is rated from low to high on the amount of influence it has on the selection of a specific BMP. For example, if there is limited space available for the placement of the BMP, then a bioretention system (with a low-impact rating) is a better choice than a wet pond practice, which has a high-impact rating. The ratings in the table apply to the typical BMP design. BMPs can be designed to affect the impact of site conditions. For instance, BMPs can be specifically designed to make routine maintenance easier.

Table 5-4. Impact of site conditions / placement constraints on BMPs

Site condition / placement factor	Factor influence/impact	RR practices				ST practices			MDE-approved ALTs						
		Bioretention / rain gardens	Bioswales	Permeable pavement	Urban infiltration	Urban filtering	Convert dry pond to wet pond	Wet pond / wetland	Street sweeping	Impervious surface elimination	Urban tree planting	Urban stream restoration	Outfall enhancement	Urban forest buffer
Community acceptance	Relative rating of how positive the impact of a BMP is on community acceptance	H	M	M	M	H	H	H	M	H	M	H	H	H
Cost per impervious acre	Relative rating of cost effectiveness	M	M	M	M	L	L	L	M	M	L	M	M	L
Drainage area	Influence of drainage area size in selecting a BMP	H	H	H	H	L	L	L	n/a	n/a	n/a	n/a	n/a	n/a
Ease-of-maintenance	Influence of a high degree of required maintenance	M	M	H	H	M	M	M	L	n/a	L	L	M	L
Habitat quality	Relative rating of how positive the impact of a BMP is on habitat	M	L	L	L	L	H	H	n/a	H	H	H	M	H
Hot spots	Impact if a pollutant hot spot is present	H	H	H	H	L	L	L	nd	n/a	M	n/a	n/a	n/a
Infrastructure	Impact on BMP placement if other infrastructure is present	M	M	M	M	M	L	M	n/a	n/a	M	L	L	M
Soils	Influence of soil type and permeability on BMP operation	L	M	H	H	L	L	L	n/a	n/a	L	n/a	n/a	L
BMP footprint space	Impact of limited space for a BMP footprint	L	M	M	M	L	M	H	n/a	n/a	L	n/a	n/a	M
Topography / Slope	Impact of high slope for BMP or drainage area	M	H	H	M	M	L	L	n/a	n/a	0	n/a	n/a	0
Water table	Impact of a high water table on BMP selection	H	H	H	H	L	L	L	n/a	n/a	0	n/a	n/a	0

Notes: Relative Impact: 0 = no impact; H = high; M = medium; L = low; n/a = practice not applicable; nd = no data available.

5.4 Identifying/Prioritizing BMPs for Each County Watershed

The County has many types of BMPs and other restoration activities available to implement to help address water quality issues and causes. But, as discussed in sections 0 and 5.3, not every BMP is suited to use for every water quality issue, water quality cause, or location. This section provides an overview of the BMP options best suited to each of the County's watersheds by reviewing, comparing, and analyzing the content of the following tables.

- Table 4-1: Identifies water quality issues by watershed
- Table 4-2: Identifies potential causes of water quality issues by watershed
- Table 5-2: Identifies BMP effectiveness at treating water issues
- Table 5-3: Identifies BMP effectiveness at addressing causes of water quality issues

Table 5-5 prioritizes BMP options by watershed. The BMPs are listed in order of suitability priority from high to low. The conversion of dry ponds to wet ponds or wetlands was prioritized as a BMP option (Table 5-5) in watersheds with dry ponds. Numerous dry ponds receive runoff from thousands of acres throughout the County. These dry ponds do not receive water quality treatment credits towards the restoration goals, since most were designed for flood control, not water quality benefits. If a dry pond is converted to a wet pond or wetland, however, the practice will receive credit for the treatment of nutrients and sediment as an ST practice.

Soil erosion near stormwater outfalls and along streams can contribute substantial amounts of sediment to the water that diminish its quality. Consequently, stream restoration has been assigned a high priority because it is the only BMP that stabilizes eroding stream channels or replaces concrete-lined channels that provide no biological benefit. Similarly, outfall stabilization is assigned a high priority because it is the only BMP that addresses outfall failure and erosion.

Stream restoration and outfall stabilization do not reduce the pollutant load generated on land like RR and ST practices do. RR practices receive a higher priority than ST practices because they are more effective at removing pollutants. Each RR practice has its advantages and disadvantages related to its effectiveness in addressing different water quality concerns and suitability for particular site conditions.

Data provided in Table 5-2, Table 5-3, and Table 5-4 can be used to identify the most effective BMPs for the different scenarios. For instance, a bioretention facility would be prioritized higher than a bioswale in the Piscataway Creek watershed, because the watershed has a TMDL for bacteria and bioswales are not as efficient as bioretention facilities, according to Table 5-3 data. Similarly, a bioretention facility might be prioritized over other RR practices based on Table 5-4 data because of its slightly better scores for habitat, ease-of-maintenance, and topography.

Table 5-5. BMP option suitability prioritized by watershed

BMP (high to low priority)	**Anacostia River**	**Mattawoman Creek**	**Piscataway Creek**	**Potomac River Basin**			**Patuxent River Basin**					
				Oxon Creek	**Potomac River middle tidal**	**Potomac River upper tidal**	**Patuxent River lower**	**Zekiah Swamp**	**Patuxent River middle**	**Patuxent River upper**	**Rocky Gorge Dam**	**Western Branch**
ALTs												
• Conversion of dry pond to wet pond	X	X	X	X	X	X	X	X	X	X		X
• Stream restoration	X	X	X	X	X	X	X	X	X	X		X
• Outfall stabilization	X	X	X	X	X	X	X	X	X	X		X
RR practices												
• Bioretention	X	X	X	X	X	X	X	X	X	X	X	X
• Urban infiltration	X	X	X			X	X		X	X		X
• Permeable pavement	X	X	X	X	X	X	X	X	X	X	X	X
ST practices												
• Urban filtering practice	X	X	X	X	X	X	X	X	X	X	X	X
• Wet pond	X								X	X		
• Wetland	X		X	X	X	X	X		X			X

5.5 Prioritizing BMP Locations

The location of a BMP or other restoration practice has a significant impact on how successful the restoration will be. For instance, a lawn care campaign will have little effect in areas with few homeowners to implement the strategy. To identify the best locations for BMPs within a watershed, the County should consider sites where the greatest water quality benefit will be realized for the available funding as well as implementing the BMPs in a desirable time frame and with minimal disruption. Three main considerations for prioritizing BMP locations are land ownership and site access, location in the stream watershed, and locations of known issues and existing treatment.

5.5.1 Land Ownership and Site Access

DoE and the Clean Water Partnership (CWP) are actively installing BMPs throughout the County. The easiest locations on which to install water quality improvement practices are municipally owned land where town halls, police stations, public schools, and libraries have been built and on rights-of-way (ROWs) or easements along roads and stormwater outfalls. For example, County personnel have site access at stormwater outfalls (usually available as flood easements), which allows them to proceed without the delay of negotiating with private landowners, facilitating faster implementation and reducing the resources spent interacting with landowners.

In some instances, the County is granted permission from a property owner to install a BMP on their land. For example, the County's Alternative Compliance Program provides incentives to faith-based and other nonprofit organizations to allow the County to install BMPs on their properties. The organizations are granted credit towards their CWA fee. The aesthetics of a restoration project are often preferred to the condition of the site before the BMP was installed. Attractive examples of watershed restoration efforts can be used in an outreach effort to encourage landowners to grant access to their own properties. A public education campaign highlighting these examples can build public support for implementing BMPs on private property.

5.5.2 Location in the Watershed

Another factor to consider in BMP placement is the location relative to the stream's headwaters. Improvements to water quality and stream stability in the stream's headwaters will provide benefits along the entire length of the stream. For instance, stream restoration is most effective if the effect of a BMP starts at the headwaters and works downstream so that, during restoration, upstream excess sediment will not damage newly restored areas downstream. Restoring conditions in the headwaters makes it easier to detect and attribute the water quality improvements to each restoration project. Adding BMPs to headwaters above stream restoration projects will help protect the stream reaches that have been restored.

Severe erosion, or head cuts, have been observed in 10 of the 12 watersheds, (none have been found in the Mattawoman Creek or Zekiah Swamp watershed), which is a strong indication that opportunities for stream restoration exist in the County (Figure 5-1). A "head cut" is where there is a sharp change in stream bed elevation caused by erosion of the stream bed. These areas continue to erode in an upstream direction, releasing sediment that is conveyed downstream.

The SCAs conducted in the 2000s (section 3.1) identified 589 sites throughout the County as having erosion issues ranging from Very Severe to Moderate. Of those sites, 63 were categorized as having Very Severe erosion, 84 as having Severe erosion, and 216 as having Moderate erosion.

Figure 5-1. Example of stream head cut.

5.5.3 Locations of Known Issues and Existing Treatment

A third key consideration in determining where to place BMPs is identifying where they have not yet been adequately implemented and where known erosion issues and areas of poor biological health exist. Figure 5-2 shows how these locations can be mapped to identify priority areas for targeted BMP development. Appendix D provides maps for the other watersheds. These locations were identified by reviewing existing and planned locations and types of BMPs (e.g., RR and ST), regulatory agency (only County MS4 land is identified), and areas of concentrated impervious surfaces. The impervious and regulatory areas were not included on the map to make it clearer and easier to read.

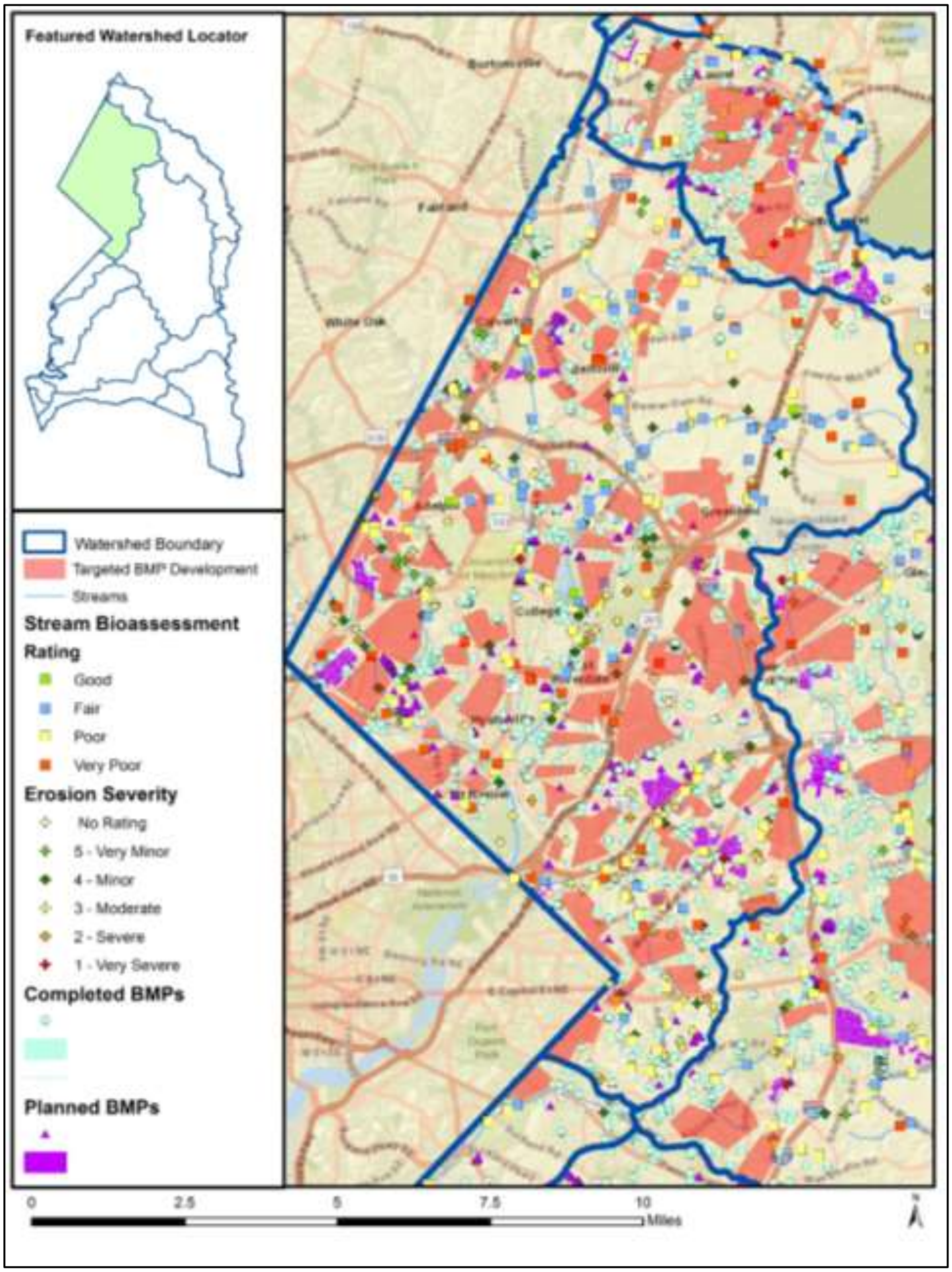

Figure 5-2. Example map of areas for BMP prioritization in the Anacostia River watershed.

6 LOAD REDUCTION BENCHMARKS AND DEADLINES

This section looks at benchmarks and end dates for meeting load reduction targets for the Chesapeake Bay and local TMDLs. The section also discusses the County' current rate of watershed restoration and difficulties in meeting the benchmarks and end dates. Finally, this section discusses nonstormwater activities that aid in watershed restoration and load reductions.

6.1 Load Reduction Benchmarks

6.1.1 Chesapeake Bay TMDL

The Chesapeake Bay TMDL and associated watershed implementation plans (WIPs) have established stormwater load reduction targets to be met by the year 2025. The EPA set a mid-TMDL benchmark of meeting 60 percent of the load reduction targets by 2017. In 2016, MDE acknowledged that the state's urban communities (e.g., Prince George's County) would not meet their load reduction targets by 2025 at their current rate of restoration implementation and that it would allow them to trade nutrient and sediment credits with WWTPs to achieve the load reduction goals.[3] Eventually, the urban communities will need to meet their load reductions through implementing stormwater BMPs. Nutrient and sediment credit trading will be allowed only for the Chesapeake Bay TMDL because of its set end date, while local TMDLs do not have an end date.[4]

6.1.2 2014 Local TMDL Restoration Plans

Each of the County's 2014 local TMDL restoration plans revised in 2015 established ambitious load reduction targets and benchmarks to be reached by 2030, setting annual goals, or "benchmarks." The following factors contribute to the overall planned implementation schedule:

- A major factor is the availability of funding, which can limit the rate of watershed restoration and BMP implementation.
- The Phase II WIP for the Chesapeake Bay TMDL has a target end date of 2025 by which to achieve its load reduction targets (section 6.1.1).
- The County has initiated the CWP, which initially focuses on managing ROW runoff for older communities located inside the Capital Beltway. The CWP is helping increase the rate of watershed restoration and BMP implementation in the County (section 6.2).

Table 6-1 presents the annual load reductions needed in the four watersheds with local TMDLs established for TN, TP, and TSS. Even though each of the restoration plans identified an end date by which to achieve load reduction targets, no end date has been mandated for the local TMDL restoration plans. While the County shares the public's urgency in achieving these reductions, resources needed for restoration activities (e.g., funding and staff) remain limited. The County and its watershed partners, however, remain committed to finding site opportunities and to expediting resources for the planning, design, and construction phases to the maximum extent practicable.

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[3] Central Maryland WIP Workshop, MDE, Catonsville, Maryland, September 21, 2016.

[4] Maryland Water Quality Trading Webinar, MDE, October 22, 2018.

Table 6-1. Annual load reduction benchmark goals for local TMDLs

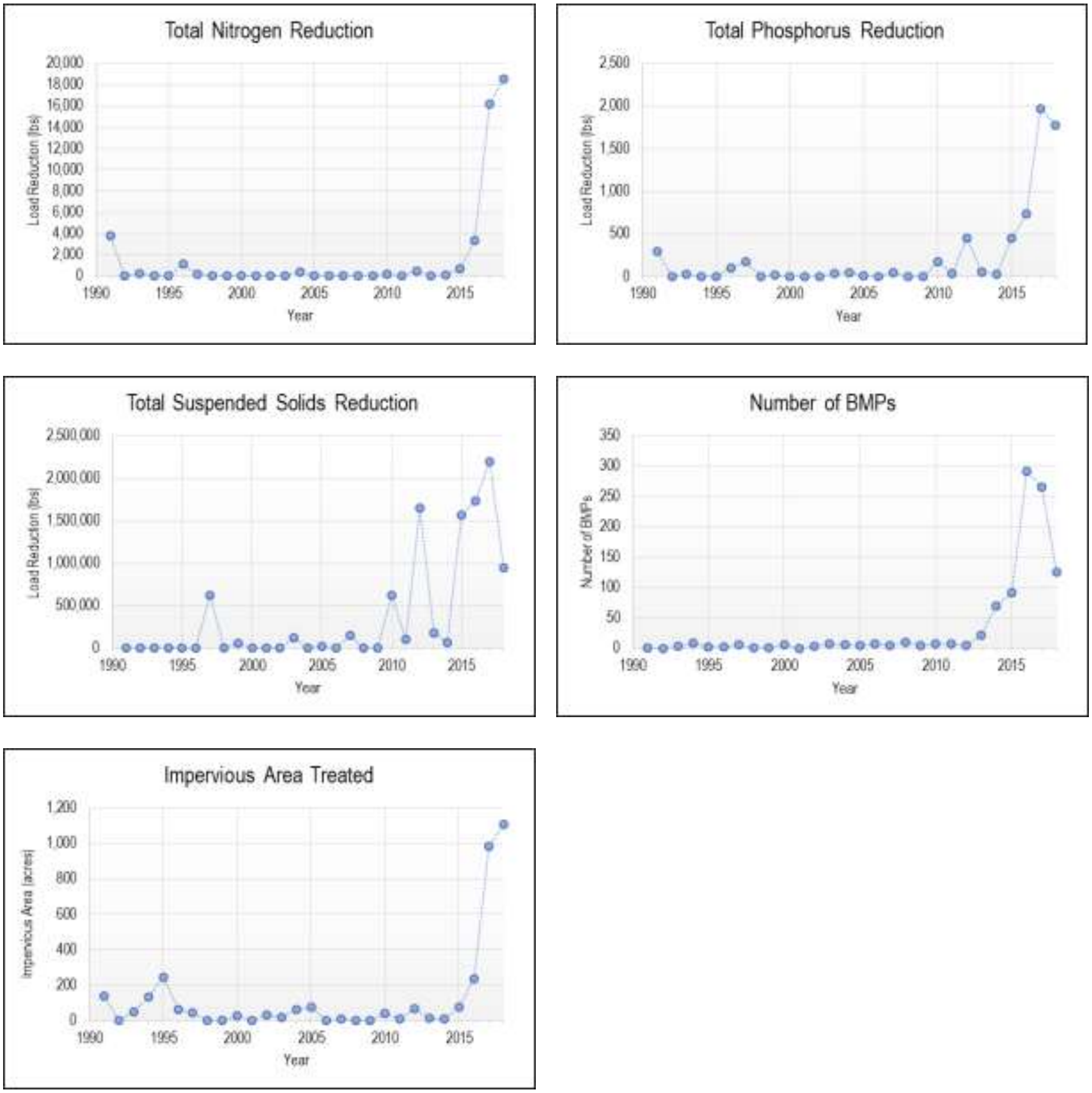
Fiscal Year	Anacostia River (lb/yr)			Mattawoman Creek (lb/yr)		Upper Patuxent (lb/yr)	Rocky Gorge Dam (lb/yr)	Total (lb/yr)		
	TN	**TP**	**TSS**	**TN**	**TP**	**TSS**	**TP**	**TN**	**TP**	**TSS**
2016	8,603	1,756	2,052,328	340	63	12,750	0.8	8,943	1,820	2,065,078
2017	9,750	1,990	2,325,971	385	71	14,450	0.9	10,135	2,062	2,340,421
2018	10,897	2,224	2,599,615	431	79	16,150	1.0	11,328	2,304	2,615,765
2019	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2020	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2021	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2022	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2023	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2024	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2025	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2026	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2027	11,283	2,303	2,691,648	446	82	16,722	1.0	11,729	2,386	2,708,370
2028	10,719	2,188	2,557,066	424	78	15,886	0.9	11,143	2,267	2,572,952
2029	9,026	1,842	2,153,318	357	66	13,378	0.8	9,383	1,909	2,166,696
2030	4,378	890	1,046,062	173	31	5,888	0.4	4,551	921	1,051,950
Total	**154,920**	**31,617**	**36,959,192**	**6,124**	**1,126**	**229,000**	**22**	**161,044**	**32,765**	**37,188,192**

Sources: Tetra Tech 2015a, 2015b, 2015c, 2015d, 2015e.
Note: lb/yr = pounds per year.

6.2 Current Implementation Rates and Benchmark Projections

The County has been installing BMPs in support of watershed restoration since the 1990s. Historically, the rate of implementation has been low (Figure 6-1). The BMP information in Figure 6-1 presented as of June 30, 2018 and reflects traditional structural BMPs including stream restoration, outfall stabilization and tree planting, however, does not consider routine maintenance such as street sweeping or catch basin cleaning. Between 1991 and 2012, the number of BMPs installed for restoration fluctuated between 1 and 10 per year. After 2012, the rate of installation vastly increased, mainly because of the creation of the CWP.

The load reductions resulting from BMPs have usually closely corresponded to the number of BMPs installed. The key exceptions occurred in the 1990s (1991 and 1997) and 2018. In these instances, the County implemented large pond projects that treat large areas, and thus have significant load reductions. The number of BMPs peaked in 2016 with a total of 291 BMPs. The majority of BMPs installed in 2016 comprised smaller BMPs such as disconnection of rooftop (29 projects) and non-rooftop runoff projects (35), rainwater harvesting (53), and impervious to pervious surface conversion projects (76). Certain BMPs, such as rainwater harvesting and rooftop disconnection, do not treat runoff from a large area, which explains why there was not a corresponding spike in TN and TP reduction to the increase in BMPs. The spike in TSS removal in 2016, however, was driven by increases in stream restoration and wet pond projects, which are typically the largest contributors to TSS removal from year to year including the peaks in 1997, 2010, and 2012.



Note: BMP implementation completed as of June 30, 2018.

Figure 6-1. Rate of BMP implementation and load reductions.

The pollutant load reductions in 2013 and 2014 also did not seem to follow the increase in BMPs installed for those years. This is due to a similar reason as discussed above for 2016. A third of the BMPs installed in 2013 and 2014 were impervious to pervious surface conversion and rainwater harvesting projects. Additionally, in 2012 there were four large stream restoration projects that are presented in the plots as peaks in pollutant reduction. This peak skews the following two years by making it seem like a large decline in reduction.

Recently, CWP's focus has been on retrofitting less effective stormwater ponds to remove additional pollutants. Because these are larger projects, fewer are installed each year, but the load reduction amount is large (Figure 6-1). In 2018, 95 percent of the load reductions came from pond retrofits. Unfortunately, only a limited number of pond retrofit opportunities exist in the County. Once those opportunities are exhausted, the County will need to rely on smaller, more numerous, and less cost-effective practices.

Compared to the annual load reduction benchmarks in Table 6-1, the values in Figure 6-1 show that in 2016 all reduction goals were missed; the TN and TP reduction goals of 8,943 lbs/yr and 1,820 lbs/yr were missed by more than half, while the TSS reduction was only under by about 15 percent. However, the annual TN reductions in 2017 were approximately 6,000 lbs over the projected 2017 annual load reduction in Table 6-1 (from the 2014 restoration plans). The 2018 load reductions exceeded the projected 2017 annual load reduction goal for TN reductions; however, TP reduction fell slightly short and TSS reduction was less than one-half of the sediment reduction goal.

The County has 589 BMPs that are in the planning, design, or construction phase. In total these projects are projected to remove 15.6 million lbs of TSS, 253,531 lbs of TN, 5,638 lbs of TP and treat runoff from an equivalent of 3,020 acres of impervious area. Micro-bioretention projects make up most of the future projects with 214 BMPs. However, the pollutant load reduction due to these BMPs only comprise a fraction of the expected total. There are 52 wet ponds in the 589 future BMPs, though, they are expected to remove 75 percent of the total impervious area, and 95 percent of the TSS, TN, and TP load reductions.

6.3 Biological and Water Quality Responses to BMP Implementation

The results of the County's biological assessments and water quality monitoring are discussed on a broad scale in sections 2.1 and 2.2, respectively. This section looks at those data at a finer scale to determine if restoration efforts by the County are reflected in the monitoring results.

6.3.1 Biological Results

As discussed in section 2.1, the County conducts 3-year rounds of biological monitoring and provides the results for each of the 41 subwatersheds in the County. Figure 6-2 and Table 6-1 show the percent degradation for each subwatershed for the three rounds of monitoring that have been completed to date.

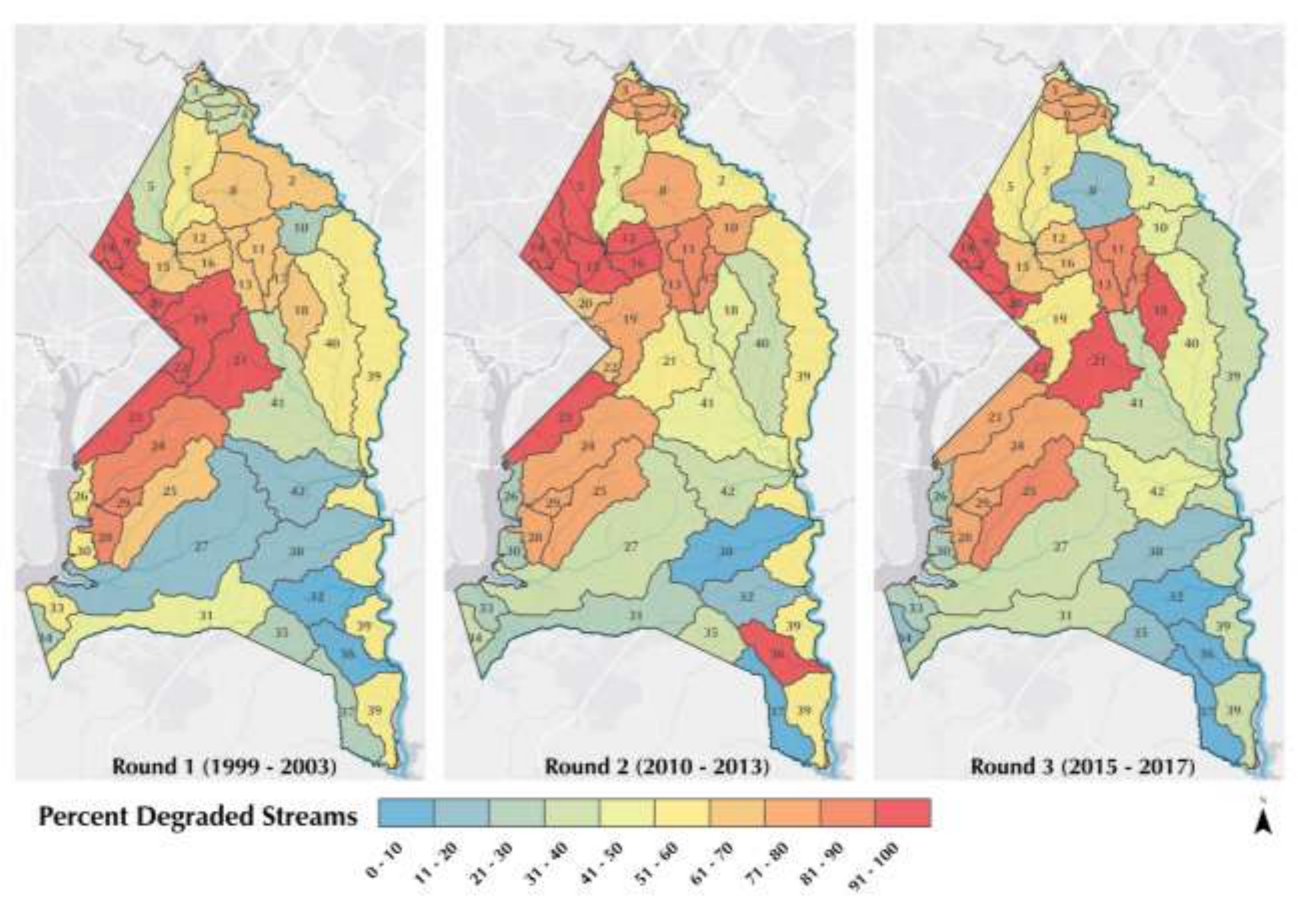


Figure 6-2. Degraded status of streams in subwatersheds in the County.

Table 6-2. Degraded status of streams in subwatersheds in the County

Watershed	Subwatershed (map ID)	Percent degraded (%)		
		R1 (1999–2003)	R2 (2010–2013)	R3 (2015–2017)
Anacostia River	(05) Paint Branch	38	100	57
	(07) Indian Creek	58	44	56
	(08) Upper Beaverdam Creek	63	71	14
	(09) Northwest Branch	100	100	100
	(12) Upper Northeast Branch	67	100	67
	(14) Sligo Creek	100	100	100
	(15) Lower Northeast Branch	67	100	67
	(16) Brier Ditch	67	100	67
	(19) Lower Beaverdam Creek	92	71	57
	(20) Upper Anacostia River	100	67	100
	(22) Lower Anacostia River	100	67	100

Watershed	Subwatershed (map ID)	Percent degraded (%)		
		R1 (1999–2003)	R2 (2010–2013)	R3 (2015–2017)
Patuxent River upper	(01) Rocky Gorge Dam	n/a	n/a	n/a
	(02) Upper Patuxent River	63	56	47
	(03) Walker Branch	40	71	80
	(04) Crow's Branch	40	71	80
	(06) Bear Branch	40	71	80
	(10) Horsepen Branch	29	75	50
Western Branch	(11) Folly Branch	63	83	86
	(13) Bald Hill Branch	63	83	86
	(17) Lottsford Branch	63	83	86
	(18) Northeast Branch (Western Branch)	67	50	100
	(21) Southwest Branch	100	57	100
	(40) Collington Branch	58	33	50
	(41) Western Branch	40	42	38
	(42) Charles Branch	20	40	50
Patuxent River lower	(32) Spice Creek	0	17	0
	(36) Black Swamp Creek	0	100	0
	(37) Swanson Creek	27	0	0
	(39) Lower Patuxent River	52	57	36
Patuxent River middle	(38) Mataponi Creek	18	0	20
Oxon Creek	(23) Oxon Run	100	100	80
Potomac River upper tidal	(24) Henson Creek	89	71	71
	(26) Upper Potomac River	57	25	25
	(28) Broad Creek	89	71	71
	(29) Hunters Mill	89	71	71
	(30) Swan Creek	57	25	25
	(33) Lower Potomac River	57	25	25
Potomac River middle tidal	(34) Pomonkey Creek	29	40	20
Piscataway Creek	(25) Tinkers Creek	62	71	86
	(27) Piscataway Creek	19	38	37

Watershed	Subwatershed (map ID)	Percent degraded (%)		
		R1 (1999–2003)	R2 (2010–2013)	R3 (2015–2017)
Mattawoman Creek	(31) Mattawoman Creek	46	27	33
Zekiah Swamp	(35) Zekiah Swamp Creek	29	40	20

Figure 6-2 and Table 6-1 show that:

- Only three of the watersheds showed improvements from R1 to R2 and from R2 to R3:
- Lower Beaverdam Creek (Map ID 19) in the Anacostia River watershed
- Upper Patuxent River (Map ID 02) in the Upper Patuxent River watershed
- Swanson Creek (Map ID 37) in the Lower Patuxent River watershed
- Fourteen other subwatersheds improved only between R1 and R2:
- But eight of those watersheds showed decline between R2 and R3.
- The remaining six stayed at the same percent degradation.
- Fourteen other subwatersheds improved only between R2 and R3.

Appendix E presents the changes in biological scores between R1 and R2 and between R2 and R3, in addition to the area treated by BMPs (ST practices, RR practices, stream restoration/ outfall stabilization, and septic connections to WWTPs or septic denitrification). Based on the data, the Lower Beaverdam Creek subwatershed has improved (i.e., percent degradation has decreased) over the past two rounds of biological monitoring. Six hundred feet of stream restoration/outfall stabilization have occurred in the watershed, which could have helped improve the stream conditions. The Lower Anacostia River subwatershed, however, showed increased degradation from R2 to R3 monitoring, while having 2,210 feet of stream restoration/outfall stabilization. R3 monitoring occurred in the upstream portion of the stream restoration project, thus did not reflect the full benefits of the stream restoration.

Determining definitively the effect of BMPs on stream health is difficult because the biological condition of a stream is influenced by a variety of factors that interact in complex ways. The same BMP can function differently in different locations depending on site-specific characteristics. The data in Figure 6-2 and Table 6-1 show that there has been measurable improvement in some of the County's subwatersheds and that, at some locations, BMPs and other restoration activities appear to be aiding in the improvement.

The County is currently planning another round of biological monitoring that will begin in 2019 and be completed in 2021. Data from that round will provide more detail on how aquatic conditions are changing as the County increases BMP implementation.

6.3.2 Water Quality Results

The monitoring data presented in appendix B were analyzed to identify any trends in water quality. Nutrient plots show decrease in concentrations and less scatter in the data. These decreases could be attributed to the numerous watershed restoration activities occurring. For instance, the decreases in nutrient concentrations were observed at a time when the capacity of WWTPs to treat nitrogen was being increased. There was also an increase in BMPs and septic upgrades during the monitoring periods.

Downward trends in nutrient concentrations in the Chesapeake Bay watershed might reasonably be expected based on the current magnitude of restoration efforts to reduce loads from agriculture, wastewater, and stormwater. Agricultural influences might include the reduced use of fertilizer in areas that are either no longer being farmed or are now operating under nutrient management plans and therefore should, over time, deliver lower nutrient loadings.

Air deposition of nitrogen, which accounts for a portion of the nitrogen loadings, should also be decreasing. The Clean Air Act of 1970 (CAA) has established regulations to reduce emissions from stationary and mobile sources, which have resulted in reducing particle pollution that contains nitrogen and phosphorus compounds. In 2006 and 2012, the EPA revised the regulations to lower the acceptable levels of particulate matter.

6.4 Difficulties in Meeting Benchmarks

The 2014 local TMDL restoration plans have an end date of 2030 by which to achieve load reduction targets. In the plans, the County had identified issues related to the forecasted implementation rate, including overall loading reduction limitations due to high allocations.

6.4.1 Required Load Reductions and Implementation

Several of the local TMDLs assign a WLA and percent load reduction to the County's MS4 (Table 6-3). MDE maintains a database of the necessary load reductions and percent load reductions. Table 6-3 provides percent load reduction information from MDE's Maryland TMDL Data Center (MDE 2018). Table 6-4 shows the number of different types of implementations identified in each of the County's local TMDL restoration plans. It includes the amount of untreated impervious area to be treated, assumed public compliance with pet waste pickup outreach, linear feet of proposed stream restoration, and number of trees proposed to be planted for watershed restoration efforts.

Table 6-3. Local TMDL percent load reductions

TMDL pollutant	Percent load reduction from MDE *TMDL Data Center* by watershed					
	Anacostia River	Piscataway Creek	Mattawoman Creek	Rocky Gorge Dam	Upper Patuxent River	Potomac River
TN	81.0%	–[a]	54.0%	–	–	–
TP	81.2%	–	47.0%	15.0%	–	–
TSS	85.0%	–	–	–	11.4%	–
BOD	58.0%	–	–	–	–	–
Bacteria	80.3%–99.9%[b]	42.6%	–	–	53.4%	–
PCBs	98.1%–99.9%[b]	5.0%–33.0%[b]	42.5%	–	–	5.0%–99.0%[b]

Source: MDE 2018.

Note:

[a] A local TMDL has not been developed or approved for this pollutant-waterbody combination.

[b] The TMDL identified different percent load reductions for different areas of the watershed; the range of percent reductions is provided.

Table 6-4. Local TMDL restoration plan implementation numbers

Implementation type	Watersheds					
	Anacostia River	**Piscataway Creek**	**Mattawoman Creek**	**Rocky Gorge Dam**	**Upper Patuxent River**	**Potomac River**
Treatment of impervious surfaces (% of otherwise untreated area)	98.6%	56% (Main Stem) 36% (Tinkers) 29% (Tidal Area)	96.1%	19.3%	53.1% (FCB) 30.0% (TSS)	42.4%
Pet waste control (% compliance)	65%	65%	65%	50%	35%	0%
Stream restoration (linear feet)	75,000	0	0	0	0	0
Tree planting (total number)	3,000	0	1,000	0	0	0

Sources: Tetra Tech 2015a, 2015b, 2015c, 2015d, 2015e.
Note: FCB = fecal coliform bacteria.

6.4.2 MDE TMDL Analysis

In the Anacostia River and Piscataway Creek watershed bacteria TMDL determinations, MDE recognized that meeting the WLAs was not feasible. The text from the Anacostia River watershed bacteria TMDL document is provided below (MDE 2006). The Piscataway Creek watershed bacteria TMDL contains similar language.

> As previously stated, water quality standards cannot be met in all subwatersheds using the MPR [maximum practicable reductions] scenario. This may occur in subwatersheds where wildlife is a significant component, or in subwatersheds that require very high reductions of fecal bacteria loads to meet water quality standards. Therefore, MDE proposes a staged approach to implementation of the required reductions, beginning with the MPR scenario, as an iterative process that first addresses those sources making the largest impacts on water quality and creating the greatest risks to human health, with consideration given to ease and cost of implementation.

and that:

> The uncertainty of BMP effectiveness for bacteria, reported within the literature, is quite large. As an example, pet waste education programs have varying results based on stakeholder involvement. Additionally, the extent of wildlife reduction associated with various BMP methods (e.g., structural, nonstructural, etc.) is uncertain. Therefore, MDE intends for the required reductions to be implemented in a staged process that first addresses those sources with the largest impact on water quality and human health risk [e.g., hot spots], with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

6.4.3 Chesapeake Bay Program Evaluations

The Chesapeake Bay Program and MDE have devised a hypothetical "everything by everyone everywhere (E3)" BMP implementation scenario (CBP 2016). It represents a "what-if" scenario in terms of the theoretical maximum levels of management controls in a watershed, regardless of cost or physical limitations in implementing BMPs, while incorporating practicality assumptions.

The E3 scenario assumes that BMPs will treat a 1-inch storm, which means that the BMP was designed to treat runoff from the first inch of a rainfall event. BMPs designed to treat a 1-inch storm, however, reduce nitrogen loads only by 57 percent, while BMPs designed to treat an entire 2.5-inch storm reduce nitrogen loads only by 72 percent. These higher efficiencies would help decrease the number of BMPs that would be needed to meet urban stormwater load reduction targets. BMPs designed to treat a 2.5-inch storm, however, require larger areas on which to be constructed, so they are not always feasible at all locations, especially on road ROWs and residential properties. This means that, while it is possible to use more effective practices that included in the E3 scenario, it is not always practicable.

The resulting load reductions can be determined using the Chesapeake Assessment Scenario Tool (CAST) version 5.4.1. The County's baseline loadings for 2010 were compared to the loadings from the E3 scenario for 2010 (CBP 2018). This comparison showed the load reductions from the hypothetical E3 scenario. Results showed that, for the County's MS4 areas, the maximum achievable load reductions under the E3 scenario were 49.6 percent for TN, 56.1 percent for TP, and 58.2 percent for TSS. In the Anacostia River watershed, the County is required to reduce nutrients by 80 percent.

The percent reductions from the E3 scenario do not achieve the local TMDL percent reductions for TN in the Mattawoman Creek watershed or for TN, TP, and TSS in the Anacostia River watershed. Increasing the BMP treatment volume to 2.5 inches, for all planned and existing BMPs in the watershed, would still not meet nitrogen reductions. In its TMDL restoration plans, the County indicated that, because of the large required load reductions, it would not meet the TN load reductions for the Anacostia River and Mattawoman Creek watersheds, the bacteria load reductions for the tidal portions of the Anacostia River watershed, or the PCB load reductions for the Anacostia River watershed, even by treating nearly 100 percent of the impervious areas in the watersheds (Tetra Tech 2015a, 2015b). Using the load reduction potential of current technology, every square inch of the Anacostia River watershed would need to be treated using the maximum efficiency BMPs (e.g., BMPs treating a 2.5-inch storm event) in addition to practices such as stream restoration, tree planting, street sweeping, and programmatic activities.

6.4.4 2030 End Date

The County is working with CWP to increase the County's TMDL implementation rates. They continue to research and evaluate innovative practices to help increase BMP efficiencies while lowering costs. Meeting the load reductions, however, will be difficult given the current technology.

The restoration plans estimated a rate of implementation that would result in achieving the TMDLs by 2030 as an initial estimate prior to knowing the rate of implementation that could be achieved by the County and CWP. It is now clear that, even with the increased BMP implementation rate and with help from the CWP, the County will not be able to meet the WLA by 2030. Rather than revising the restoration plan, however, the County proposes to use 2030 as a provisional milestone until the restoration plans and their end dates are revised.

6.4.5 Local Restoration Plan Revisions and Updates

Given the current rate of restoration implementation, the County proposes to update the local TMDL restoration plans in the third year of each MS4 permit cycle, with the first such update completed in 2021. These updates will use more comprehensive information on the actual rate of implementation and take advantage of recent technological advancements and increases in BMP load reduction efficiencies to more accurately estimate the end date by which the load reduction targets will be met. In addition, Round 4 of the countywide biological assessments will be completed in 2021 and will be used in the revision process. The results of each of the revision will be included in a plan addendum with updates to provisional milestones and costs.

The current restoration plans recognize that quantifying nutrient and bacteria load contributions from pollutant sources (e.g., illicit sewer connections and sanitary sewer overflows [SSOs]) can be difficult. There are ongoing activities to eliminate these sources (section 6.5.2). Addressing these sources will decrease the overall number of BMPs to be installed, potentially resulting in compliance being achieved sooner at a lower cost.

The County requests that MDE be involved in the restoration plan revision process and in updating the baseline loads and target load reductions. Most of the original TMDLs were developed more than 10 years ago (Table 1-1) and, since that time, the County has made concerted efforts to reduce illicit discharges and septic leaks. In addition, the WSSC is in the process of completing their Sewer Repair, Replacement and Rehabilitation (SR3) Program, which will address SSOs. The cumulative effect of these actions on water quality, however, has not yet been quantified.

Consequently, the County requests that MDE update the current water quality conditions in the watershed, along with the overall TMDLs and WLAs using the most recent water quality data available to determine if the load reduction required has significantly changed. The County has also requested that MDE continue its watershed monitoring programs to collect more recent water quality data that could be used in revision the restoration plan.

6.5 Nonstormwater Programs to Reduce Loads

6.5.1 County MS4 Programmatic Activities with Undetermined Load Reduction Potential

While the County is actively looking to further improve its rate of implementation and the efficiency of its BMPs, it will continue to undertake and support a variety of programs and technical projects expected to help improve water quality and provide other co-benefits.

Although percent removal efficiencies can be determined for BMPs, estimating potential load reductions from programmatic initiatives is challenging since some of the initiatives require public participation and a change in long-standing behaviors. The cumulative effects of these activities will help reduce loads entering local water bodies, thus improving their health. Most activities encourage behavior change by educating the public on how they can help improve water quality. The cumulative improvements in water quality resulting from these activities will be reflected in the County’s countywide MS4 permit monitoring program, along with other monitoring efforts (e.g., MDE).

- **Pet Waste Disposal:** If not disposed of properly, pet waste can contribute to significant bacteria loadings in addition to nutrient and BOD loadings to local waterways. Load reductions resulting from pet waste campaigns will be due to increased public education and pet owner access to pet waste stations and bags. As stated, the exact load reductions are difficult to quantify, but ultimately will include reducing nutrient and bacteria loadings to local water bodies. Waste from stray dogs and cats is not readily disposed of properly, thus it can be considered a source of nutrients and bacteria. Additional load reductions could result from stray dog and cat spay and neuter campaigns (for either pet or stray animals) as well as from fines for abandoning pets and adoption fairs.
- **Lawn Fertilizer Reduction:** A lawn care management program consists primarily of outreach to advise both residential and commercial landowners on how to use less fertilizer and apply it properly. Additional outreach can be conducted on other ways to maintain healthy yards that do not need fertilizer in the first place. Keeping applied fertilizers off paved surfaces and reducing the amount of fertilizer applied in the watershed can help reduce nitrogen and phosphorus loads. The actual load reductions depend on public compliance with lawn care practices encouraged by the program.
- **Litter Reduction:** The County maintains an aggressive litter control and collection program along County-maintained roadways. Measures the County is implementing include developing an Adopt-A-Stream program, launching the PGCLitterTRAK mobile application tracking tool, involving communities and municipalities in the Clean Sweep Initiative in the Anacostia River watershed, collaborating with the University of Maryland on a litter source reduction study specifically for the County, and kicking off the County's first trash trap project (DoE 2017). The County's litter control efforts and street sweeping programs removed more than 4,000 tons of debris and solid waste from County roadways during fiscal year 2017 (DoE 2018). The County expects nutrient, TSS, BOD, and bacteria load reductions associated with litter control; however, these could not be quantified. The load reductions will result from reducing improperly disposed of food waste (which in turn feeds nuisance wildlife that deposit bacteria in fecal matter) and other organic materials available to enter the storm sewer system and eventually settle to stream beds.
- **Urban Tree Planting:** Trees are known to provide numerous public health and social benefits. They clean the air, beautify neighborhoods and landscapes, help to conserve energy, help to reduce water pollution and soil erosion, cool city streets, increase property values, reduce runoff, and provide food and habitat for wildlife, among other benefits. The County's goal is to preserve, maintain, enhance, and restore tree canopy coverage on developed and developing sites for the benefit of County residents and future generations. The County is working to promote and increase tree plantings and increase the County's tree canopy coverage, which will help provide water quality, air quality, and habitat benefits. The County has several programs and materials that promote tree plantings: Tree ReLEAF Grant program; Tree Planting Demonstration program; Arbor Day Every Day program; Stormwater Stewardship Grants for Trees; and Right Tree, Right Place program. Expanding the urban tree canopy receives a small load reduction credit as part of the Chesapeake Bay TMDL.

6.5.2 Non-MS4 Technical Activities with Unknown Load Reduction Potential

The loading rates of nutrients and bacteria can also be reduced through a variety of technical measures not considered part of the County's MS4 WLA requirements, including correcting SSOs, eliminating septic leaks, and reducing atmospheric deposition. Each of these activities can contribute to reducing chronic loading rates or the frequency of spikes in pollutant concentrations. The cumulative improvements in the water quality from these activities will be reflected in monitoring efforts. Load reductions from these activities will decrease the overall amount of BMPs that will need to be installed, thus potentially decreasing cost and moving the date of compliance closer.

- **Sewer Repair and Rehabilitation:** One source of the nutrients and bacteria found in stormwater is aging sewer systems. In extreme cases, aging sewer lines result in SSOs. The single most effective measure to reduce SSOs is to repair and rehabilitate existing sewer lines. WSSC is under a 2005 consent decree with the EPA to overhaul its sewer lines to reduce SSOs under their SR3 Program. The improvements to leaky sewer lines could dramatically reduce human bacteria loads, along with nutrients, BOD, and TSS. Loadings from SSOs and other sewer leaks are reflected in water quality monitoring data. These data were used in TMDL development, meaning that loads from SSOs and other sewer leaks are assumed to contribute to the overall load from urban areas (e.g., the County's MS4 area). Load reductions from repairing sewer lines can be counted towards the County's stormwater load reduction progress if the proper information (e.g., pipe flow) is available.
- **On-Site Disposal System Repair and Replacement:** Nutrient and BOD loads from failing septic tanks are not part of the County's stormwater MS4 load reductions; however, upgrading septic systems or connecting houses to a sanitary sewer system could lower nitrogen loads to County streams. Nitrogen in the effluent from septic tanks enters the groundwater, which then can recharge County streams, thus adding nitrogen to the streams. It is difficult to accurately predict the number of failing septic systems, systems that would be connected to sanitary sewer systems, or systems that need to be improved. If the number of failing septic systems (or even the number of septic systems in general) is reduced significantly, it could improve water quality and help reduce the number of stormwater BMPs required for water bodies to meet applicable water quality criteria in the watershed. This would be determined through monitoring and the restoration plan's adaptive management approach.
- Atmospheric Deposition Reductions: Data and modeling results analyzed for the Chesapeake Bay TMDL show that atmospheric deposition is the largest single source of nitrogen loading in the Bay watershed. They also indicate that during the 1985 to 2005 Bay modeling period, the nitrogen loads were declining. The Chesapeake Bay TMDL (which includes the entire County) provides load allocations for atmospheric deposition of nitrogen. The Bay TMDL considers air deposition on land as part of a jurisdiction's allocated loads because it becomes mixed with nitrogen loads from other land-based sources, is controlled in the same way as other land-based sources and is indistinguishable from other land-based sources. The Bay TMDL assumes that implementing CAA measures through 2020 will result in significant emissions reductions that will, in turn, reduce the amount of nitrogen deposited on land surfaces.

These nitrogen reductions are expected to take place and, therefore, will not require additional BMPs. Explicit analysis of expected reductions is not available.

Bioretention facilities (above) and permeable pavement (right) installed by the Clean Water Partnership as part of the Alternative Compliance Program.

7 CONCLUSION

The County is committed to improving the quality of its watersheds. This assessment is a step in the process of determining current conditions of the watersheds and collecting information that can be used to develop restoration strategies. This section presents key findings as well as current County initiatives, and recommendations for future efforts.

7.1 Key Water Assessment Findings

The key findings of the watershed assessment include the following:

- The County faces large watershed restoration requirements, especially from the local TMDLs for the Anacostia River watershed.
- The countywide biological assessments indicate that the stream health in some watersheds is improving. The County is currently planning a fourth round of monitoring after a recent push of restoration activity. The results will be available in 2021.
- Nutrient data show a decrease in concentrations over time in all watersheds. TSS concentrations increased at some locations and decreased at others. Chloride concentrations spike during winter rains, following winter snow events. Many monitoring stations are on large water bodies that require time to respond to upstream restoration activities.
- The County's streams were first impacted when forests were converted to agriculture over the last 250 years, resulting in stream bank erosion. These streams continue to have erosion issues.
- The County has been making progress in reducing the amount of trash in its streams and waterways. It has implemented several programs and initiatives to combat this problem, and data show that the efforts are working.
- Bacteria, nutrients, and sediment are the most widespread water quality issues within the County.
- The most widespread potential causes of water quality issues are land-use changes (including historical agriculture) that alter stream hydrology, channel erosion, industrial facilities, and wastewater leakages.
- The County is making progress with implementation and programmatic activities through CWP, its own Capital Improvement Program, and community outreach efforts. The rate of progress has increased in each of the past several years.

7.2 Existing Water Quality Improvement Efforts

The County has many existing programs that either directly or potentially decrease water quality issues, including the following:

- Many BMPs and other restoration activities are available to help address water quality issue and causes. This assessment provides an overview of the best BMP options.
- Location of a BMP or other restoration practice has a significant impact on its success. Three main factors should be considered in prioritizing BMP locations throughout the

County: (1) land ownership / site access, (2) location in the stream watershed, and (3) locations of known issues and existing treatment.

- One key factor in determining where to place BMPs is identifying where they have not been and where there are known erosion issues and areas of poor biological health. For instance, stream restoration projects should be prioritized for areas of known erosion issues.

7.3 Future Activities

There will be many restoration-related activities over the next several years, including the following:

- The County plans to continue to look for restoration opportunities on properties owned be schools, religious and other nonprofit organizations, and municipalities.

  However, as BMPs are constructed on these properties or they are eliminated from consideration due to lack of space or utility conflicts, The County should create partnerships with commercial enterprises (e.g., apartment and townhome communities) and in industrial areas to develop new opportunities for BMP implementation. Those areas have large impervious areas that could be treated. Many also have large pervious areas where BMPs could be implemented.
- The County should maintain or increase its rate of BMP implementation and load reduction. It should continue to explore innovative technologies and cost-saving measures to help increase BMP cost-efficiency.
- The County will continue to track and monitor BMP implementation and stream health (i.e., chemistry, biology, and physical monitoring). Information on these monitoring efforts is included in the County’s annual MS4 permit report, which is available on the County’s stormwater website.[5]
- The County will update the local TMDL restoration plans during the third year of the next MS4 permit in 2021. This revision process should include an analysis of the local TMDL end dates and consideration of innovative technologies.

Recently completed stream restoration project. Rocks were used to stabilize the banks and fresh vegetation was planted along the left and right banks.

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APPENDIX A: STREAM CONCEPTS CONSIDERED IN THE ASSESSMENT

Sediment in Streams

Chesapeake Bay restoration focuses on reducing the amount of suspended sediment reaching the Bay from upstream sources. Eroded sediment occurs in two forms: suspended sediment and bedload sediment. Suspended sediment is transported in suspension in the water column. Bedload sediment moves along the bottom in a process known as "saltation," in which sediment too large to be suspended bumps along the bottom in stops and starts. Bedload sediment is important because it contributes to increased loads of suspended sediment although it cannot be easily measured. It does this by forming depositional features that cause more channel erosion, which, in turn, contributes significantly to suspended sediment in subsequent runoff events. Monitoring and the use of measurement techniques (e.g., the Rosgen BANCS model) can help identify the sites of severe channel erosion and predict suspended sediment loads. This monitoring should be done in first-, second-, and third-order stream reaches rather than in fourth- and higher order reaches located further downstream.

Stability and Instability

A great deal of attention has been focused on the impact of land-use changes on water. Land-use changes that increase stormwater runoff are detrimental to stream quality and aquatic life. The major stream changes resulting from increased runoff are channel enlargement, increases in sediment supply, loss of aquatic habitat, wider fluctuations in flow, and wider variations in water temperature.

Healthy conditions for aquatic life are maintained in stable streams, which are characterized by two dynamic equilibrium processes (1) the equilibrium between peak annual flows and channel capacity and (2) the equilibrium between sediment supply and sediment transport. When sediment supply and sediment transport are in equilibrium, slow rates of erosion on the outsides of meander bends are matched by slow rates of deposition on the inside of meander bends and the sediment supplied by the watershed is transported quickly downstream. Sediment delivered from the watershed is mostly fine sediment that travels as suspended sediment.

An increase in the flow regime or excess sediment can disturb these equilibria. Increased flows can cause channel enlargement (bank erosion), which increases the sediment supply. When the rate of sediment supply increase exceeds the rate of sediment transport, the excess sediment further accelerates the rate of erosion in a positive feedback process. If a channel is unable to transport its current sediment load, it will be unable to transport additional sediment. Excess sediment causes depositional features to form, which, in turn, generates erosion, thus creating still more sediment, creating a self-propagating process of accelerated erosion. Once a stream begins to exhibit accelerated erosion, restoring the equilibrium naturally might not occur for decades.

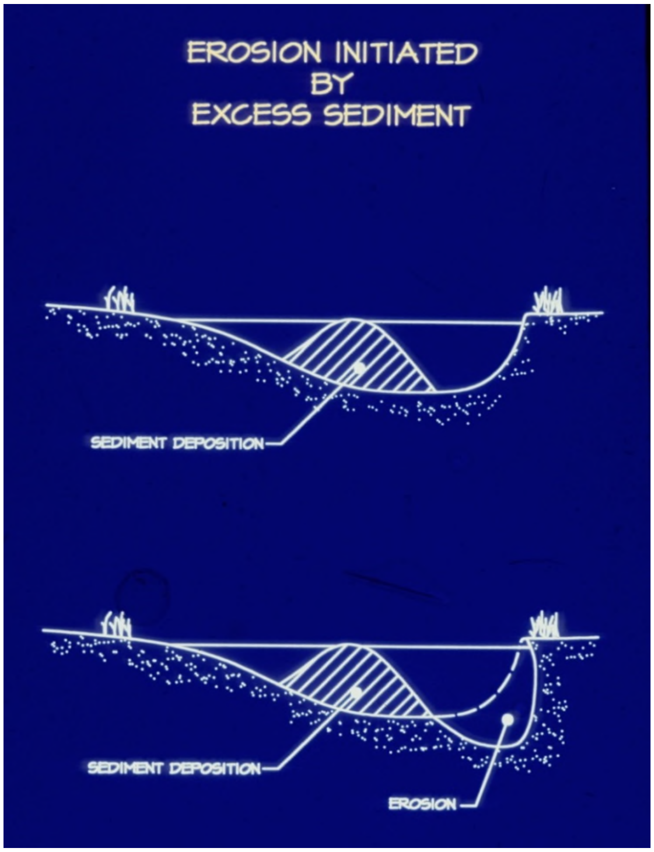
Sediment in streams can impact aquatic life in several ways. Excess fine sediment, which fills the interstices in the gravel in the channel bed, can eliminate macroinvertebrate- and fish-spawning habitat. Suspended sediment can block enough light to reduce or stop photosynthetic activity. In healthy streams, aquatic life in the stream processes the food supplied from upstream. Material that primarily enters the system in the fall as leaf litter from riparian vegetation is processed in the food web. In a stream with excess sediment, there are no benthic macroinvertebrates to process the leaf litter. The excess sediment tends to smooth the streambed, allowing this material to flush more quickly downstream without being degraded and allowing nutrients, organic carbon, and other inputs to be transported through the system and taken up in anaerobic digestion.

The sediment eroding from the bed and banks of a stream has associated nitrogen and phosphorous. Thus, erosion is also delivering excess amounts of these nutrients, while the channel might no longer have any aquatic life to process them.

Example of Self-Propagating Erosion Process

Source: Gracie 1994

Figure A-1 shows an illustration of how excess sediment forms a mid-channel bar that decreases the ability of the channel to carry flows (Gracie 1994). This situation causes channel erosion in the adjacent stream bank. The new erosion supplies more sediment in the channel, which already has more than it can transport, and, consequently, the process becomes self-propagating, moving downstream in an increasing rate. The stream will return to equilibrium only after the erosion has resulted in a channel large enough to handle increased flows and the excess sediment has moved downstream into a naturally larger channel that can transport it without losing equilibrium.



Source: Gracie 1994

Figure A-1. Schematic diagram of accelerated bank erosion

Ranking Streams

Ranking–Lateral Erosion

The original SCA methodology, which rates erosion problems observed at a given point in time, is not effective for predicting the rates at which erosion will subsequently occur, nor is it a reliable method for rating erosion. The Bank Assessment of Nonpoint Source Consequences of Sediment (BANCS) model is a better tool for ranking erosion rates than the SCA model. The BANCS model is an accepted tool for ranking lateral erosion rates. In addition, it can be used for crediting stream restoration rates for sediment prevented during runoff.

The BANCS model can be used to rank the severity of lateral erosion rates. It uses two factors to estimate erosion rates: (1) the Bank Erosion Hazard Index (BEHI) and (2) the shear stress in the near-bank region (one-third of the bank width nearest the bank). BEHI estimates the potential of the stream bank to be eroded, and the shear stress in the near-bank estimates the force that causes erosion. The model can be used to predict actual erosion rates in feet per year if it is calibrated for a hydrophysiographic region (an area of the same annual precipitation within a physiographic province) by measuring the erosion rates at several sites over a 1-year period and correlating those measurements with the model results.

Multiplying the lateral erosion rate in feet per year by the area of the eroding bank surface and the density of the sediment gives the weight of the sediment lost per year. Even when the model has not been calibrated, its results can still be used to rank the relative erodibility of different sites based on some reasonable assumptions. One calibration has been performed of the eastern coastal plain by Richard Starr (Richard Starr, U.S. Fish and Wildlife, personal communication), which correlates very closely with Dave Rosgen's Colorado curve (Rosgen 1996).

The following measurements are needed for the BANCS model:

- Total bank height
- Bank angle
- Rooting density of vegetation
- Materials in the bank
- Bankfull height
- Rooting depth of vegetation
- Percent bank protection

The shear stress distribution estimates the shear stress in the one-third of the width closest to the bank being evaluated. It can be estimated using one of the following relationships:

- Percentage of cross-sectional area in the near-bank region
- Ratio of maximum depth to average depth

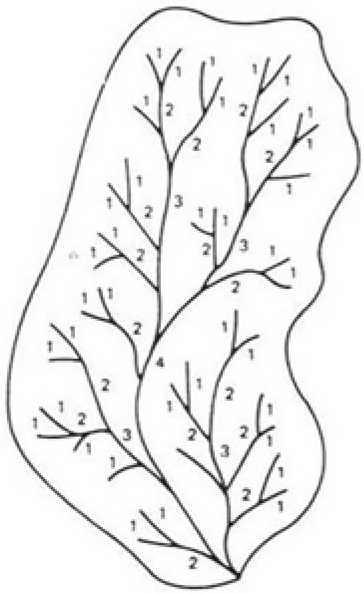
When the model has been populated, taking the average height of the bank times the total length results in the volume of soil that will be eroded.

Ranking–Incision or Vertical Erosion

There are no quantitative models that can quantify the sediment delivery that head cuts generate. It is generally known, however, that head cuts destabilize streams in a compounded way. Rosgen (1996) has discussed a descriptive channel evolution model in which a stable channel incises, creating steep banks that cannot maintain their slope without failing and soils sliding down the slope. The over-steepened banks fail and begin to fill the incised channel with additional sediment. The incised channel does not allow for flood relief and, consequently, flood flows are confined inside the channel rather than dissipating over a floodplain. Flood relief allows rivers and streams to spread out and relieve stress during floods. If the channel incises, the banks are steepened, becoming more vertical. The stream will then experience larger floods because the flows no longer can reach the former floodplain. Stabilizing head cuts should be a priority in restoring any unstable stream channel. Quantifying the rate of head cutting is not necessary because all head cuts are sediment sources.

Stream Orders

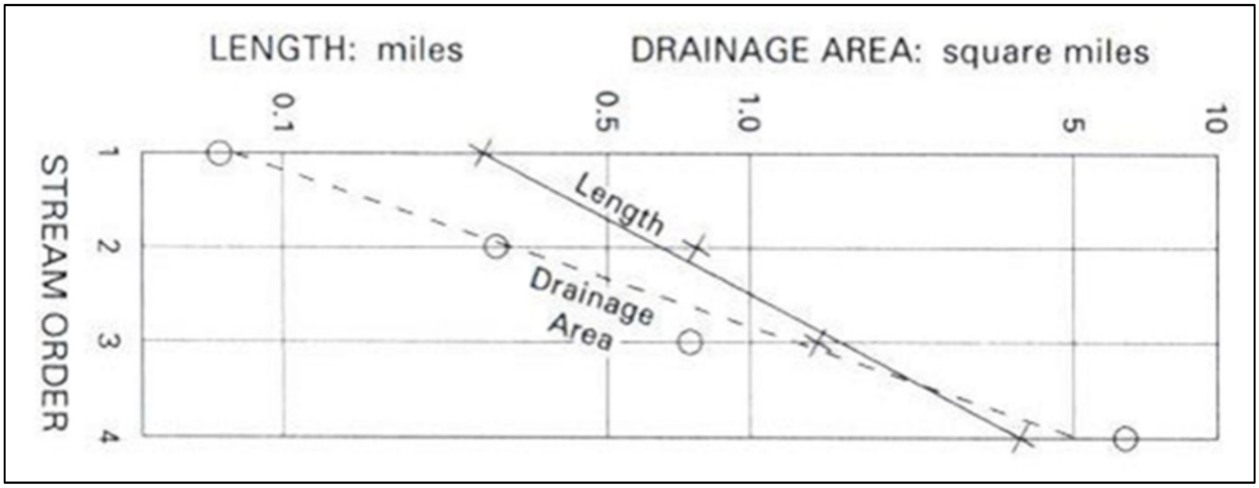
Stream order is a classification system to help describe the relative size of streams. Figure A-2 shows a stream order hierarchy, numbered from the top down. Headwaters are typically associated with what can be categorized as first-order streams and their watersheds. Watersheds are dominated by small, first-order headwater streams and watersheds (Figure A-2). Two first-order streams combine to make a second-order stream. Two second-order streams combine to make a third-order stream, and so forth (Figure A-2). Typically, the surface area of a fourth-order watershed is made up of approximately 50 percent first-order streams, 29 percent second-order, and 14 percent and 7.5 percent of third- and fourth-order streams, respectively (McCuen 1998).



Source: McCuen 1998

Figure A-2. Stream order hierarchy.

Watersheds for first-order streams range in drainage area from approximately 0.05 to 0.3 square miles (mi^2) (40 to 120 acres), while second-order watersheds range from 0.3 to 0.8 mi^2 (120 to 300 acres) in the Mid-Atlantic Piedmont and Coastal regions, in which Prince George's County is located (Figure A-3) (Leopold 1994). Under natural conditions, first- and second-order watersheds and streams tend to be wetlands and intermittent streams, primarily exhibiting flows in response to rainfall events. Slopes of small streams typically range from 2 to 3 percent, exerting erosive power during storm events. Stream channels are susceptible to hydrologic disturbance such as urban stormflows produce. They can easily become a source of sediment via accelerated erosion, with the eroded sediment traveling downstream to higher order streams.



Source: Leopold 1994.

Figure A-3. Typical stream length and drainage area as functions of stream order for Watts Branch above Glen, MD.

The typical drainage area for third-order streams is 0.8–3 mi^2 (Leopold 1994). Those streams are usually perennial (flowing year-round). If not too highly disturbed or polluted, these streams can be very productive with diverse and robust biota. The pressures of urban and infrastructure development (e.g., channelization and piping), however, can result in their elimination because of the related habitat destruction. Streams with relatively small base flows can be hydrologically sensitive to changes in groundwater-surface water interactions such as reduced recharge of aquifers or excessive pumping. In some cases, streams can be altered from perennial to intermittent, resulting in extensive loss of habitat. In addition, these streams can be sensitive to large volumes of sediment delivered from upstream (first and second order) geomorphically unstable areas of the watershed. The combination of increased stormwater runoff volumes and sediment loads causes accelerated erosion of the stream channel, reducing or eliminating the capacity of the stream to support a healthy biota.

Fourth-order streams are perennial and have drainage areas greater than 3 mi^2, although they are typically under 10 mi^2 (Leopold 1994). These biologically productive streams are less sensitive to decreases in base flow than third-order streams, but maintaining sufficient base flow is still important. They are affected by the same flow and sedimentation processes mentioned above, although flooding considerations are more acutely important. Two fourth-order streams can combine to make a fifth-order stream, and so forth.

APPENDIX B: WATER QUALITY PLOTS AND TABLES

Contents

Tables

Figures

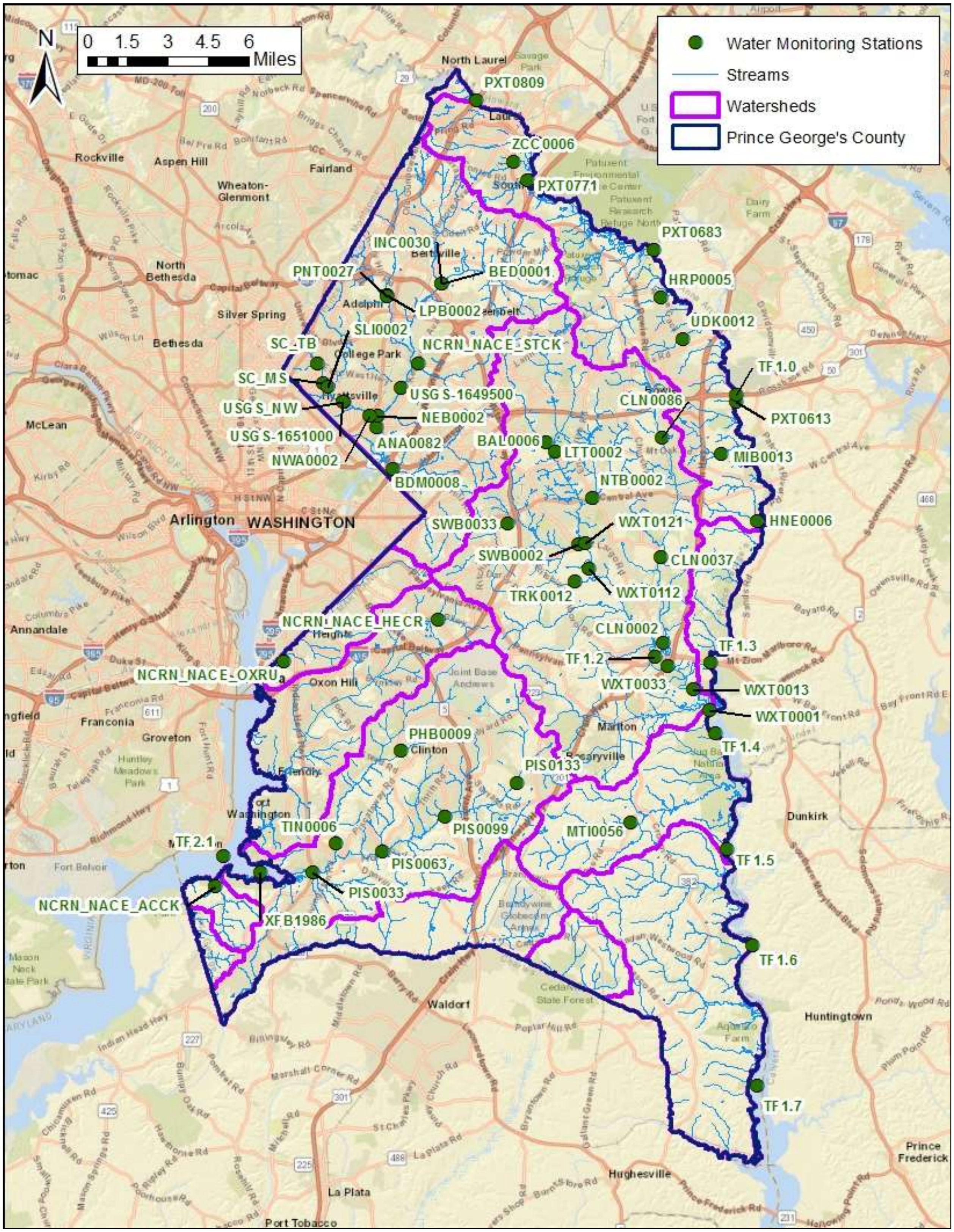


Figure B-1. Locations of water quality monitoring stations referenced in Appendix B.

Total Nitrogen (TN)

Table B-1. Summary of TN data by watershed

Watershed	Station ID	Station name	Date min.	Date max.	Number of records	Min. value (mg/L)	Mean value (mg/L)	Max. value (mg/L)
Anacostia River	ANA0082	Anacostia River	1/9/90	2/1/17	181	0.39	1.50	2.35
	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	7/23/03	10/12/17	341	0.03	1.80	8.10
	USGS-1651000	Northwest Branch Anacostia River near Hyattsville, MD	7/23/03	7/28/17	137	0.30	2.35	5.90
Upper Patuxent River	TF1.0	TF1.0	1/8/90	2/7/17	456	1.04	2.34	5.05
Middle Patuxent River	TF1.3	TF1.3	1/16/90	2/7/17	293	0.87	1.96	4.36
	Tf1.4	TF1.4	1/16/90	2/7/17	290	0.52	1.86	3.98
Lower Patuxent River	TF1.6	TF1.6	1/16/90	2/7/17	270	0.70	1.38	3.21
	TF1.7	TF1.7	1/16/90	2/7/17	271	0.44	1.18	3.03
Western Branch	TF1.2	TF1.2	1/16/90	1/10/17	321	0.23	0.92	3.56
	WXT0001	Western Branch	10/9/90	2/7/17	275	0.69	1.99	10.91
	WXT0013	Western Branch	12/15/97	1/12/17	42	0.00	1.49	10.07
Potomac River	TF2.1	TF2.1	1/17/90	2/6/17	221	0.61	2.55	5.08
Piscataway Creek	PIS0033	PIS0033	1/17/90	11/14/16	209	0.05	1.11	4.59
	XFB1986	XFB1986	1/17/90	2/6/17	212	0.44	2.46	6.10

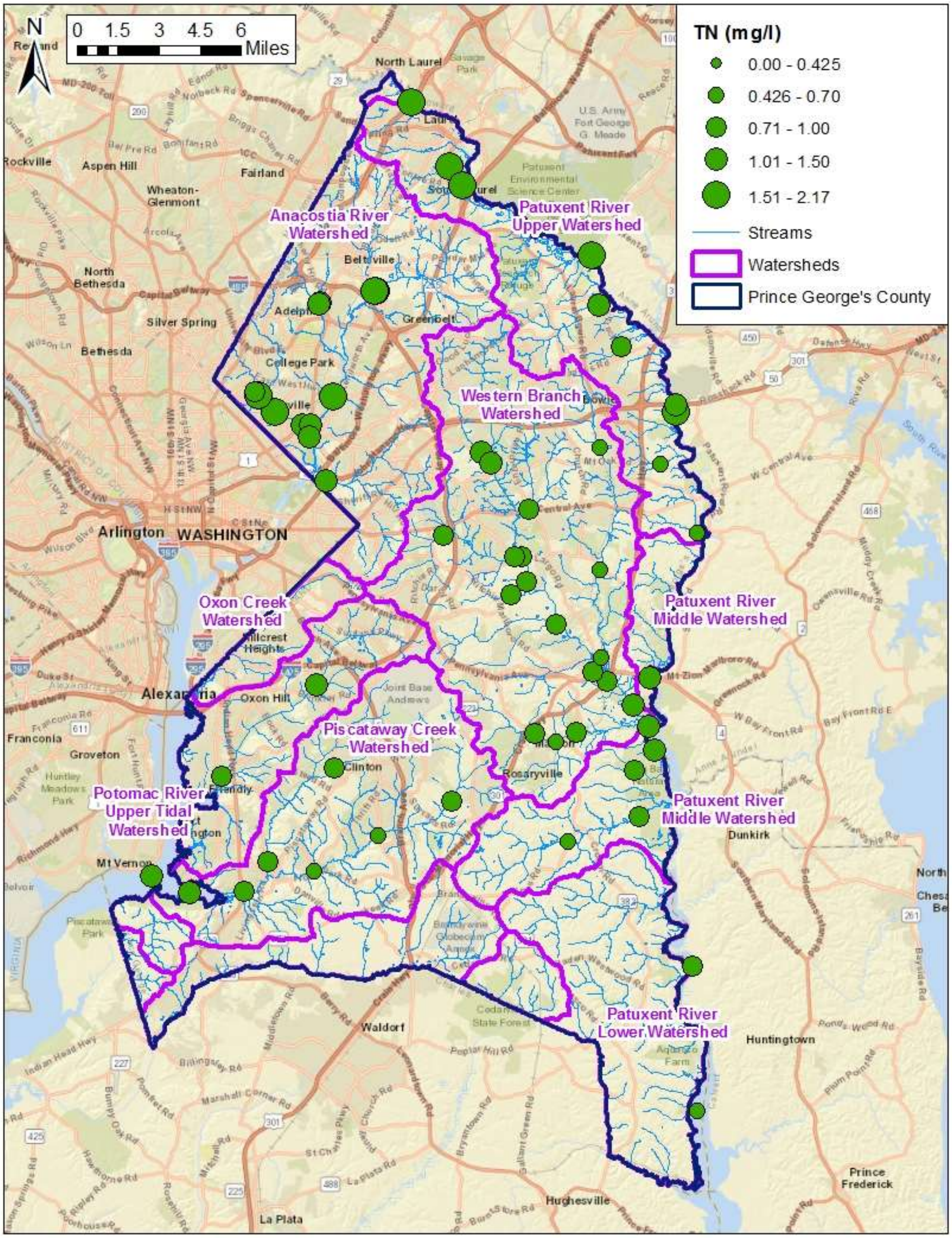


Figure B-2. Map of TN concentration in various locations throughout the watersheds in Prince George's County.

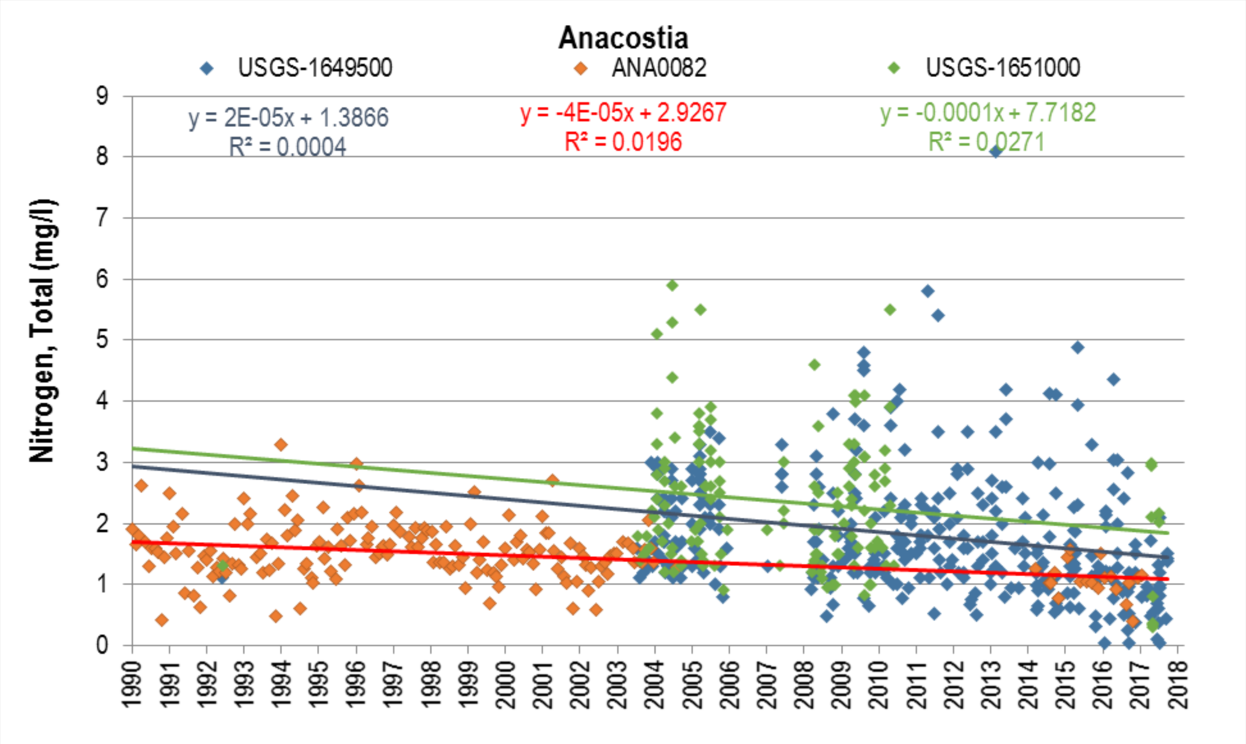


Figure B-3. Plot of TN over time in the Anacostia River watershed.

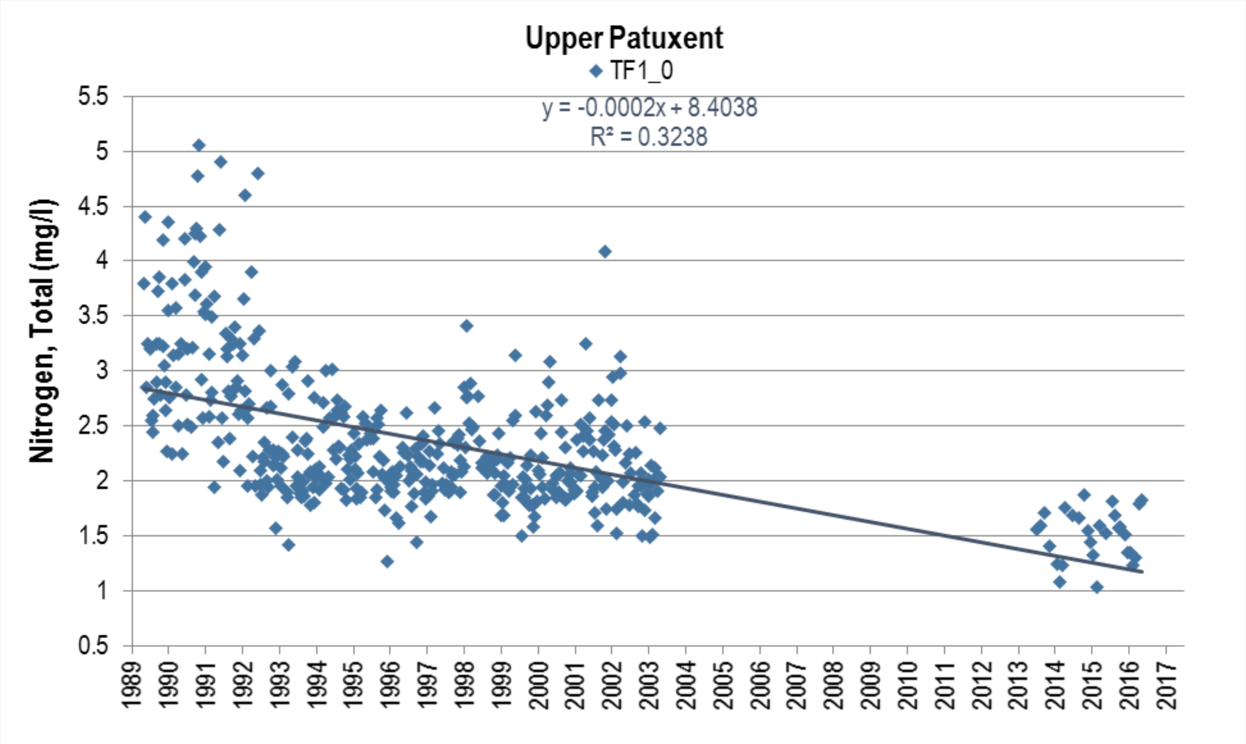


Figure B-4. Plot of TN over time in the Upper Patuxent River watershed.

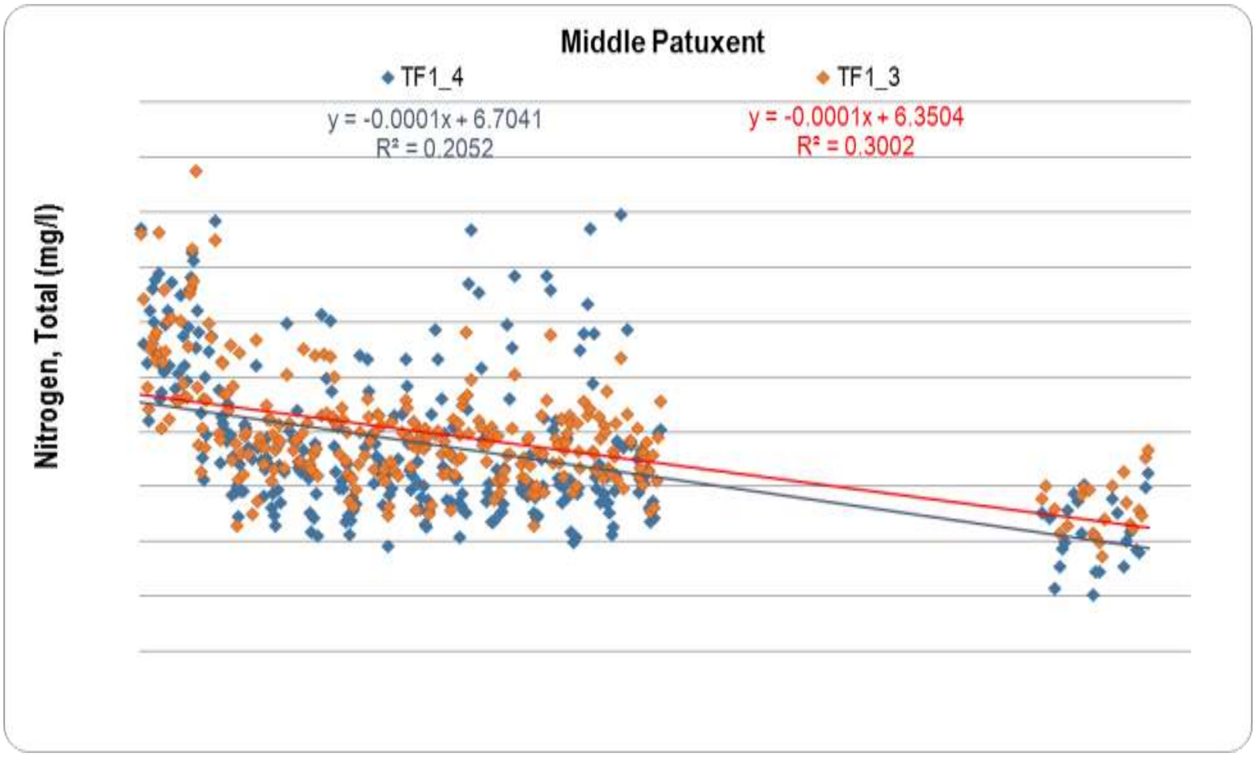


Figure B-5. Plot of TN over time in the Middle Patuxent River watershed.

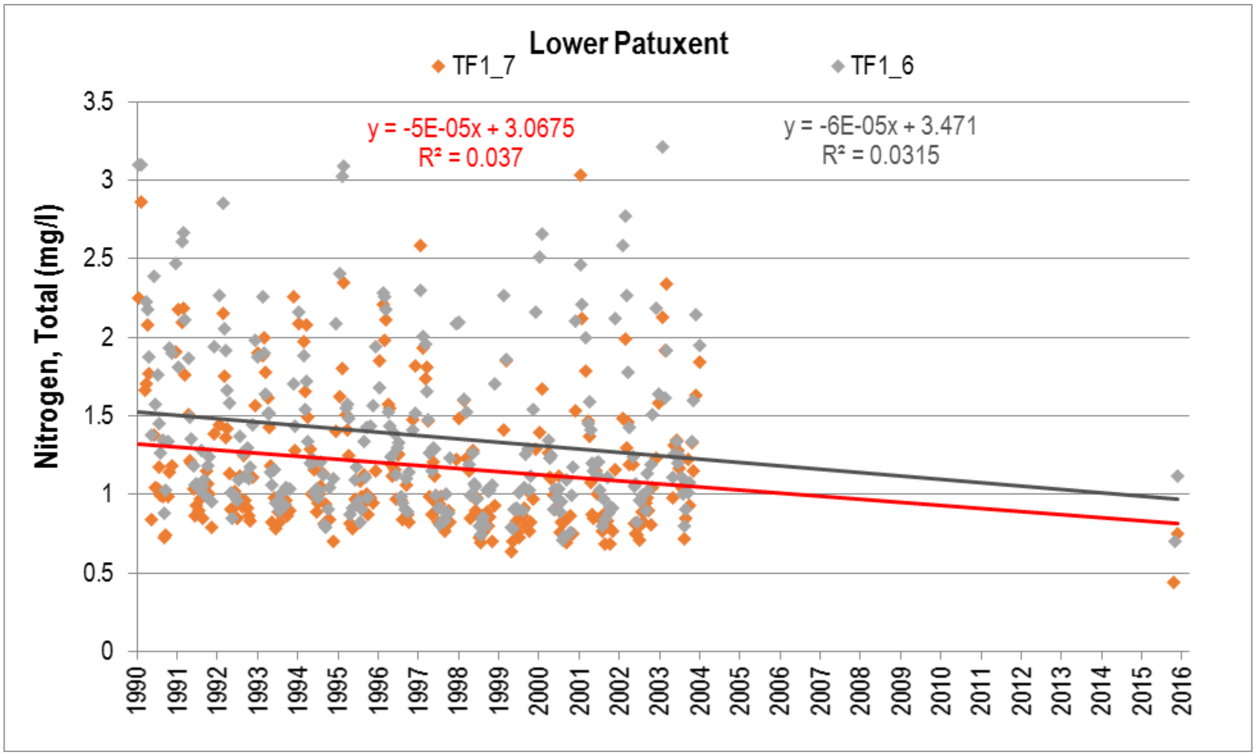


Figure B-6. Plot of TN over time in the Lower Patuxent River watershed.

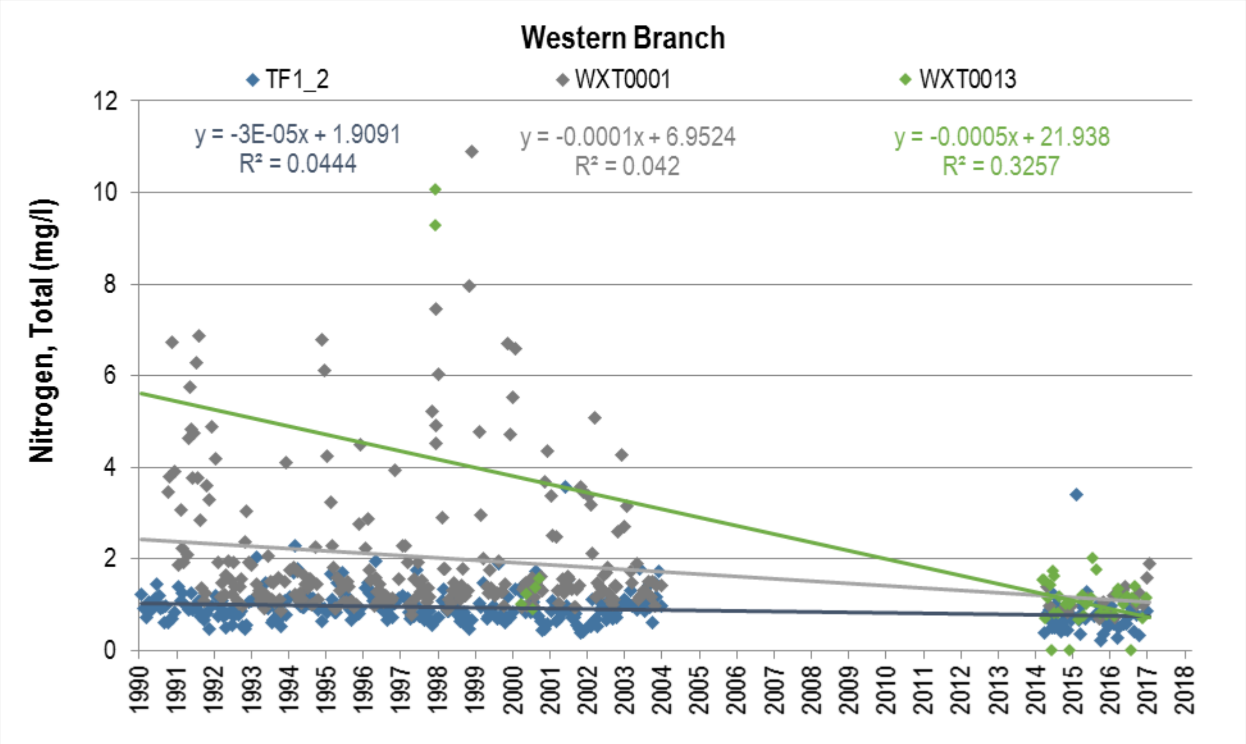


Figure B-7. Plot of TN over time in the Western Branch watershed.

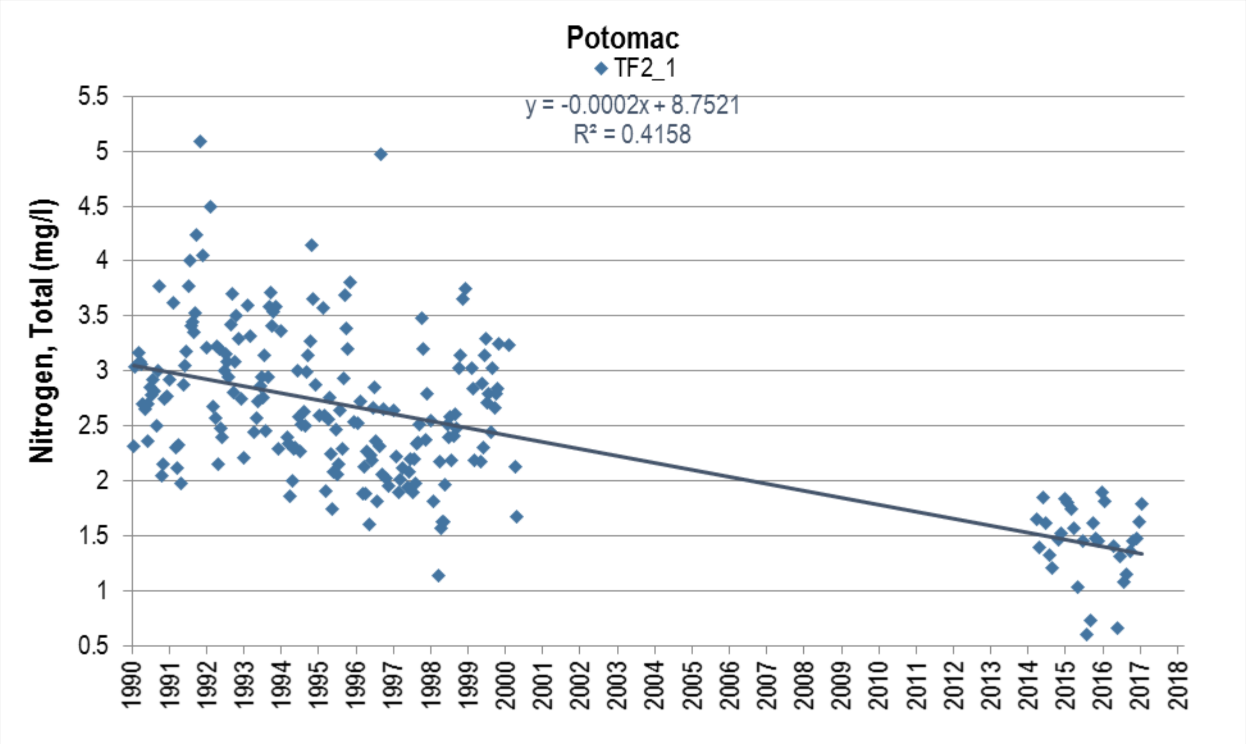


Figure B-8. Plot of TN over time in the Potomac River watershed.

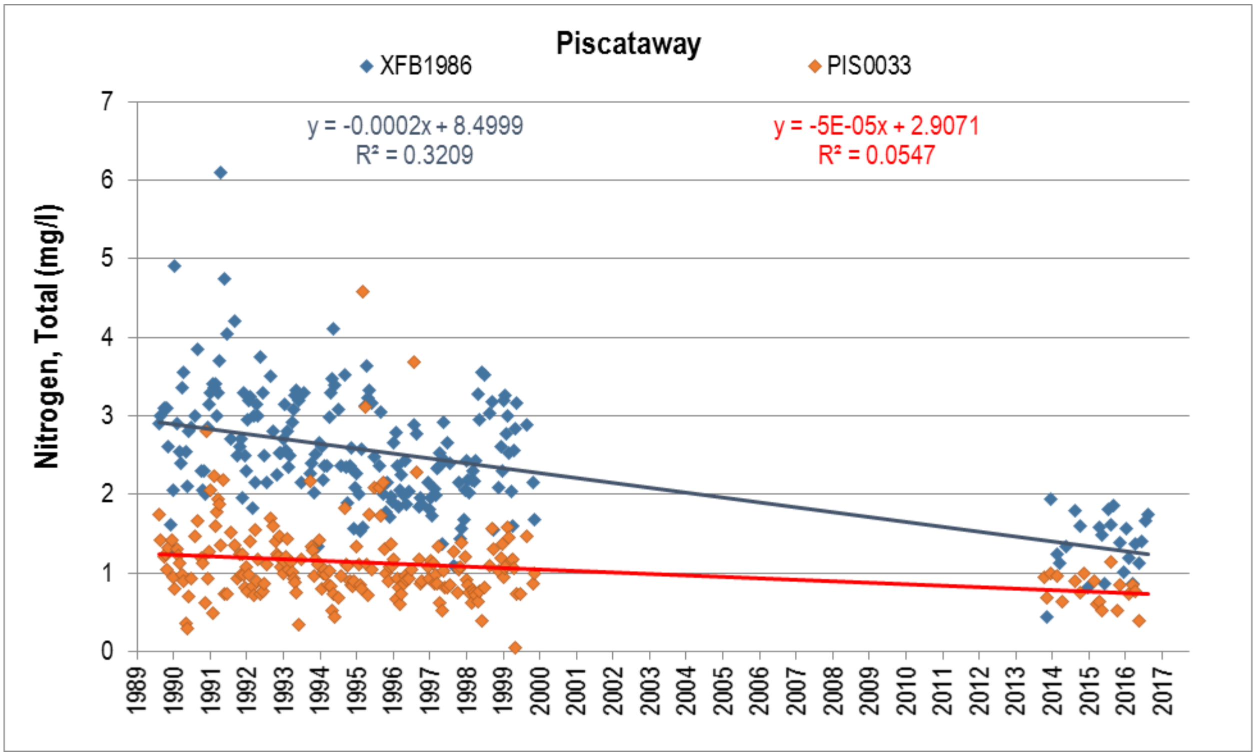


Figure B-9. Plot of TN over time in the Piscataway Creek watershed.

Total Phosphorus (TP)

Table B-2. Summary of TP data by watershed

Watershed	Station ID	Station name	Date min.	Date max.	Number of records	Min. value (mg/L)	Mean value (mg/L)	Max. value (mg/L)
Anacostia River	ANA0082	Anacostia River	01/09/90	1/4/17	185	0.01	0.06	0.7
	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	01/02/92	10/12/17	312	0.01	0.23	1.08
Upper Patuxent River	PG003	Bear Branch at Contee Rd.	6/15/07	6/19/17	167	0.01	0.08	0.37
	PG005	Bear Branch above Laurel Lake	6/15/07	6/19/17	142	0	0.1	0.44
	TF1.0	TF1.0	1/8/90	2/7/17	412	0.01	0.12	0.72
Middle Patuxent River	TF1.3	TF1.3	1/16/90	2/7/17	248	0.00	0.11	0.45
	TF1.4	TF1.4	1/16/90	2/7/17	244	0.02	0.14	0.73
Lower Patuxent River	TF1.6	TF1.6	1/16/90	2/7/17	255	0.03	0.16	0.44
	TF1.7	TF1.7	1/16/90	2/7/17	252	0.02	0.14	0.4
Potomac River	TF2.1	TF2.1	1/17/90	2/6/17	226	0.01	0.09	1.9
Piscataway Creek	PIS0033	PIS0033	2/05/90	1/4/17	213	0.01	0.11	0.7
	XFB1986	XFB1986	2/05/90	10/12/17	25	0.01	0.09	0.4
Western Branch	TF1.2	TF1.2	1/16/90	2/7/17	281	0.01	0.09	0.6
	WXT0001	Western Branch	10/09/90	2/7/17	233	0.02	0.21	1.29

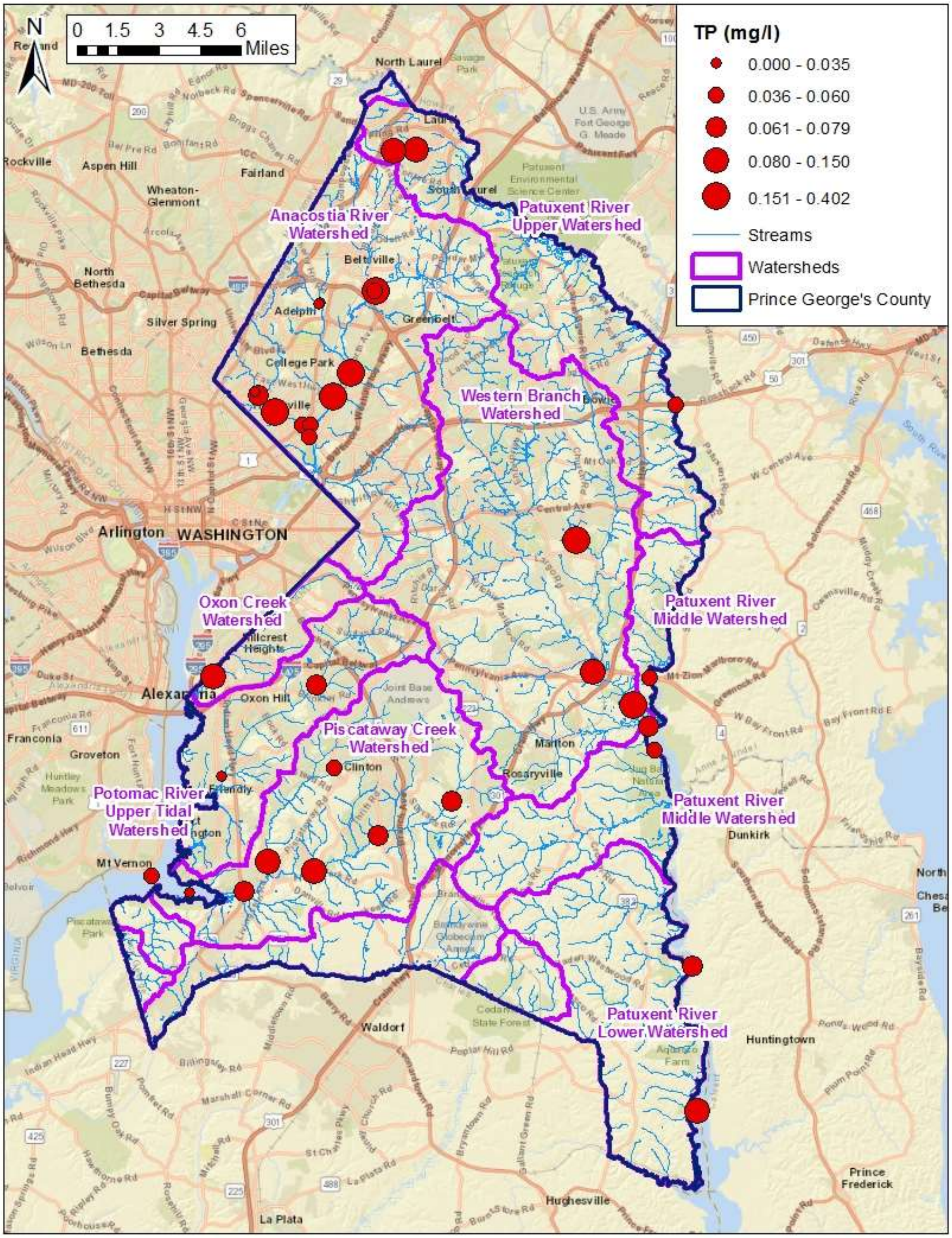


Figure B-10. Map of TP concentration in various locations throughout the watersheds in Prince George’s County.

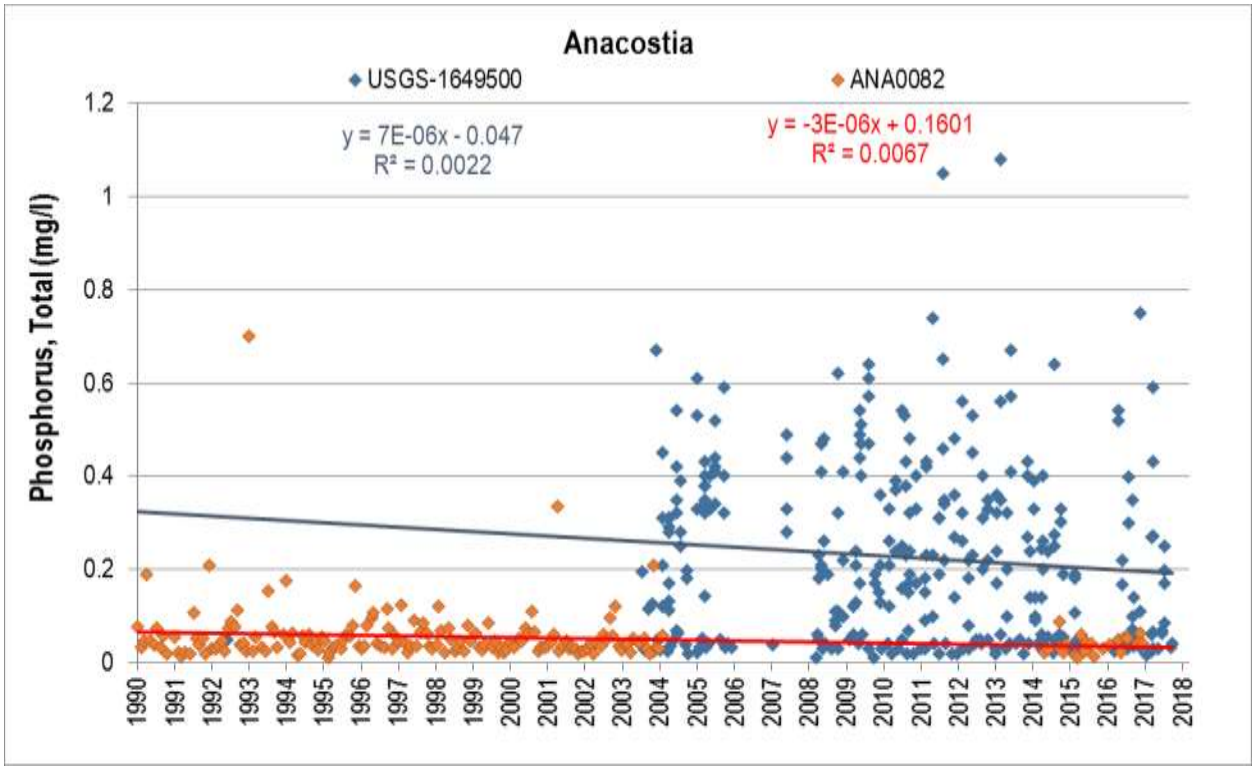


Figure B-11. Plot of TP over time in the Anacostia River watershed.

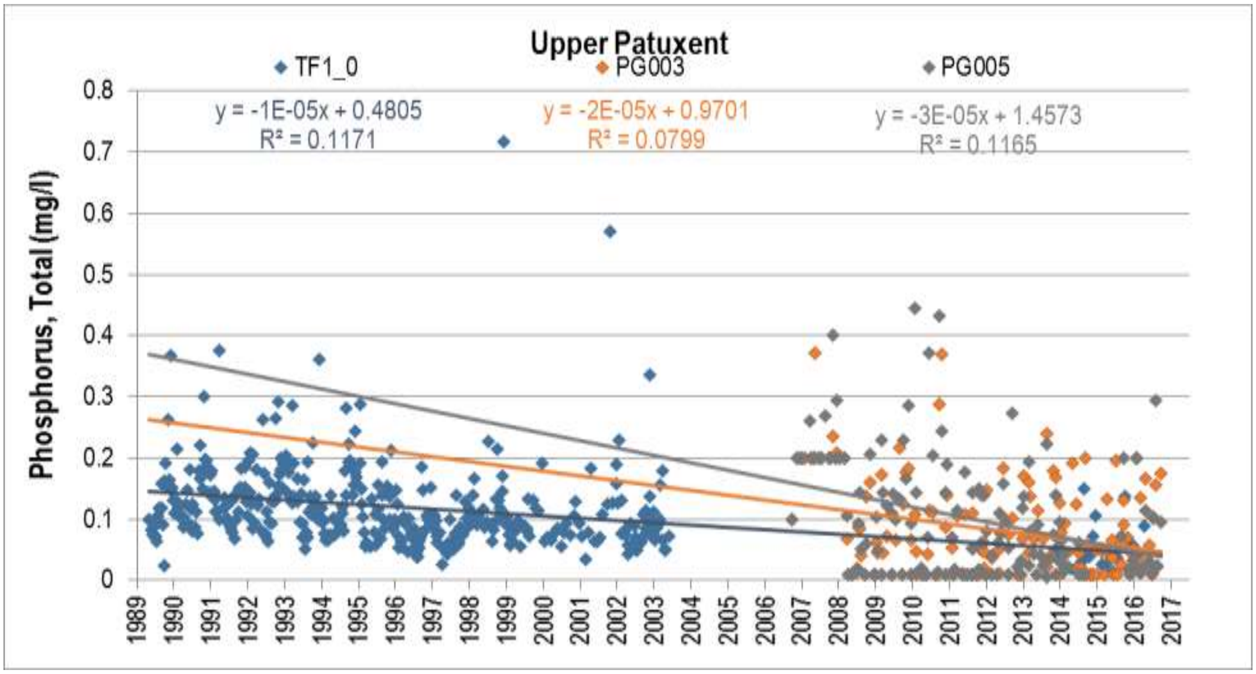


Figure B-12. Plot of TP over time in the Upper Patuxent River watershed.

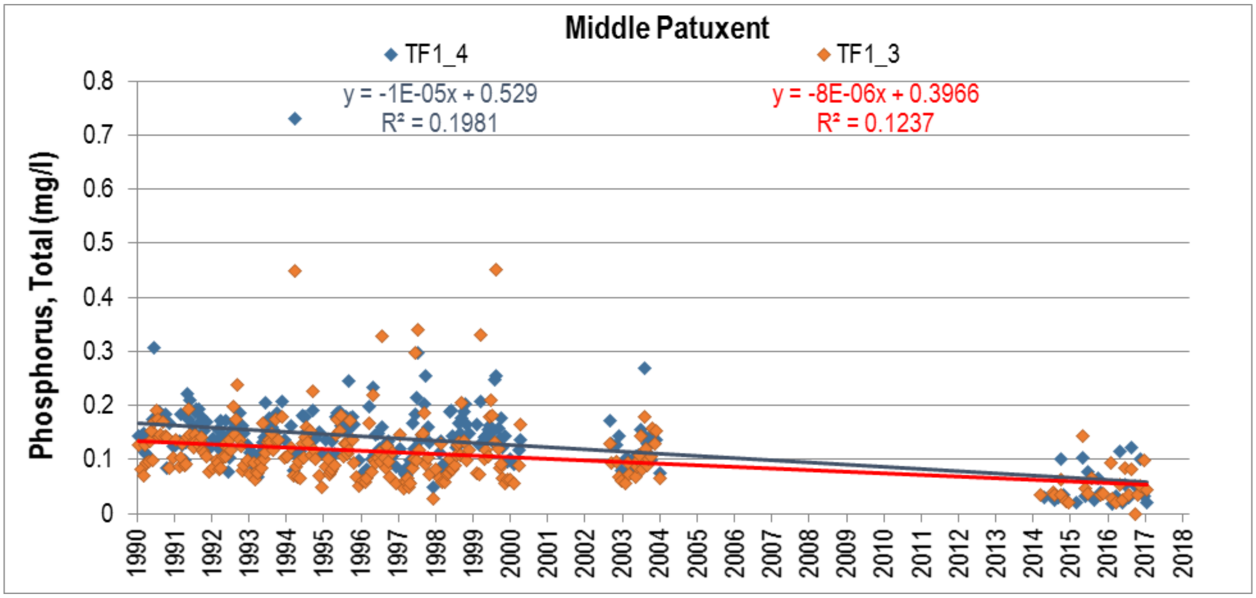


Figure B-13. Plot of TP over time in the Middle Patuxent River watershed.

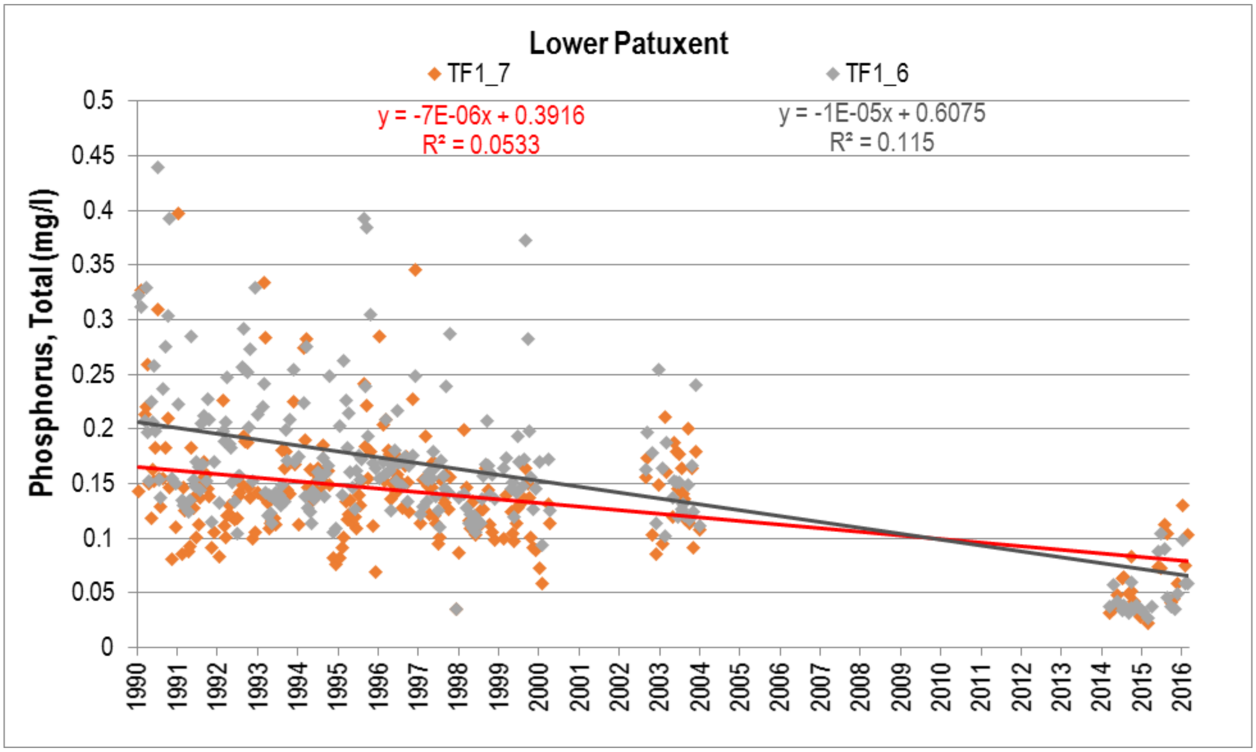


Figure B-14. Plot of TP over time in the Lower Patuxent River watershed.

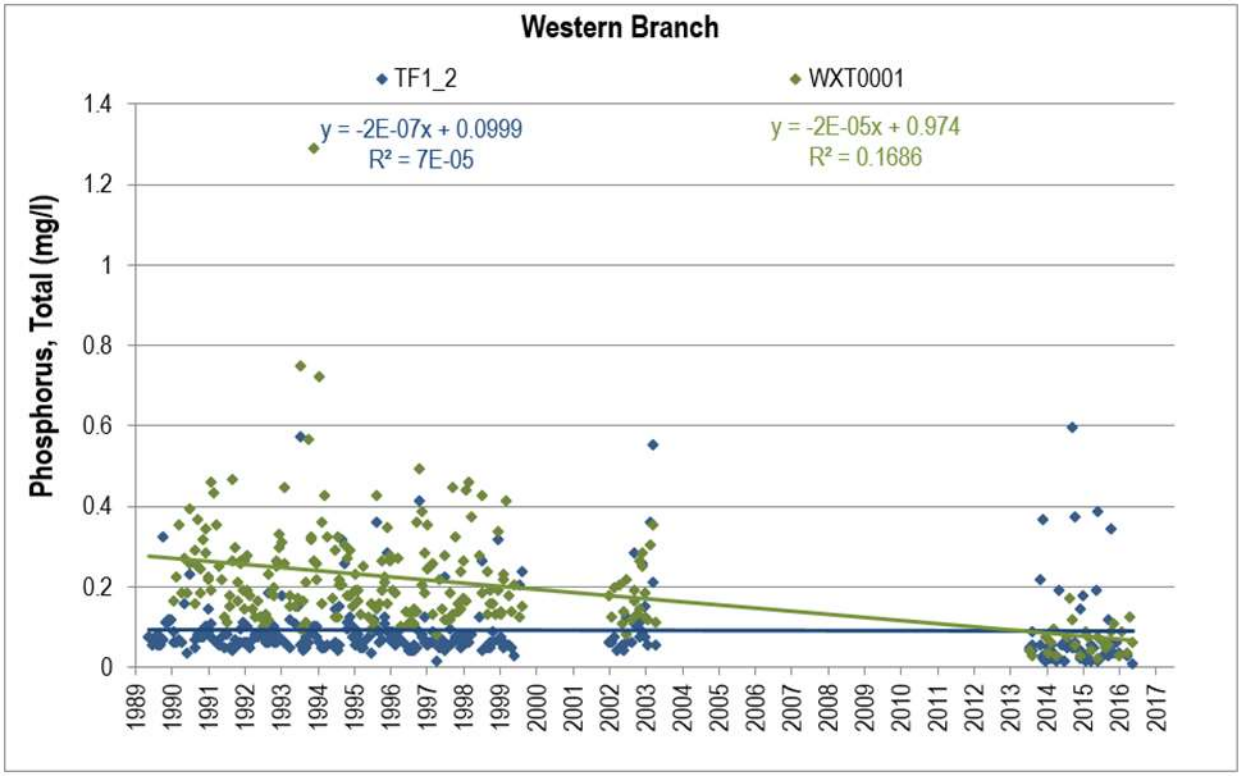


Figure B-15. Plot of TP over time in the Western Branch watershed.

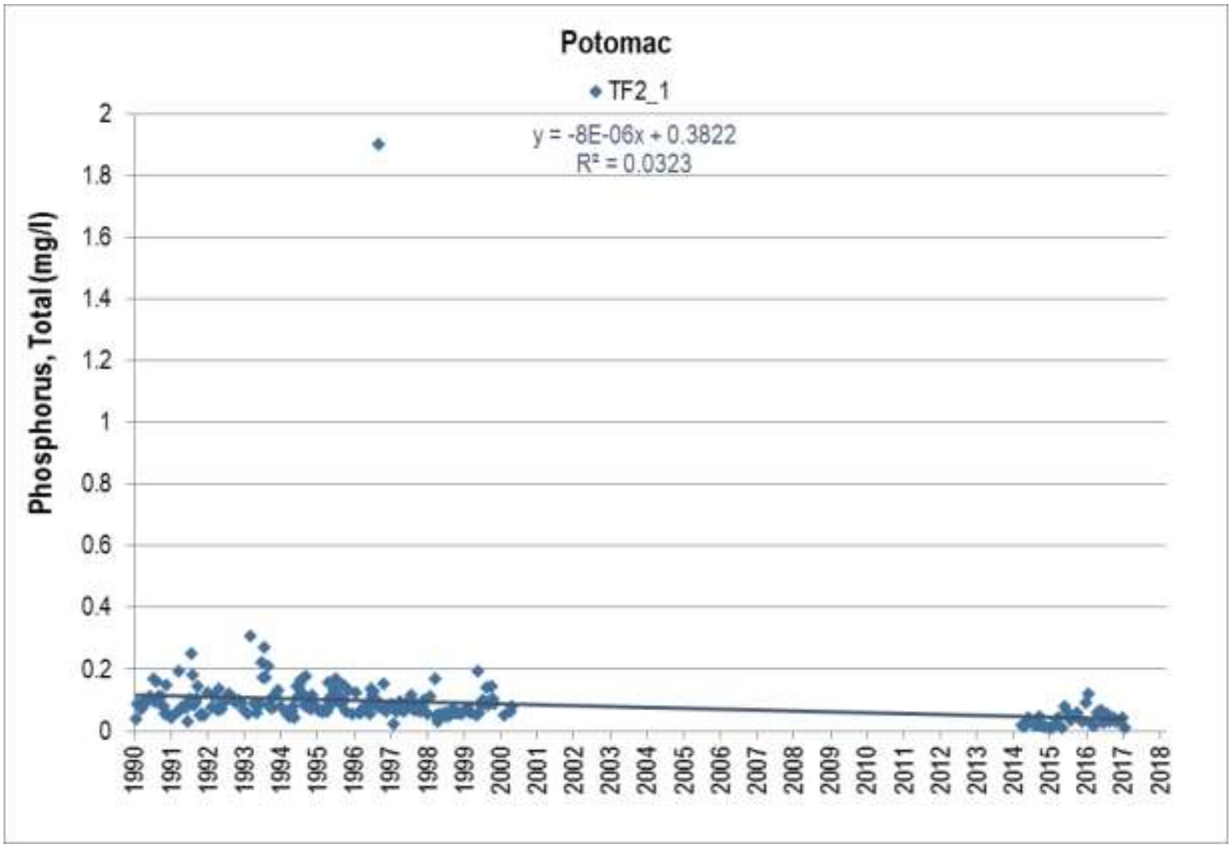


Figure B-16. Plot of TP over time in the Potomac River watershed.

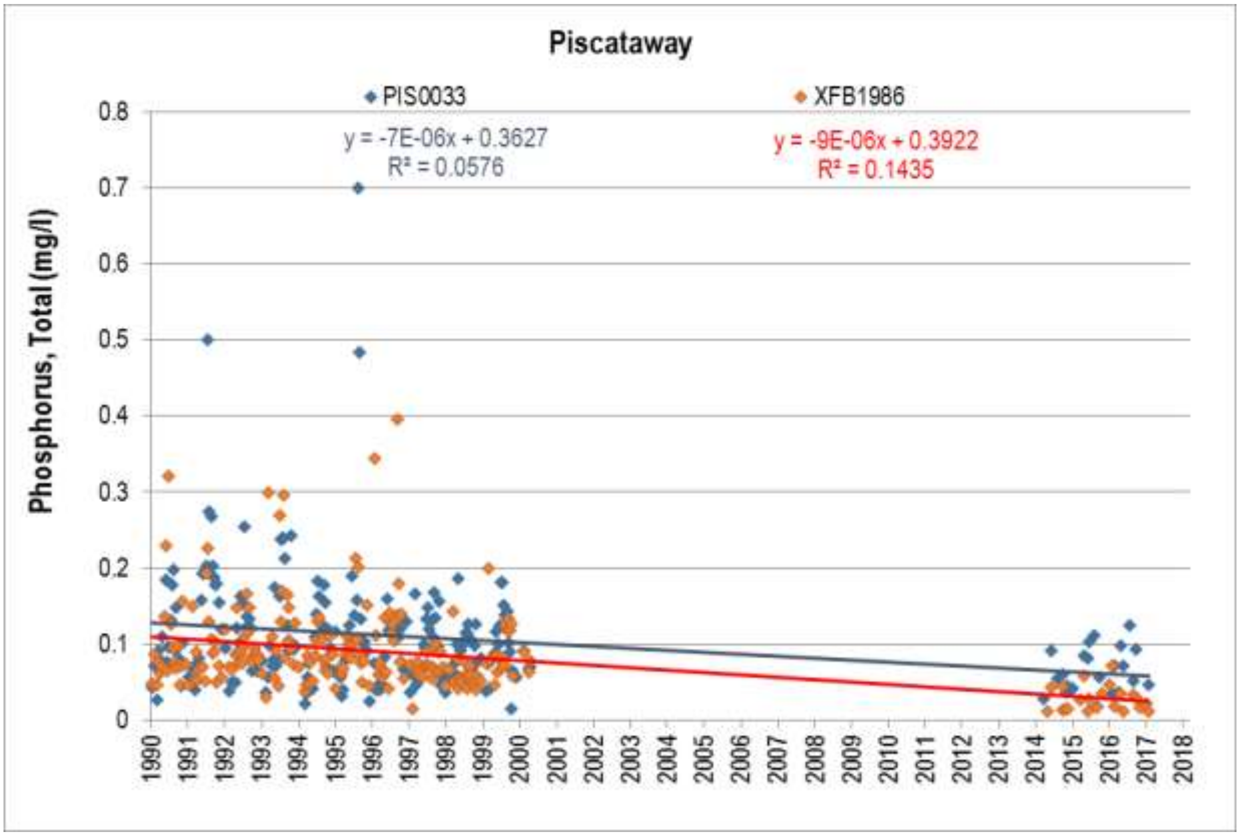


Figure B-17. Plot of TP over time in the Piscataway Creek watershed.

Total Suspended Solids (TSS)

Table B-3. Summary of TSS data by watershed

Watershed	Station ID	Station name	Date min.	Date max.	Number of records	Min. value (mg/L)	Mean value (mg/L)	Max. value (mg/L)
Anacostia River	ANA0082	Anacostia River	1/9/90	2/1/17	266	1.00	19.42	486.00
	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	9/27/95	10/12/17	203	0.50	186.13	1,930.00
Upper Patuxent River	PG003	Bear Branch at Contee Rd.	6/15/07	6/19/17	167	0.80	86.43	691.64
	PG005	Bear Branch above Laurel Lake	6/15/07	6/19/17	142	0.50	140.11	1,610.00
	TF1.0	TF1.0	1/8/90	2/7/17	540	1.00	21.53	482.25
Middle Patuxent River	TF1.3	TF1.3	1/16/90	2/7/17	381	1.60	18.14	227.00
	TF1.4	TF1.4	1/16/90	2/7/17	382	3.00	25.90	322.00
Lower Patuxent River	TF1.5	TF1.5	1/16/90	11/1/12	318	11.75	44.83	192.13
	TF1.6	TF1.6	1/16/90	2/7/17	383	15.50	50.10	210.67
	TF1.7	TF1.7	1/16/90	2/7/17	383	8.00	36.60	136.43
Western Branch	TF1.2	TF1.2	1/16/90	2/7/17	402	0.00	31.82	934.00
	WXT0001	Western Branch	10/9/90	2/7/17	369	3.50	23.38	275.00
	WXT0013	Western Branch	12/15/97	2/1/17	81	2.40	21.27	154.00
Potomac River	TF2.1	TF2.1	1/17/90	2/6/17	386	4.80	34.60	1,473.33
Piscataway Creek	PIS0033	PIS0033	1/17/90	2/6/17	363	1.00	12.62	152.50
	XFB1986	XFB1986	1/17/90	2/6/17	386	3.00	21.88	270.00

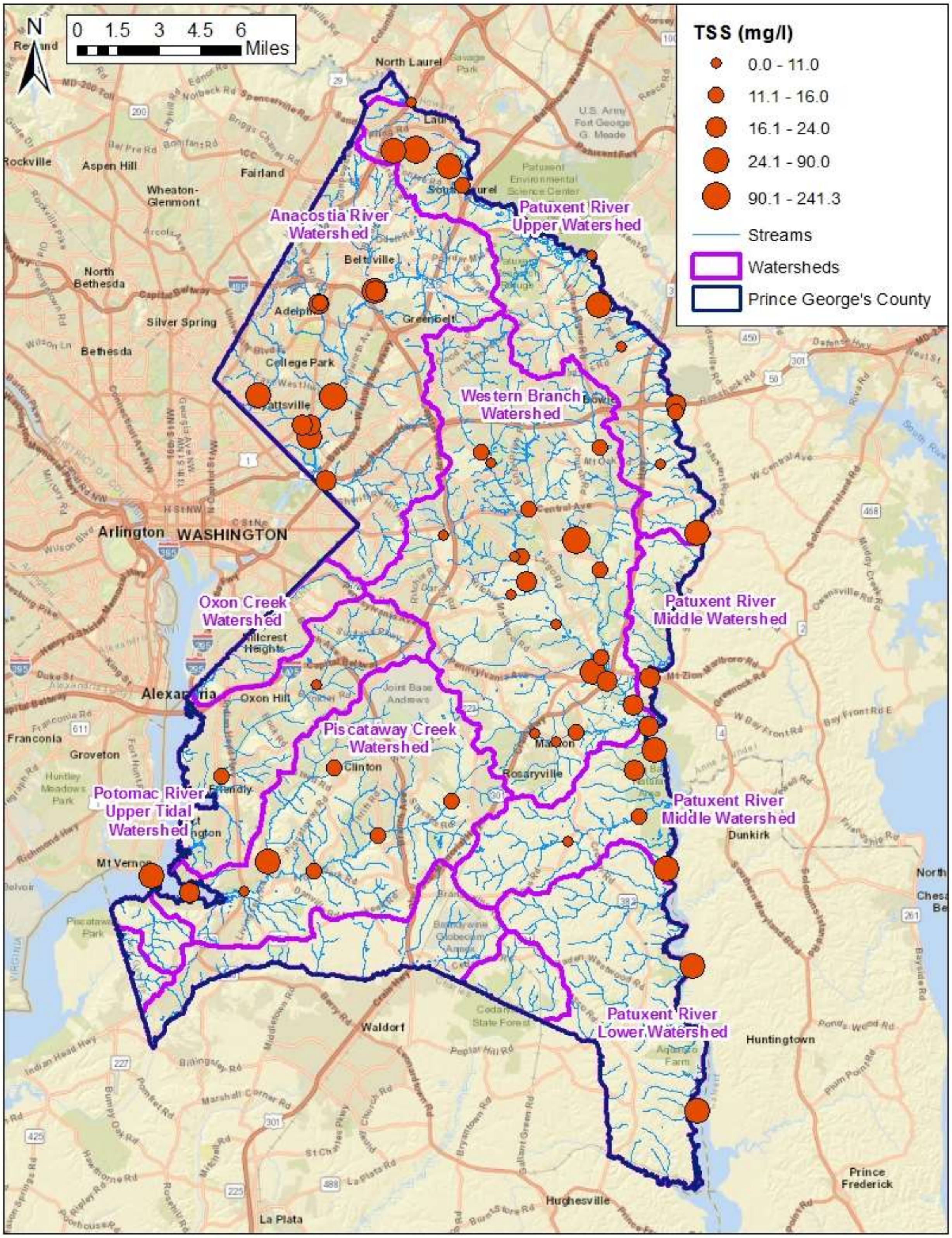


Figure B-18. Map of TSS concentration in various locations throughout the watersheds in Prince George's County.

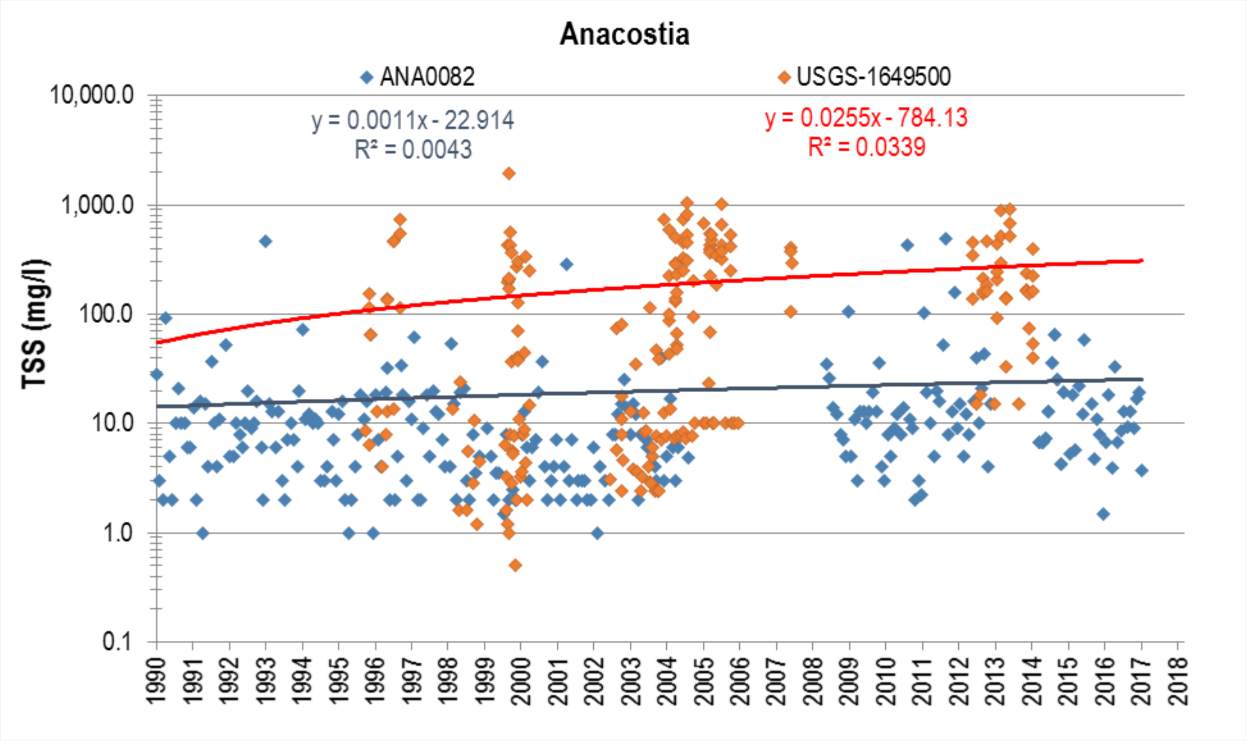


Figure B-19. Plot of TSS over time in the Anacostia River watershed.

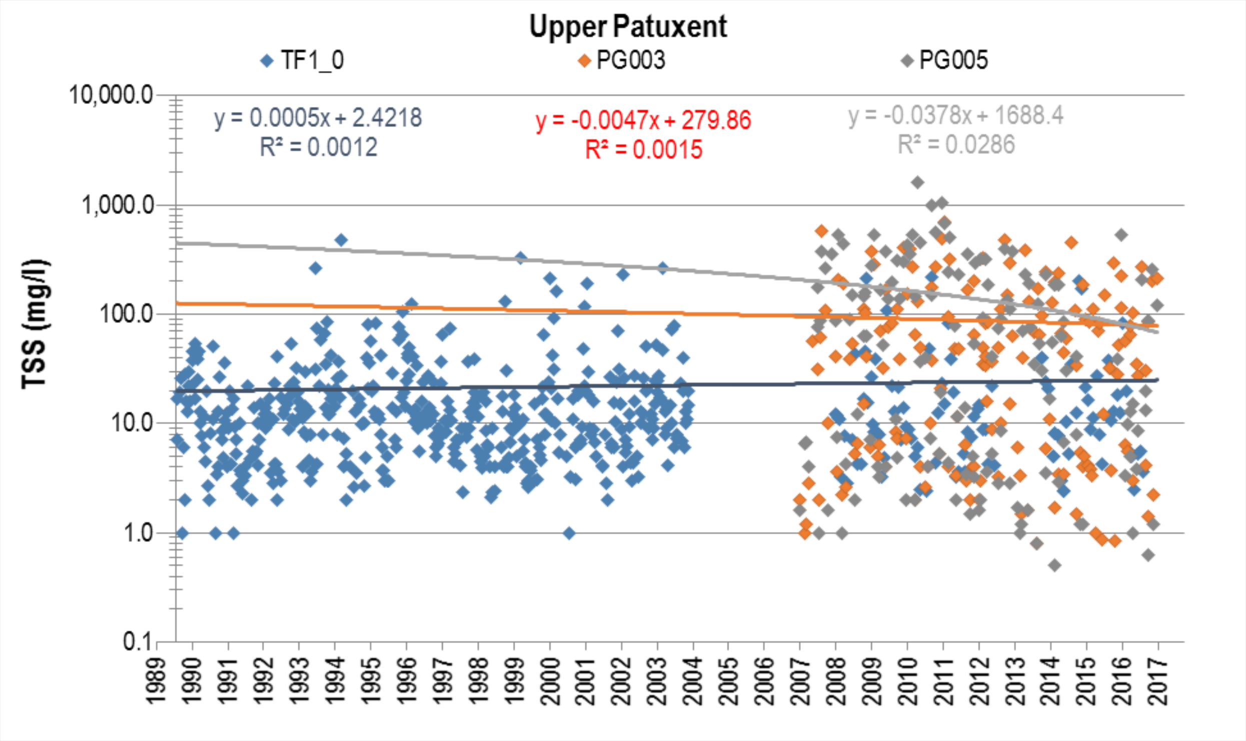


Figure B-20. Plot of TSS over time in the Upper Patuxent River watershed.

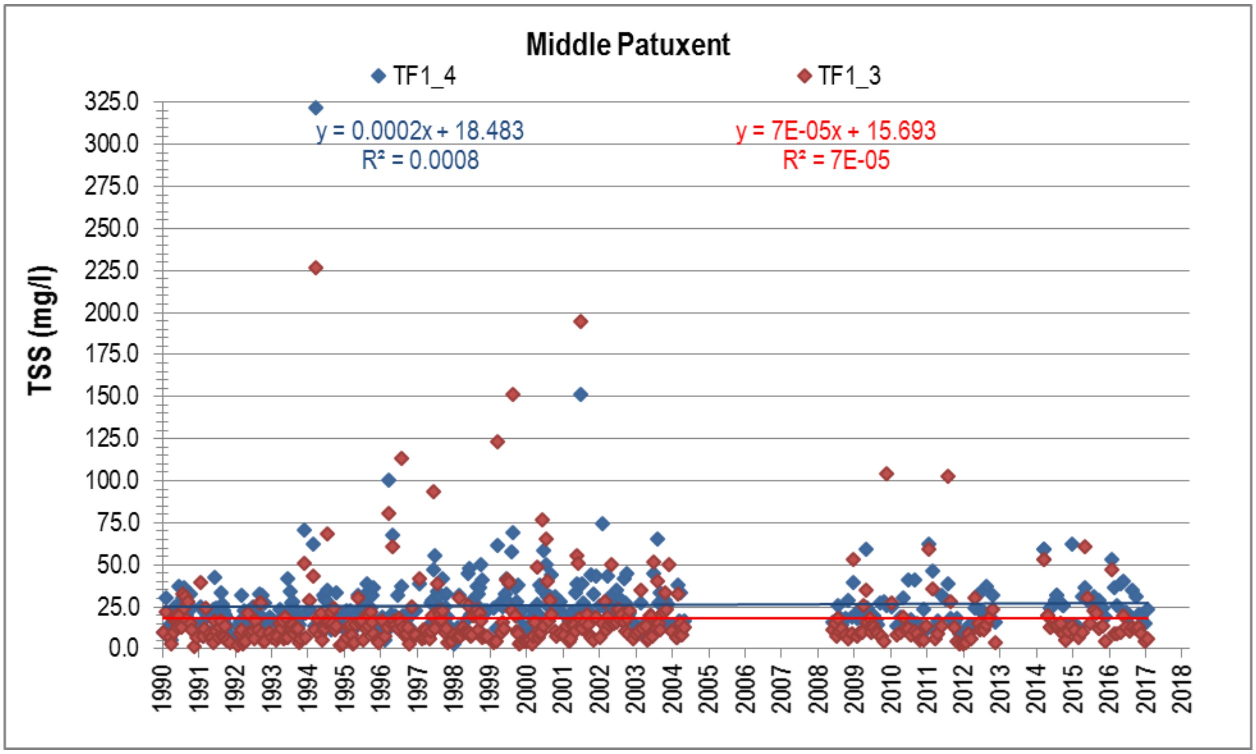


Figure B-21. Plot of TSS over time in the Middle Patuxent River watershed.

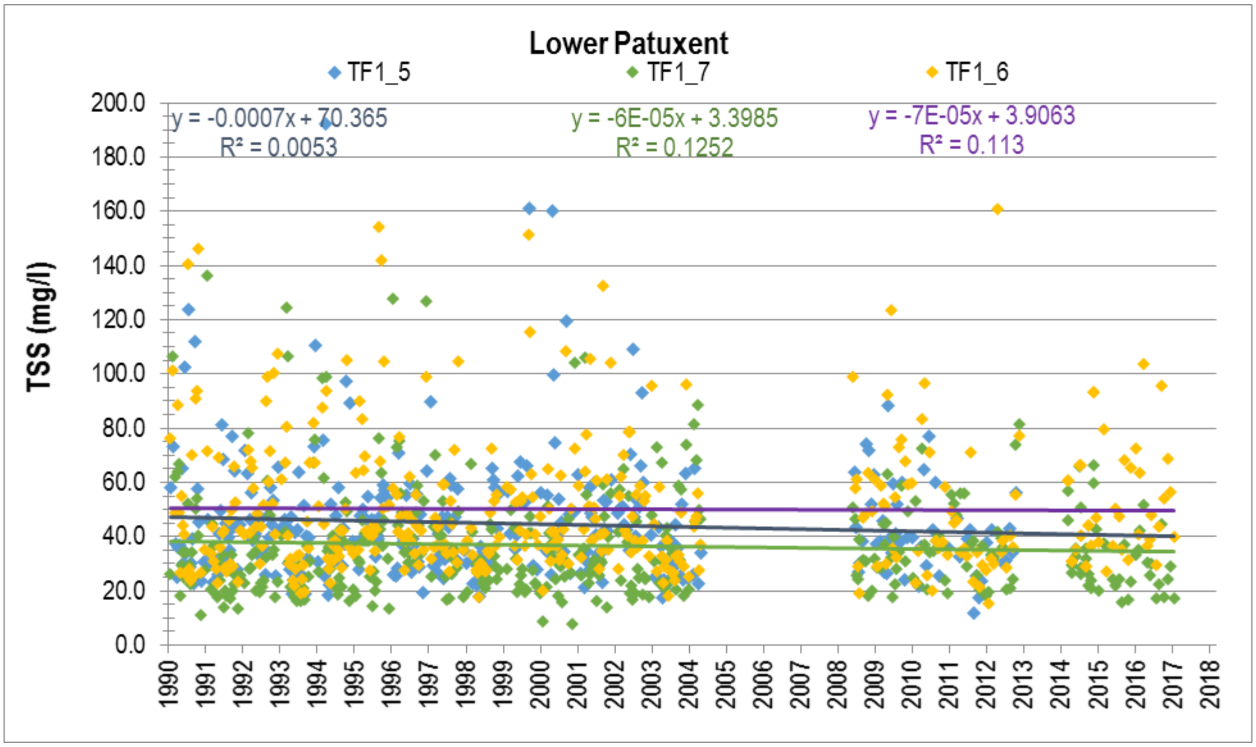


Figure B-22. Plot of TSS over time in the Lower Patuxent River watershed.

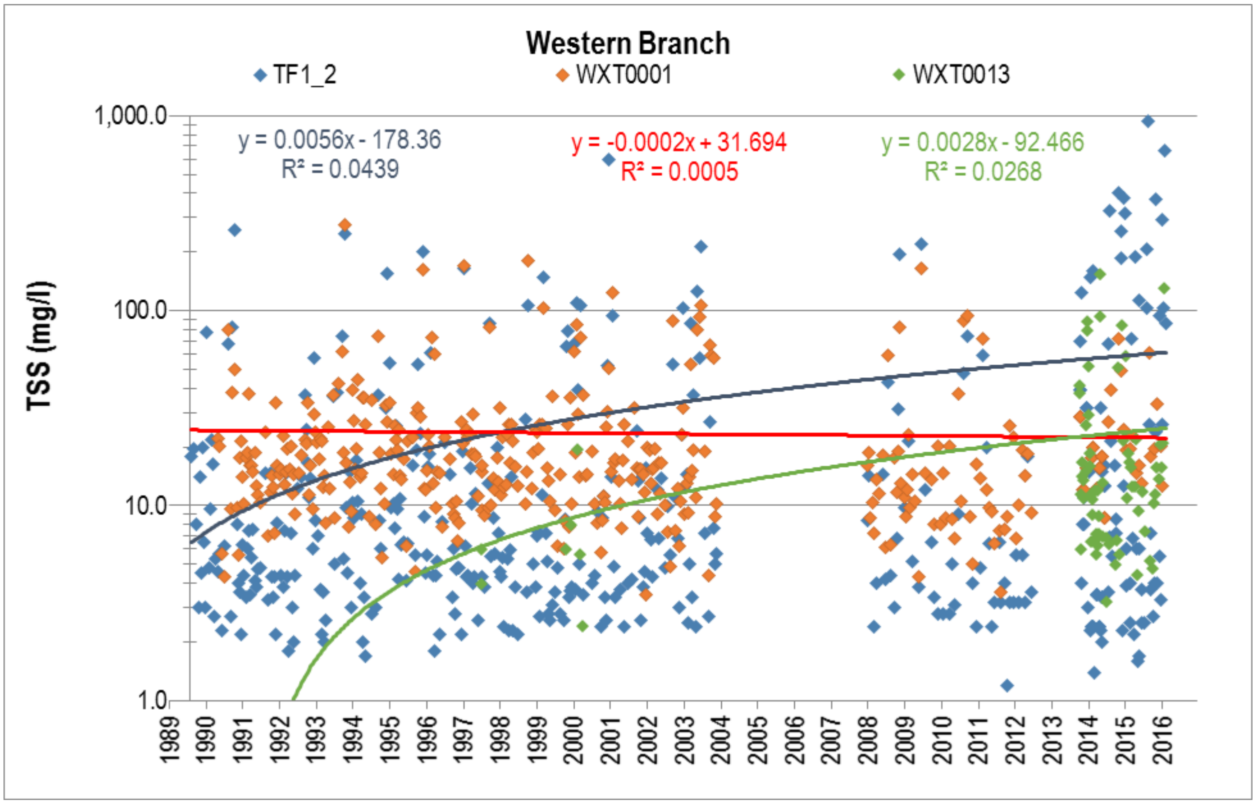


Figure B-23. Plot of TSS over time in the Western Branch watershed.

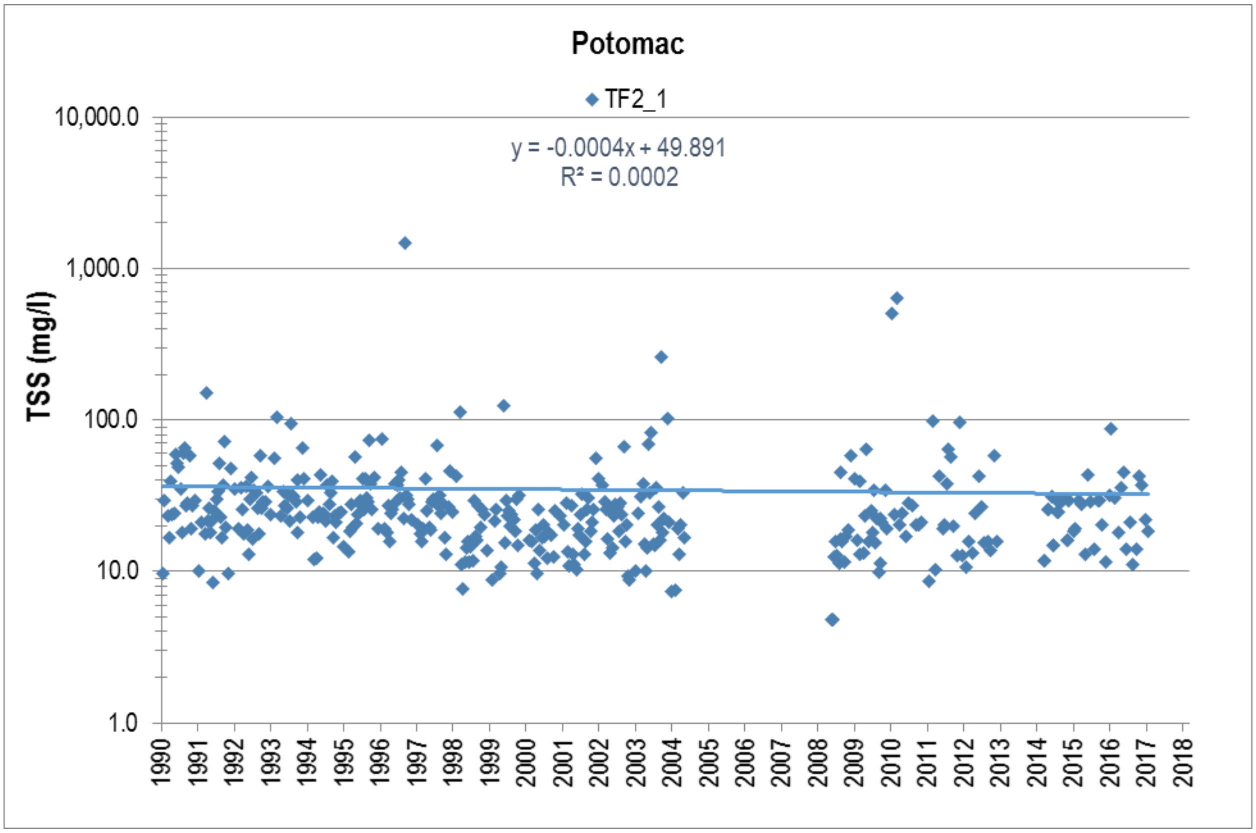


Figure B-24. Plot of TSS over time in the Potomac River watershed.

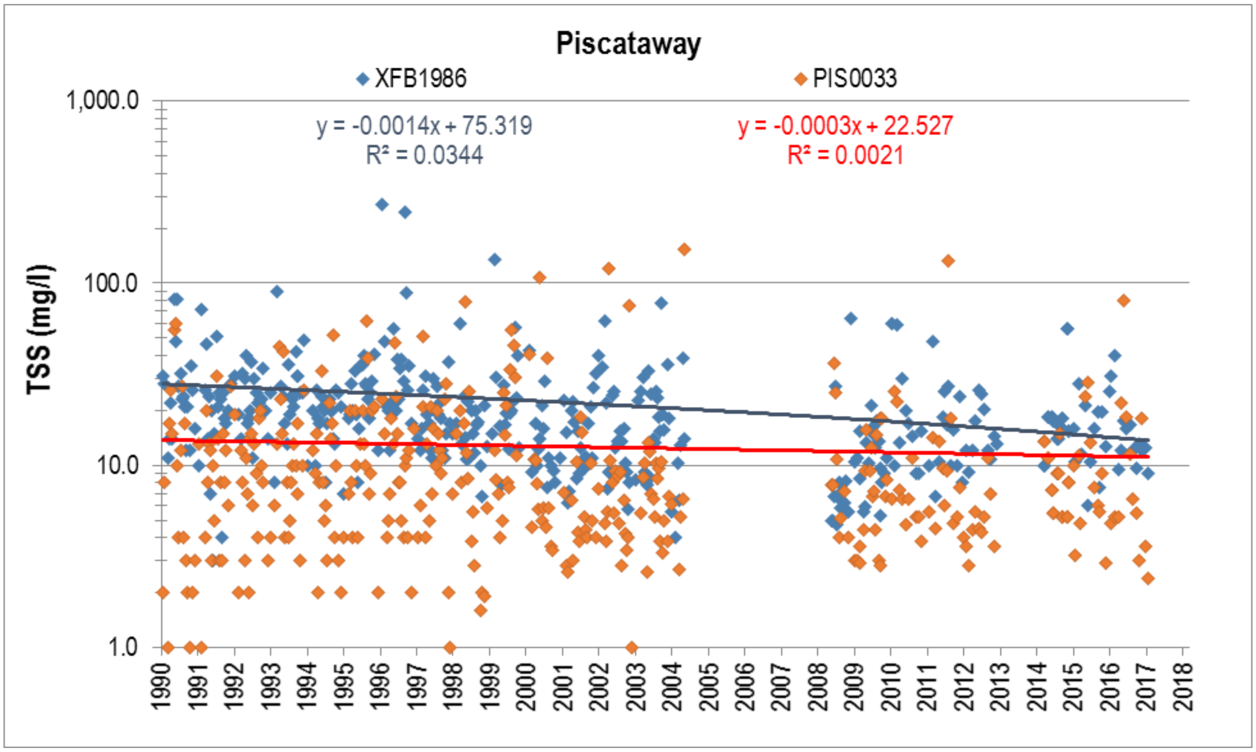


Figure B-25. Plot of TSS over time in the Piscataway Creek watershed.

E. coli

Table B-4. Summary of *E. coli* data by watershed

Watershed	Station ID	Station name	Date min.	Date max.	Number of records	Min. value (mg/L)	Mean value (mg/L)	Max. value (mg/L)
Anacostia River	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	12/11/03	12/4/17	315	21	9,777.42	120,000
Upper Patuxent River	PG003	Bear Branch at Contee Rd.	10/15/09	6/23/17	109	2	2,610.76	87,521.92
	PG005	Bear Branch above Laurel Lakes	10/15/09	6/23/17	94	2	2,455.90	82,487.40

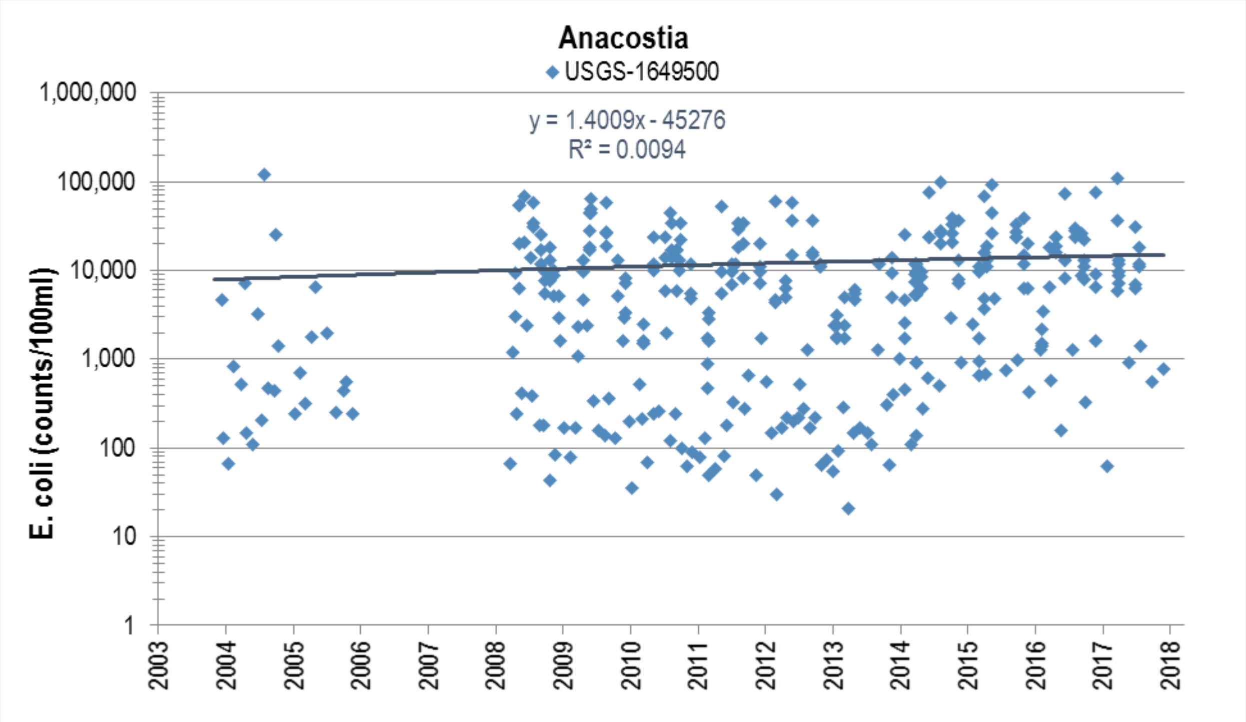


Figure B-26. Plot of *E. coli* over time in the Anacostia River watershed.

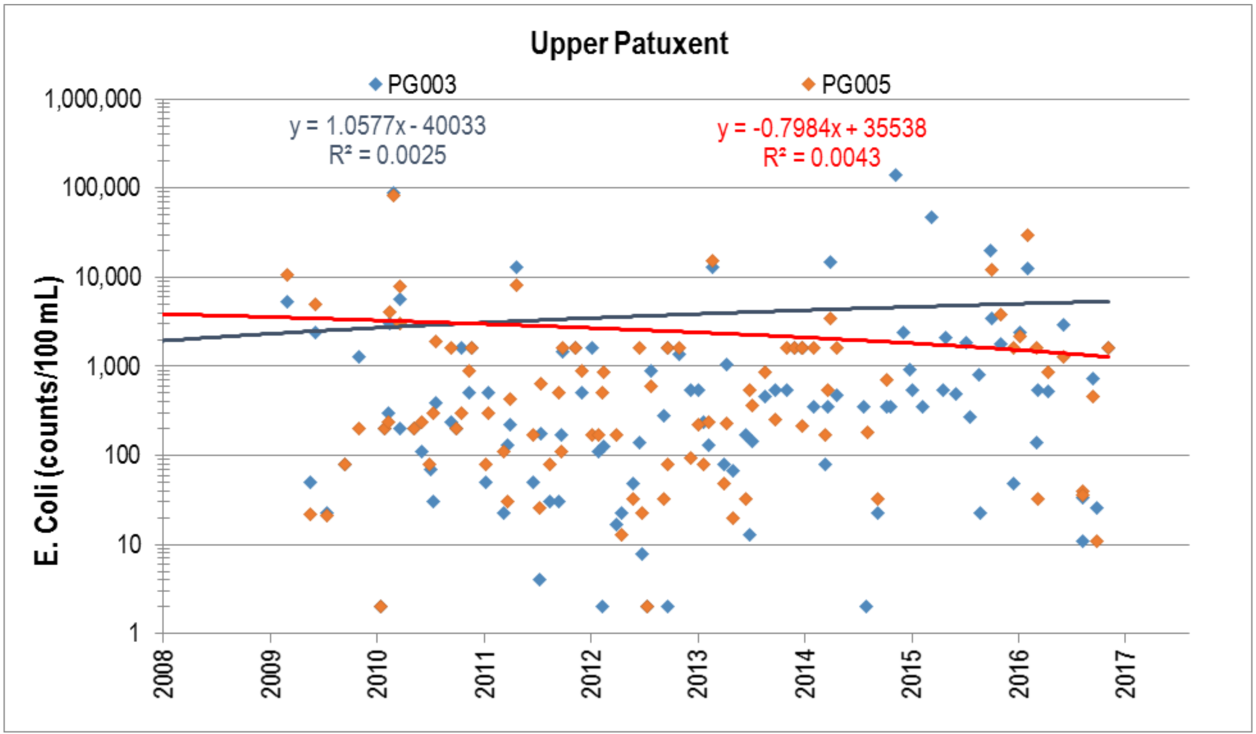


Figure B-27. Plot of *E. coli* over time in the Upper Patuxent River watershed.

Dissolved Oxygen (DO)

Table B-5. Summary of DO data by watershed

Watershed	Station ID	Station Name	Date Min.	Date Max.	Number of Records	Min. Value (mg/L)	Mean Value (mg/L)	Max. Value (mg/L)
Anacostia River	ANA0082	Anacostia River	1/9/90	12/5/12	226	3.30	10.28	14.79
	NCRN_NACE_STCK	Still Creek	3/6/06	7/25/16	82	2.27	8.55	13.75
Rocky Gorge Dam	PXT0809	Upper Patuxent at base of Rocky Gorge Dam	10/14/99	12/12/11	64	5.20	9.48	14.10
Upper Patuxent	TF1.0	TF1.0	1/8/90	12/3/12	510	5.80	8.80	13.10
Middle Patuxent	TF1.3	TF1.3	1/16/90	12/3/12	339	4.70	8.45	13.49
	TF1.4	TF1.4	1/16/90	12/3/12	341	4.40	8.36	14.10
Lower Patuxent	TF1.5	TF1.5	1/16/90	11/1/12	317	3.24	8.75	13.77
	TF1.6	TF1.6	1/16/90	12/3/12	339	2.33	8.13	12.90
	TF1.7	TF1.7	1/16/90	12/3/12	340	2.95	7.41	15.35
Western Branch	TF1.2	TF1.2	1/16/90	12/3/12	342	5.70	9.32	13.90
	WXT0001	Western Branch	10/9/90	12/3/12	327	3.80	8.12	12.60
Potomac River	NCRN_NACE_ACCK	Accokeek Creek trib.	11/29/05	5/24/12	52	2.51	8.26	13.90
	NCRN_NACE_HECR	Henson Creek	3/6/06	7/25/16	83	2.60	8.97	19.41
	NCRN_NACE_OXRU	Oxon Run	11/29/05	7/25/16	78	2.90	10.11	15.00
	TF2.1	TF2.1	1/17/90	12/12/12	344	3.25	8.75	14.05
Piscataway River	PIS0033	PIS0033	1/17/90	12/12/12	346	0.67	8.50	14.98
	XFB1986	XFB1986	1/17/90	12/12/12	344	4.10	9.66	16.60

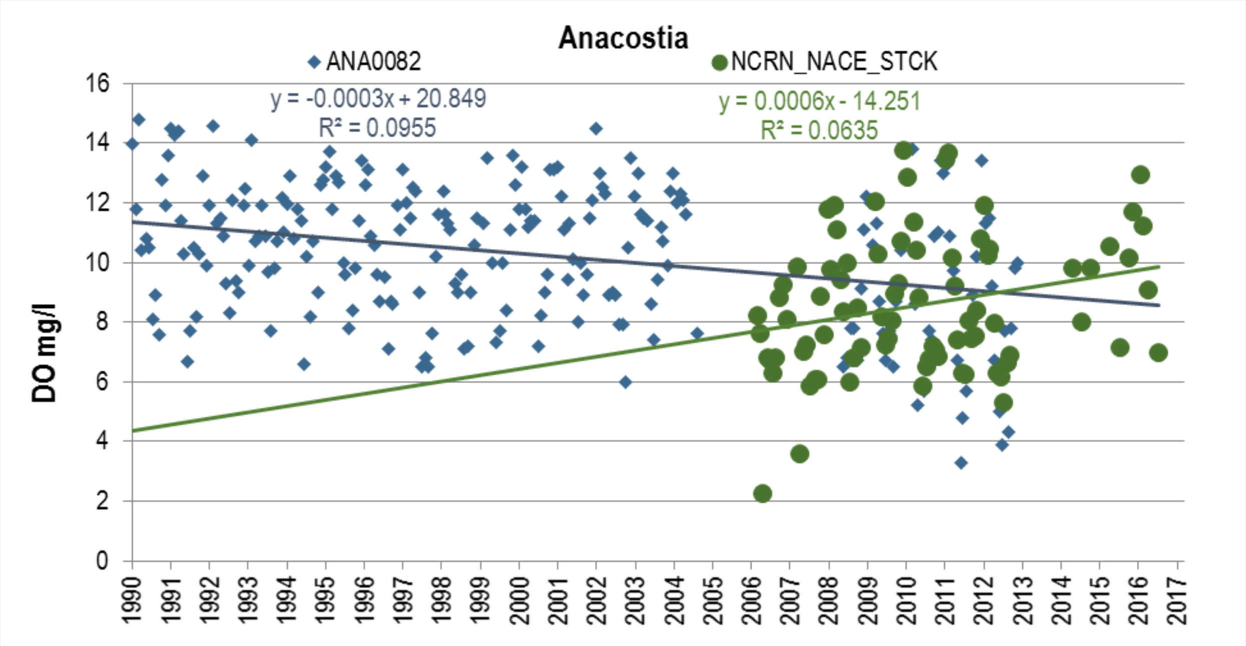


Figure B-28. Plot of DO over time in the Anacostia River watershed.

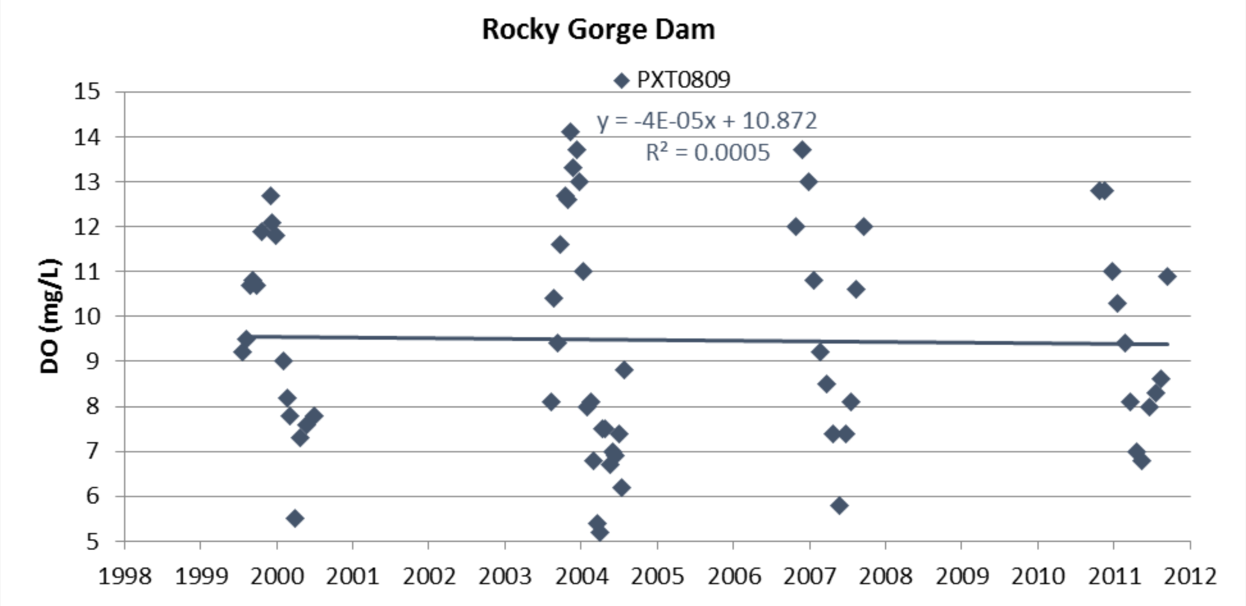


Figure B-29. Plot of DO over time in the Rocky Gorge Dam watershed.

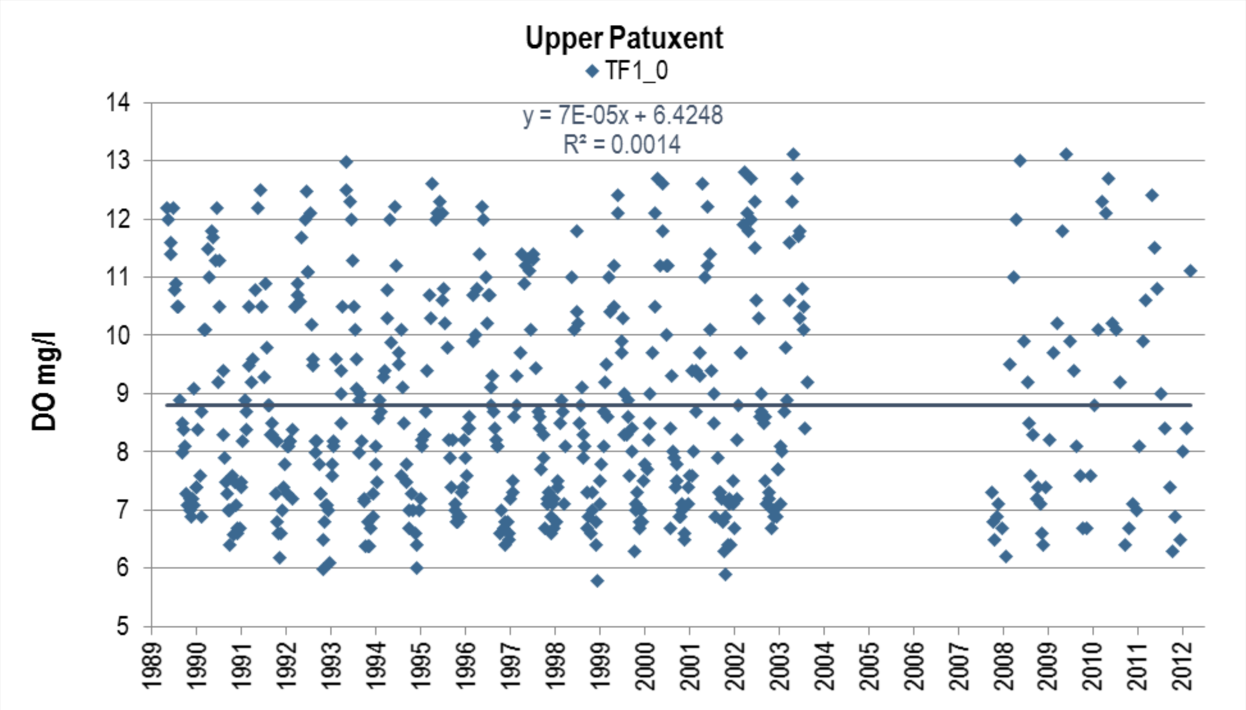


Figure B-30. Plot of DO over time in the Upper Patuxent River watershed.

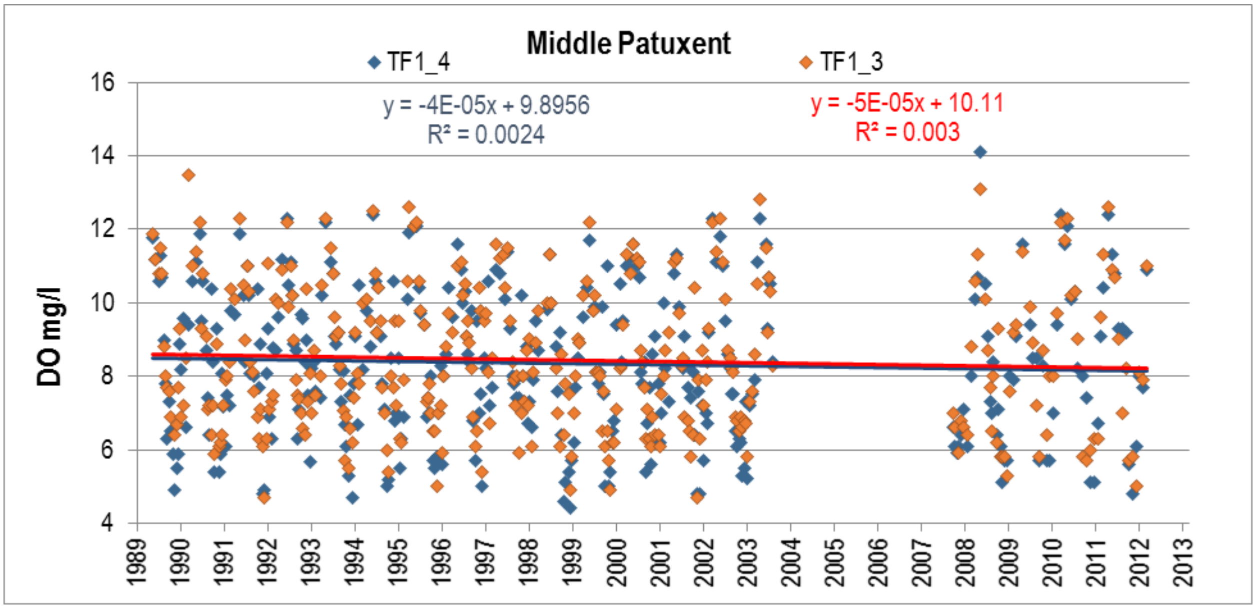


Figure B-31. Plot of DO over time in the Middle Patuxent River watershed.

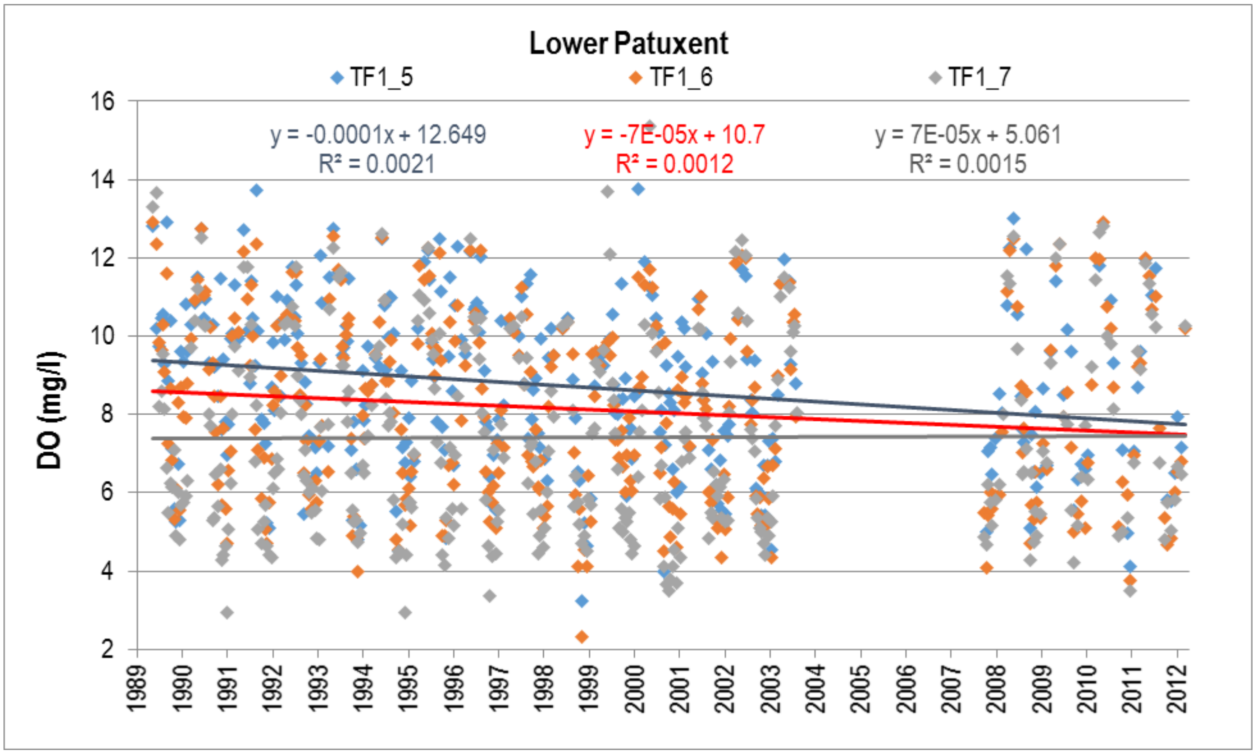


Figure B-32. Plot of DO over time in the Lower Patuxent River watershed.

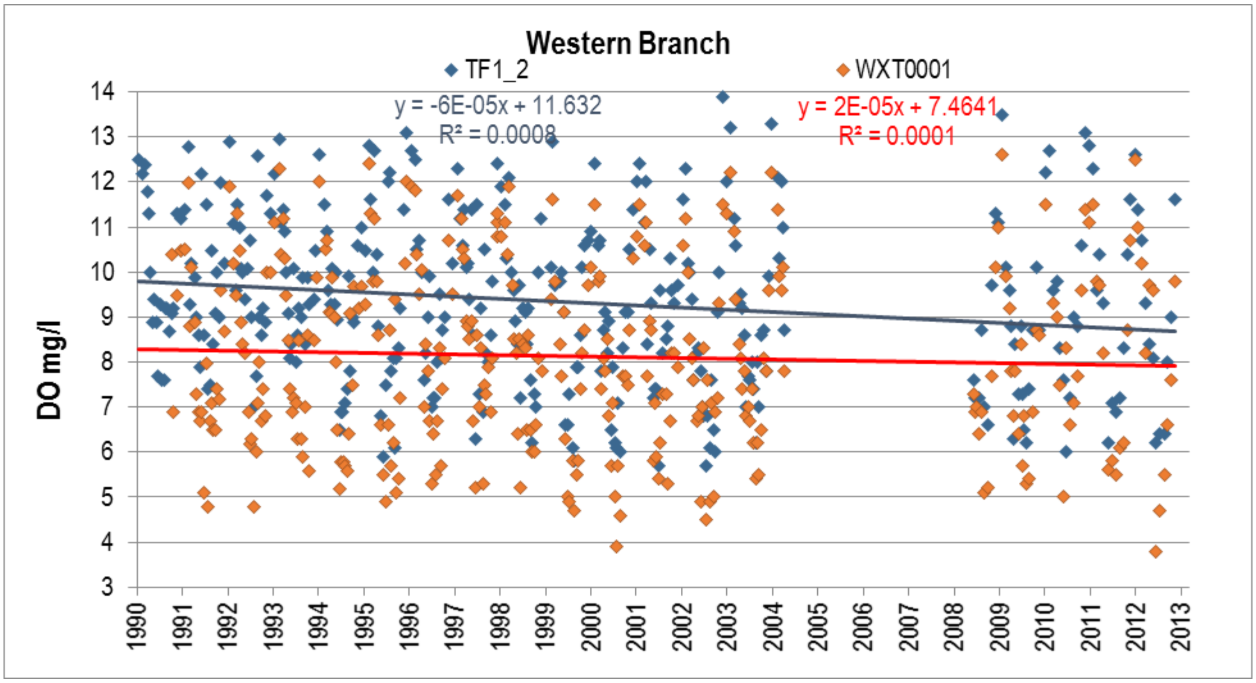


Figure B-33. Plot of DO over time in the Western Branch watershed.

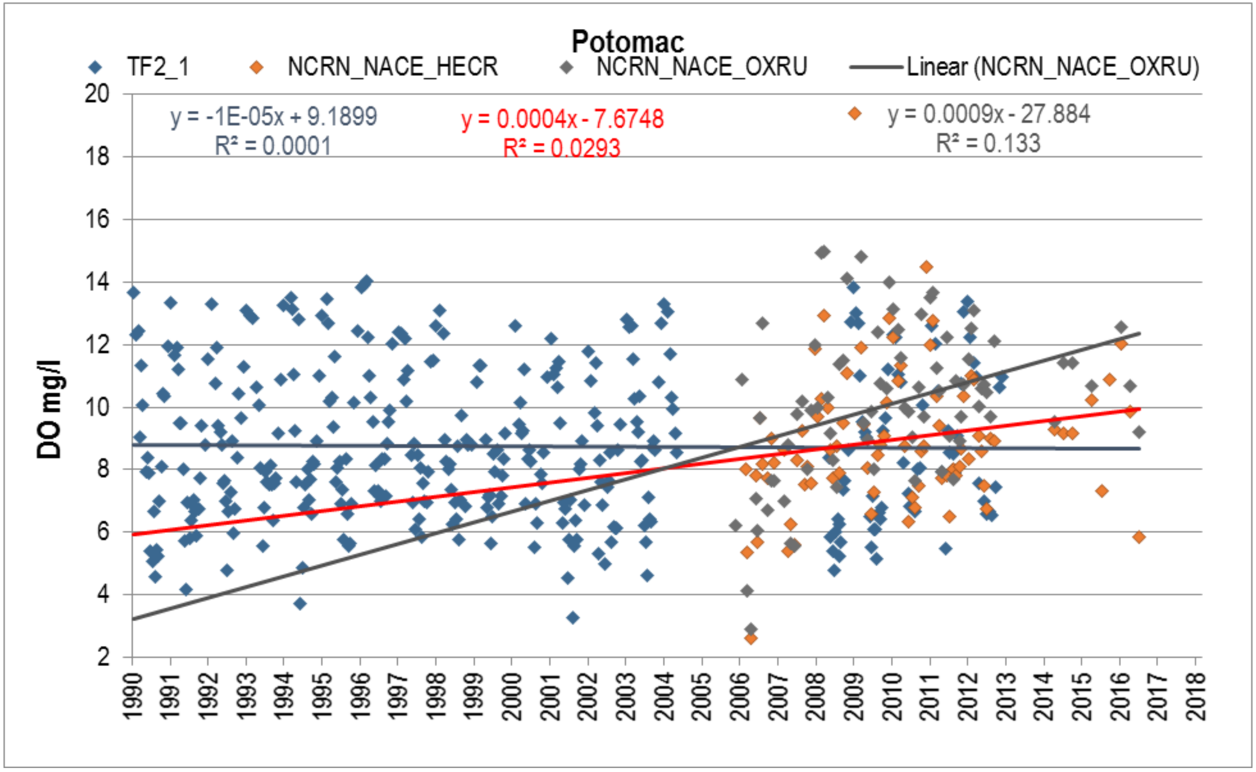


Figure B-34. Plot of DO over time in the Potomac River watershed.

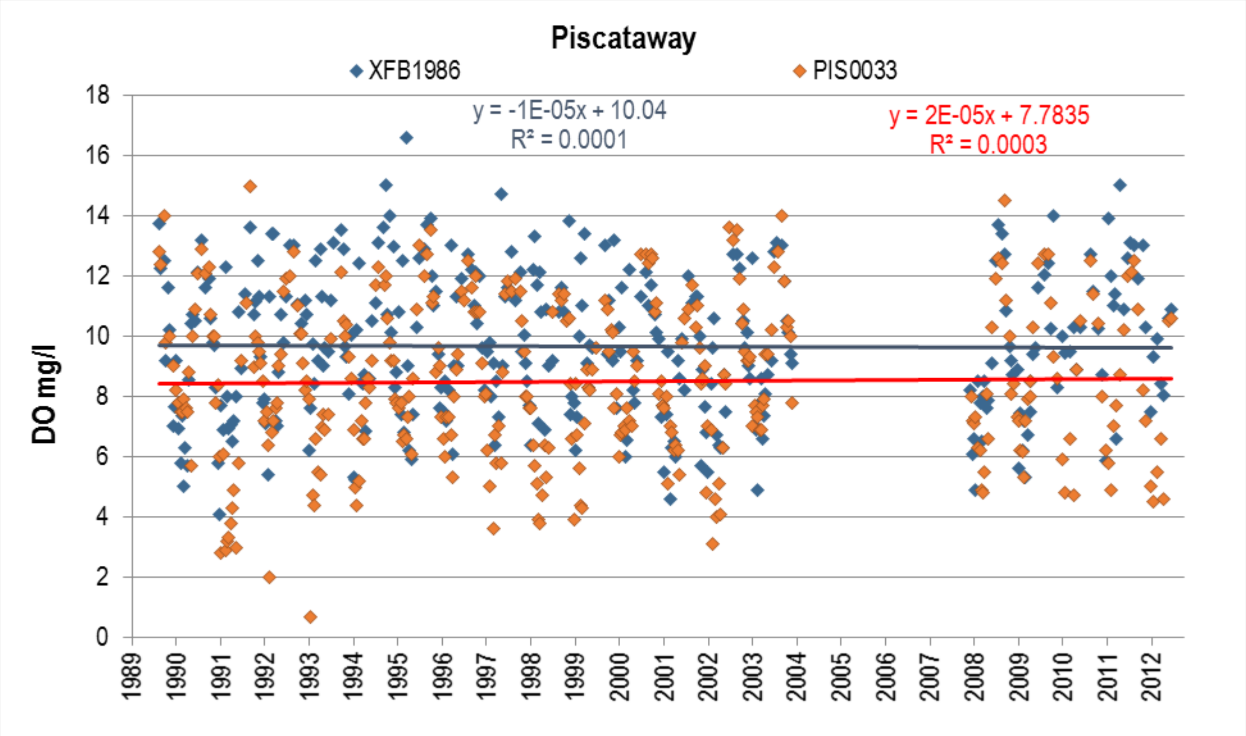


Figure B-35. Plot of DO over time in the Piscataway Creek watershed.

Chloride

Table B-6. Summary of chloride data by watershed

Watershed	Station ID	Station Name	Date Min.	Date Max.	Number of Records	Min. Value (mg/L)	Mean Value (mg/L)	Max. Value (mg/L)
Anacostia River	ANA0082	Anacostia River	5/11/11	9/3/14	32	10.69	65.92	134.38
	BDM0008	Beaverdam Creek	6/16/08	12/15/08	7	7.80	63.46	94.55
	BED0001	Beaverdam Creek	10/7/02	12/15/08	33	15.20	33.23	83.30
	INC0030	Indian Creek	10/7/02	12/15/08	32	14.60	65.85	899.30
	LPB0002	Little Paint Branch	6/16/08	12/15/08	7	51.90	67.72	83.20
	NEB0002	Northeast Branch	10/7/02	12/15/08	33	18.00	65.71	589.30
	NWA0002	Northwest Branch	10/7/02	12/15/08	33	12.80	92.02	1,230.00
	PNT0027	Paint Branch	6/16/08	12/15/08	7	44.34	53.69	67.37
	SLI0002	Sligo Creek	6/16/08	12/15/08	7	69.50	111.26	149.30
	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	8/19/63	10/12/17	174	3.62	79.10	632.00
	USGS-1651000	Northwest Br Anacostia River Nr Hyattsville, MD	8/19/63	1/17/07	15	6.80	18.49	50.10
Piscataway River	PHB0009	Pea Hill Branch	6/17/08	12/16/08	7	32.90	62.05	78.40
	PIS0063	Piscataway Creek	6/17/08	12/16/08	7	16.01	26.34	36.29
	PIS0099	Piscataway Creek	6/17/08	12/16/08	7	18.87	27.67	33.80
	PIS0133	Piscataway Creek	6/17/08	12/16/08	7	16.42	22.68	29.12
	TIN0006	Tinkers Creek	6/17/08	12/16/08	7	22.30	40.85	54.20

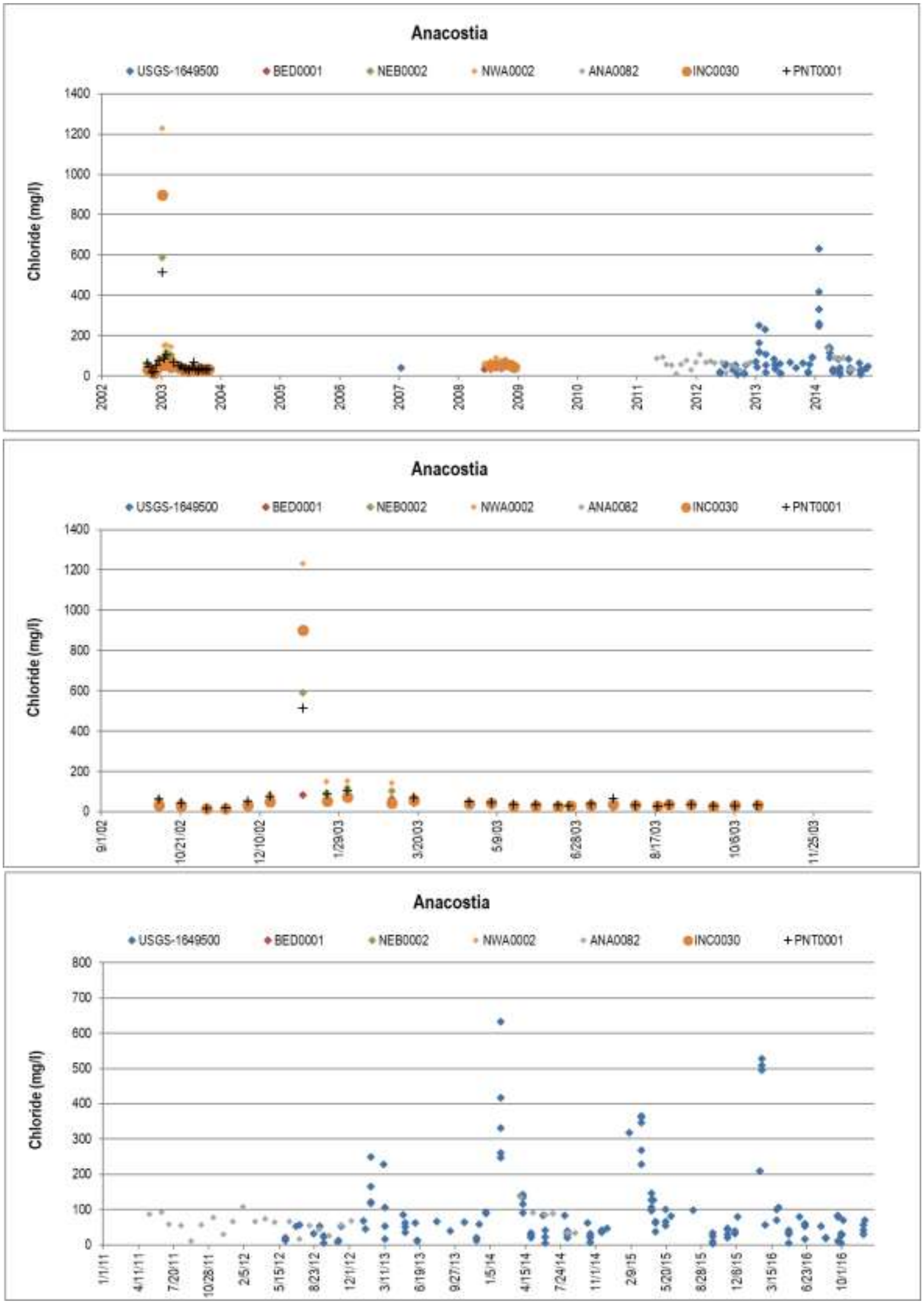


Figure B-36. Plot of chloride over time in the Anacostia River watershed.

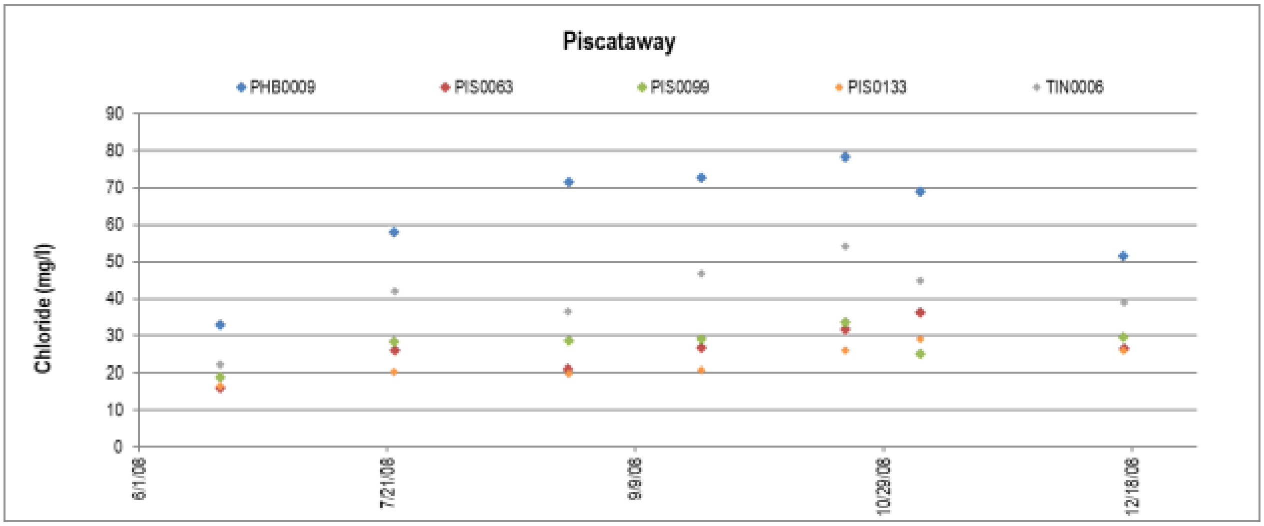


Figure B-37. Plot of chloride over time in the Piscataway Creek watershed.

Sulfate

Table B-7. Summary of sulfate data in the Anacostia River watershed

Station ID	Station Name	Parameter	Date Min.	Date Max.	Number of Records	Min. Value (mg/L)	Mean Value (mg/L)	Max. Value (mg/L)
ANA0082	Anacostia River	Sulfate, Dissolved	5/11/11	9/3/14	24	4.00	12.79	18.25
ANA0082	Anacostia River	Sulfate, Total	4/2/14	9/3/14	6	7.11	13.19	17.06
USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	Sulfate, Dissolved	8/19/63	1/18/07	15	14.00	36.89	77.00
USGS-1651000	Northwest Br Anacostia River Nr Hyattsville, MD	Sulfate, Dissolved	8/19/63	1/17/07	15	14.00	18.96	25.00

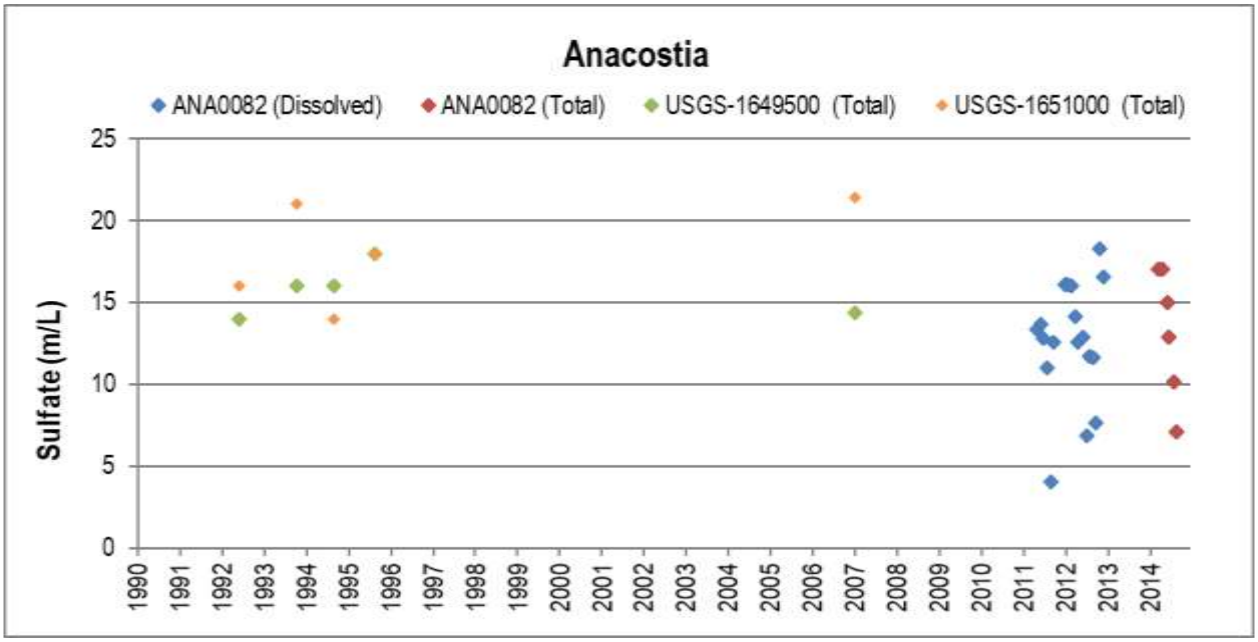


Figure B-38. Plot of sulfate over time in the Piscataway Creek watershed.

Polychlorinated Biphenyls (PCBs)

Table B-8. Summary of total PCB data for the Anacostia River watershed

Station ID	Station name	Date min.	Date max.	Number of records	Min. (ng/L)	Mean (ng/L)	Max. (ng/L)
NEB0016	Northeast Branch Anacostia River	4/13/04	10/7/05	31	0.10	3.66	15.67
NWB	Northwest Branch of the Anacostia River	4/13/04	10/7/05	30	0.24	4.77	12.51

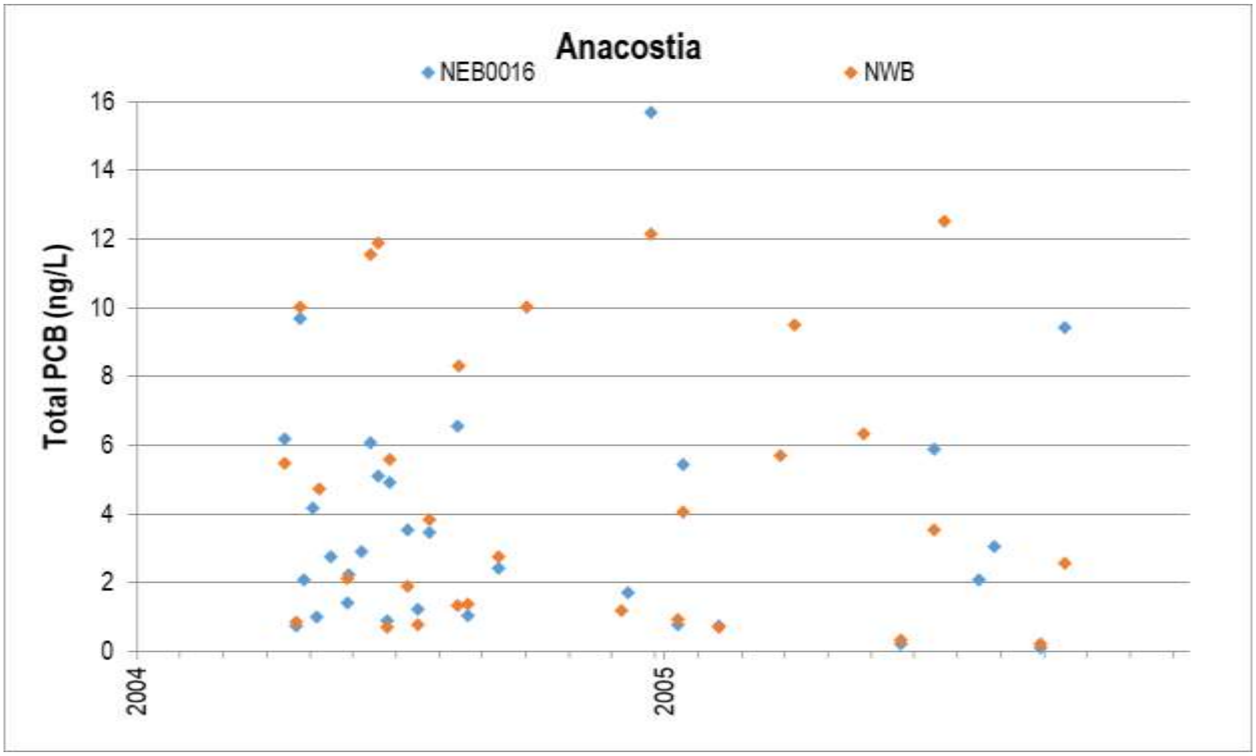


Figure B-39. Total PCBs over time in the Anacostia River watershed.

pH

Table B-9. Summary of pH data by watershed

Watershed	Station ID	Station Name	Date Min.	Date Max.	Number of Records	Min. Value (S.U.)	Mean Value (S.U.)	Max. Value ((S.U.)
Anacostia	ANA0082	Anacostia River	1/7/86	2/1/17	314	5.70	7.65	9.60
	BDM0008	Beaverdam Creek	1/28/08	12/15/08	12	7.10	7.58	8.10
	BED0001	Beaverdam Creek	10/7/02	12/15/08	38	6.30	6.99	7.60
	INC0030	Indian Creek	10/7/02	12/15/08	38	6.60	7.15	7.80
	LPB0002	Little Paint Branch	1/28/08	12/15/08	12	6.70	7.52	8.20
	NCRN_NACE_STCK	Still Creek	3/6/06	7/25/16	84	6.76	7.34	8.30
	NEB0002	Northeast Branch	10/7/02	12/15/08	54	6.80	7.85	9.30
	NWA0002	Northwest Branch	10/7/02	12/15/08	54	6.90	7.47	8.80
	PNT0027	Paint Branch	1/28/08	12/15/08	12	6.80	7.53	8.00
	SC_MS	Main Stem	9/4/04	6/6/09	143	7.22	7.74	8.45
	SC_TB	Takoma Branch	10/9/04	6/6/09	142	7.22	7.81	8.04
	SLI0002	Sligo Creek	1/28/08	12/15/08	12	7.00	7.76	8.50
	USGS_NW	USGS NW Branch	9/4/04	6/26/10	137	6.80	7.32	7.80
	USGS-1649500	Northeast Branch Anacostia River at Riverdale, MD	8/19/63	12/4/17	475	6.30	7.27	8.80

Watershed	Station ID	Station Name	Date Min.	Date Max.	Number of Records	Min. Value (S.U.)	Mean Value (S.U.)	Max. Value ((S.U.)
	USGS-1651000	Northwest Br Anacostia River Nr Hyattsville, MD	8/19/63	6/9/10	204	6.50	7.33	8.30
Lower Patuxent	TF1.5	TF1.5	1/9/85	11/1/12	1115	0.00	7.65	9.40
	TF1.6	TF1.6	1/9/85	2/7/17	1120	0.00	7.61	10.20
	TF1.7	TF1.7	1/9/85	2/7/17	859	6.50	7.47	9.40
Middle Patuxent	MTI0056	Mataponi Creek	1/24/07	12/19/07	12	6.40	6.85	7.30
	TF1.3	TF1.3	1/9/85	2/7/17	485	0.69	7.31	9.00
	TF1.4	TF1.4	1/9/85	2/7/17	486	6.10	7.29	8.90
Piscataway	PHB0009	Pea Hill Branch	1/29/08	12/16/08	12	6.60	7.13	7.70
	PIS0033	PIS0033	1/6/86	2/6/17	460	5.60	7.19	9.50
	PIS0063	Piscataway Creek	1/29/08	12/16/08	12	6.70	7.02	7.40
	PIS0099	Piscataway Creek	1/29/08	12/16/08	12	6.50	7.07	7.50
	PIS0133	Piscataway Creek	1/29/08	12/16/08	12	6.70	7.21	8.00
	TIN0006	Tinkers Creek	1/29/08	12/16/08	12	6.70	7.01	7.30
	XFB1986	XFB1986	1/6/86	2/6/17	537	6.50	7.91	9.50
Potomac	NCRN_NACE_ACCK	Accoceek Creek tributary	11/29/05	5/24/12	51	6.72	7.61	8.21
	NCRN_NACE_HECR	Henson Creek	3/6/06	7/25/16	83	6.35	7.36	8.70
	NCRN_NACE_OXRU	Oxon Run	11/29/05	7/25/16	79	6.91	8.08	9.47
	TF2.1	TF2.1	1/6/86	2/6/17	898	6.20	7.73	9.20
Rocky Gorge	PXT0809	Upper Patuxent River @ Base of Rocky Gorge Dam	10/14/99	12/17/07	52	6.20	7.32	8.80
Upper Patuxent	HNE0006	Honey Branch	1/23/07	12/18/07	12	6.80	7.43	7.90
	HRP0005	Horsepen Branch	1/23/07	12/18/07	12	6.70	7.09	7.40
	MIB0013	Mill Branch	1/23/07	12/18/07	12	6.70	7.19	7.60
	PXT0613	Patuxent River	11/4/03	12/18/07	36	6.80	7.36	8.10
	PXT0683	Upper Patuxent River	1/23/07	12/18/07	11	6.70	7.20	7.40
	PXT0771	Upper Patuxent River @ Brock Bridge Road	1/23/07	12/18/07	12	7.20	7.63	7.90
	TF1.0	TF1.0	1/9/85	2/7/17	702	6.20	7.32	9.10
	UDK0012	Unnamed Tributary to Patuxent River	1/23/07	12/18/07	12	6.50	6.97	7.40
	ZCC0006	Unnamed Tributary to Crow Branch	1/23/07	12/18/07	12	7.20	7.56	7.90
Western Branch	BAL0006	Bald Hill Branch	1/24/07	12/19/07	12	6.40	7.02	7.60
	CLN0002	Collington Branch	1/24/07	12/19/07	12	6.90	7.24	7.60
	CLN0037	Collington Branch	1/24/07	12/19/07	12	6.70	7.22	7.60
	CLN0086	Collington Branch	1/24/07	12/19/07	12	6.50	7.08	7.60
	LTT0002	Lottsford Branch	1/24/07	12/19/07	12	6.50	6.99	7.60

Watershed	Station ID	Station Name	Date Min.	Date Max.	Number of Records	Min. Value (S.U.)	Mean Value (S.U.)	Max. Value ((S.U.)
	NTB0002	Northeast Branch Western Branch Patuxent River	1/24/07	12/19/07	12	6.50	7.08	7.80
	SWB0002	Southwest Branch Western Branch Patuxent River	1/24/07	12/19/07	12	6.60	7.23	7.50
	SWB0033	Southwest Branch Western Branch Patuxent River	1/24/07	12/19/07	12	6.40	7.18	7.70
	TF1.2	TF1.2	1/9/85	2/7/17	536	6.30	7.37	9.60
	TRK0012	Turkey Branch	1/24/07	12/19/07	12	6.70	7.33	7.70
	WXT0001	Western Branch	10/9/90	2/7/17	369	0.67	7.19	9.30
	WXT0013	Western Branch	12/15/97	2/1/17	239	6.72	7.31	7.84
	WXT0033	Western Branch	12/15/97	12/19/07	19	6.40	7.17	7.50
	WXT0112	Western Branch Patuxent River	1/24/07	12/19/07	12	6.80	7.18	7.60
	WXT0121	Western Branch Patuxent River	1/24/07	12/19/07	12	6.70	7.08	7.40

Note: S.U. = standard pH units

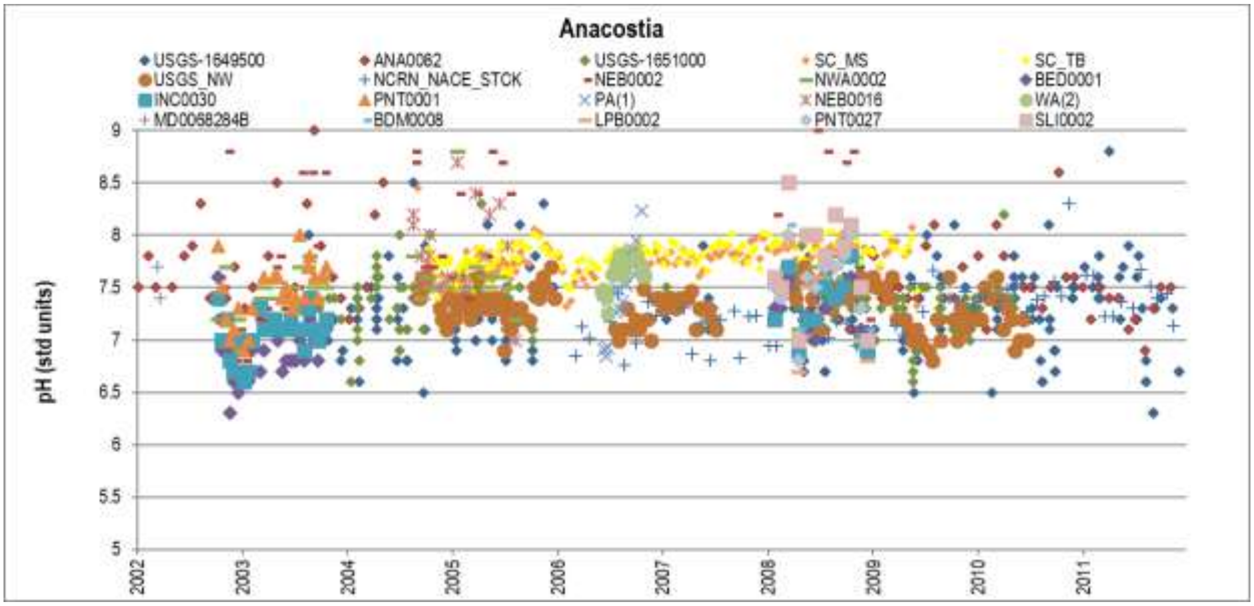


Figure B-40. Plot of pH over time in the Anacostia River watershed.

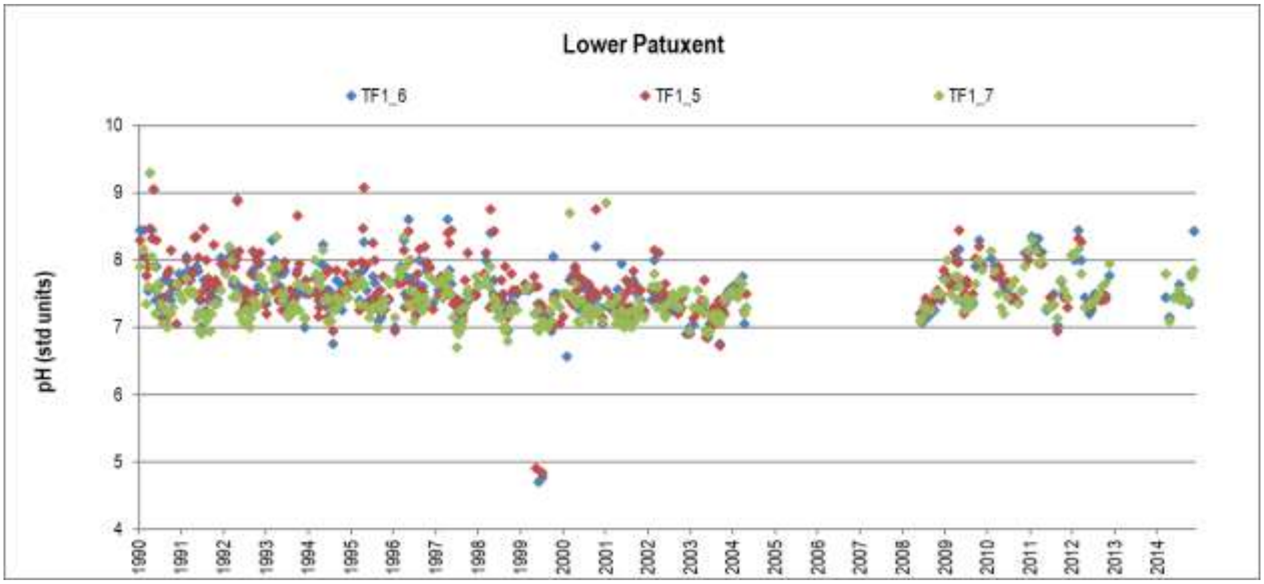


Figure B-41. Plot of pH over time in the Lower Patuxent River watershed.

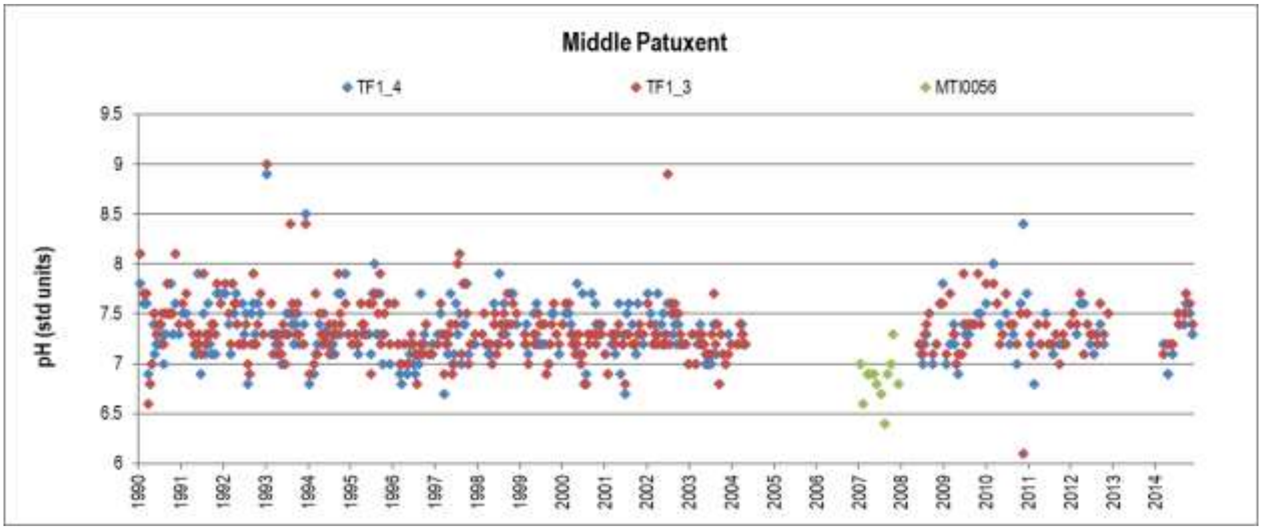


Figure B-42. Plot of pH over time in the Middle Patuxent River watershed.

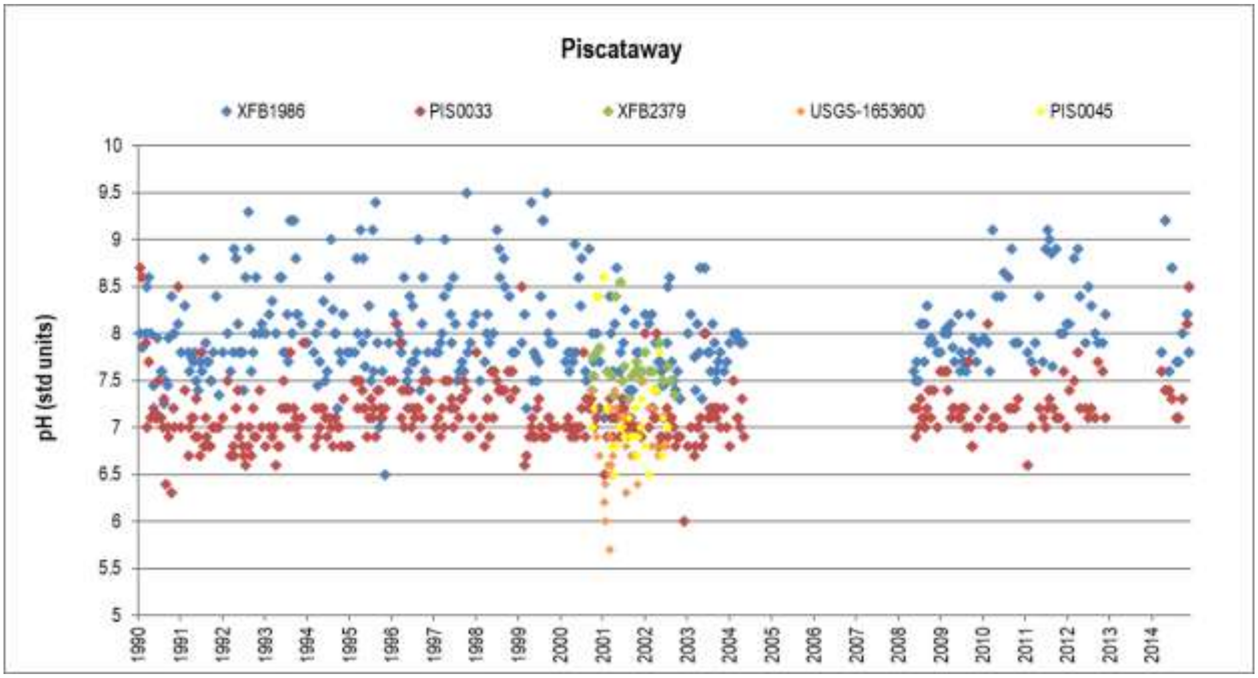


Figure B-43. Plot of pH over time in the Piscataway Creek watershed.

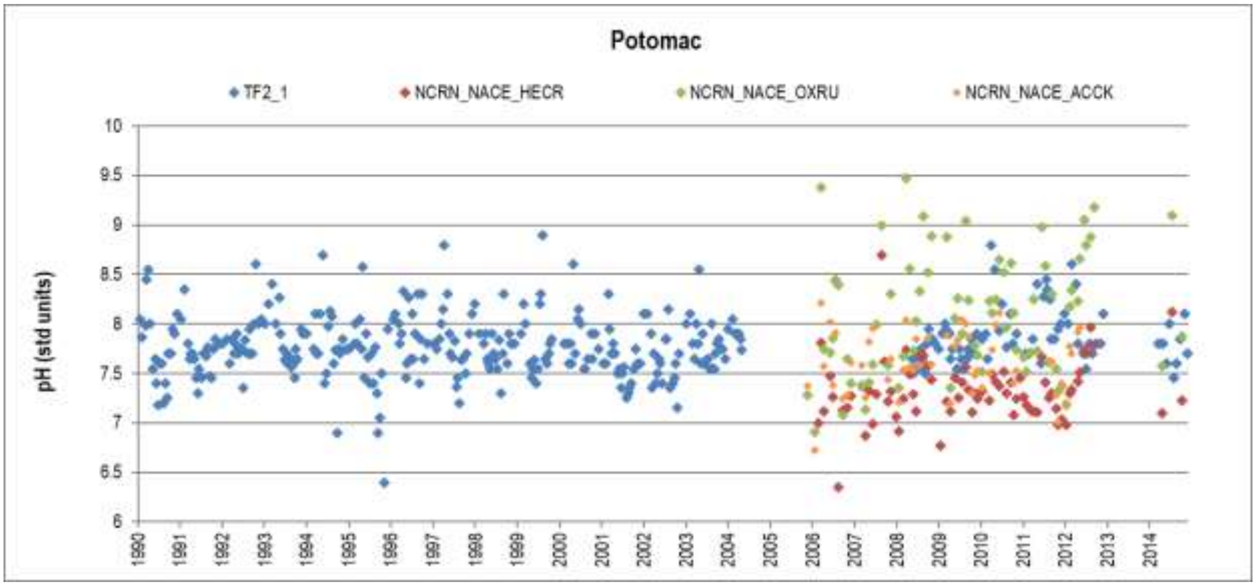


Figure B-44. Plot of pH over time in the Potomac River watershed.

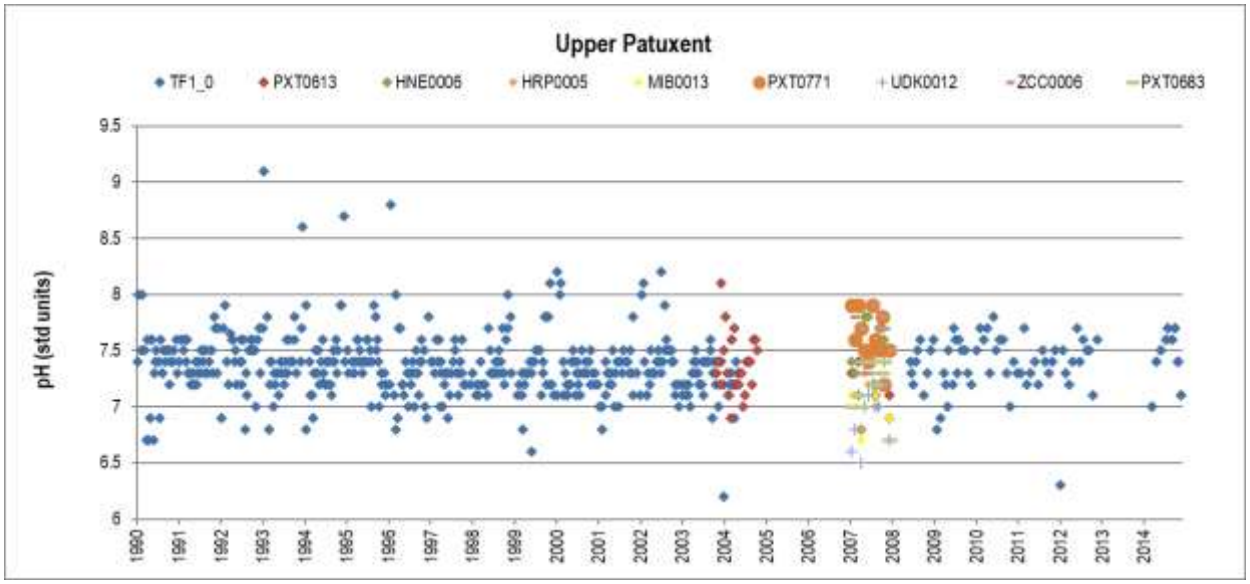


Figure B-45. Plot of pH over time in the Upper Patuxent River watershed.

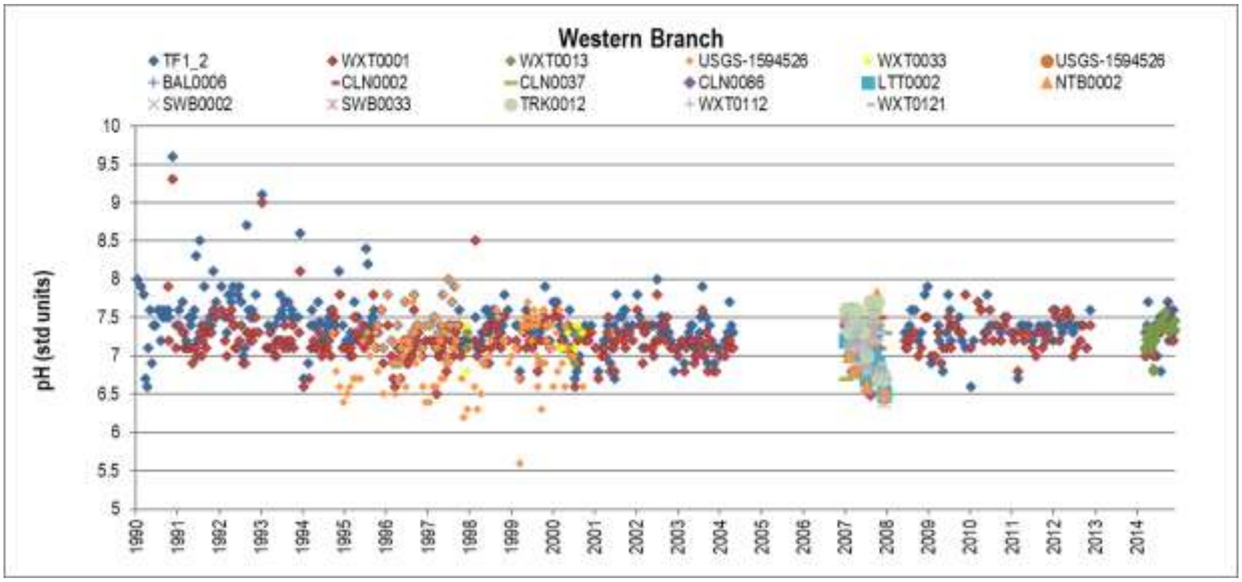


Figure B-46. Plot of pH over time in the Western Branch watershed.

APPENDIX C: VISUAL INSPECTION PHOTOGRAPH COMPARISONS

Contents

Figures

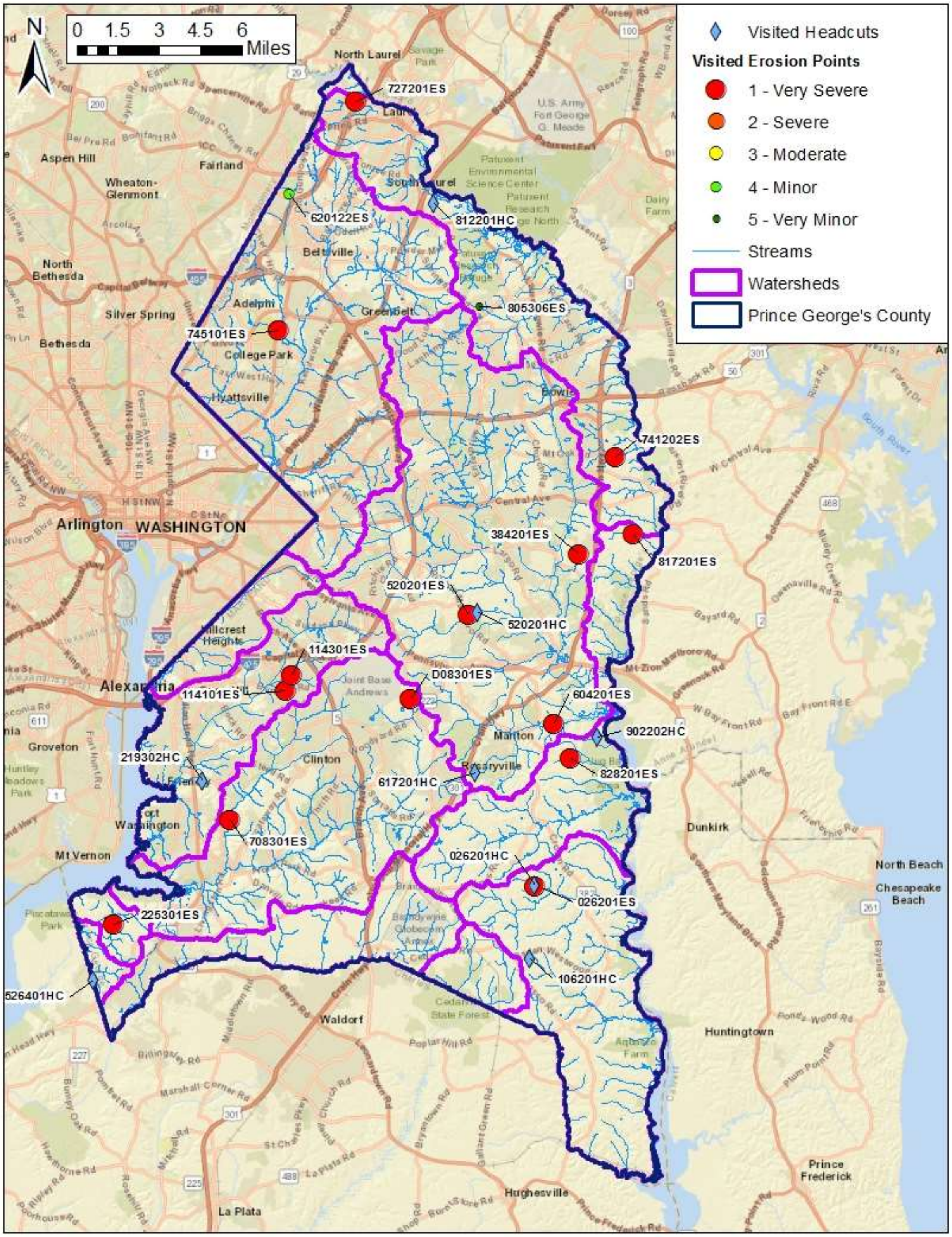


Figure C-1. Locations of site visits.

Anacostia River Watershed

Figure C-2. Location ID 620122ES on April 17, 2006.

Figure C-3. Location ID 620122ES on March 1, 2018.

Figure C-4. Location ID 745101ES on March 7, 2006.

Figure C-5. Location ID 745101ES on February 14, 2018.

Upper Patuxent River Watershed

Figure C-6. Location ID 727201ES1 on July 26, 2009.

Figure C-7. Location ID 727201ES1 on February 14, 2018.

Figure C-8. Location ID 812201HC1 on August 11, 2009.

Figure C-9. Location ID 812201HC1 on February 14, 2018.

Figure C-10. Location ID 805306ES on December 29, 2009.

Figure C-11. Location ID 805306ES on March 1, 2018.

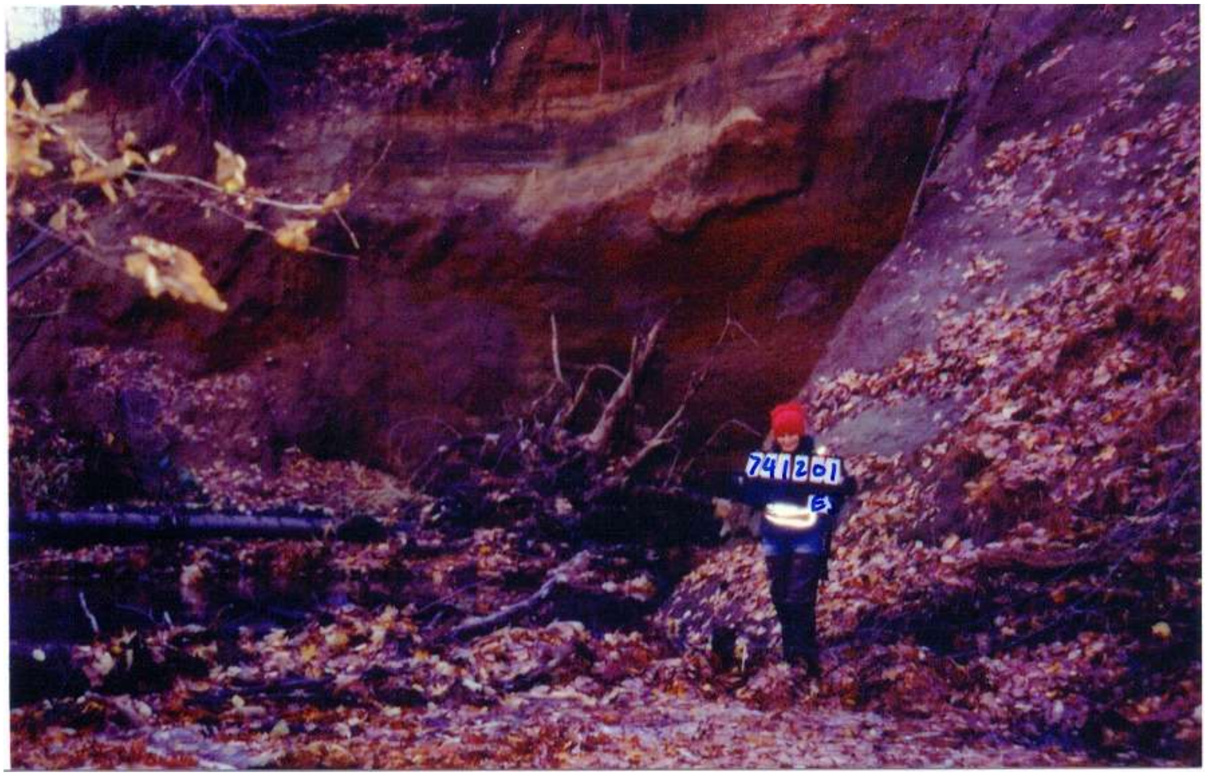


Figure C-12. Location ID 741201ES on December 29, 2009.

Figure C-13. Location ID 741201ES on February 27, 2018.

Piscataway Creek Watershed

Figure C-14. Location ID D08301ES1 on December 7, 2008.

Figure C-15. Location ID D08301ES1 on February 9, 2018.

Figure C-16. Location ID 708301ES on July 7, 2008.

Figure C-17. Location ID 708301ES on February 8, 2018.

Middle Potomac River Watershed

Figure C-18. Location ID 526401HC on May 25, 2010.

Figure C-19. Location ID 526401HC on February 8, 2018.

Figure C-20. Location ID 225301ES1 on February 24, 2009.

Figure C-21. Location ID 225301ES1 on February 8, 2018.

Upper Potomac

Figure C-22. Location ID 114301ES5 on January 13, 2009.

Figure C-23. Location ID 114301ES1 on February 23, 2018.

Figure C-24. Location ID 114101ES1 on January 13, 2009.

Figure C-25. Location ID 114101ES1 on February 23, 2018.

Figure C-26. Location ID 219302HC1 on February 18, 2009.

Figure C-27. Location ID 219302HC1 on February 8, 2018.

Middle Patuxent River Watershed

Figure C-28. Location ID 817201ES1 on August 16, 2009.

Figure C-29. Location ID 817201ES1 on February 27, 2018.

Figure C-30. Location ID 828201ES1 on August 27, 2009.

Figure C-31. Location ID 828201ES1 on February 12, 2018.

Figure C-32. Location ID 902202HC1 on September 1, 2009.

Figure C-33. Location ID 902202HC1 on February 12, 2018.

Lower Patuxent River Watershed

Figure C-34. Location ID 026201ES1 on October 25, 2009.

Figure C-35. Location ID 026201ES1 on February 9, 2018.

Figure C-36. Location ID 026201HC1 on October 25, 2009.

Figure C-37. Location ID 026201HC1 on February 9, 2018.

Figure C-38. Location ID 106201HC on January 5, 2010.

Figure C-39. Location ID 106201HC on February 9, 2018.

Western Branch Watershed

Figure C-40. Location ID 604201ES1 on June 3, 2009.

Figure C-41. Location ID 604201ES1 on February 12, 2018.

Figure C-42. Location ID 384201ES on May 26, 2003.

Figure C-43. Location ID 384201ES on February 27, 2018.

Figure C-44. Location ID 520201ES1 on May 19, 2009.

Figure C-45. Location ID 520201ES1 on March 1, 2018.

Figure C-46. Location ID 520201HC on May 19, 2009.

Figure C-47. Location ID 520201HC on March 1, 2018.

Figure C-48. Location ID 617201HC on June 16, 2009.

Figure C-49. Location ID 617201HC on February 9, 2018.

APPENDIX D: WATERSHED MAPS FOR THE PRIORITIZED BMP LOCATIONS

Figures

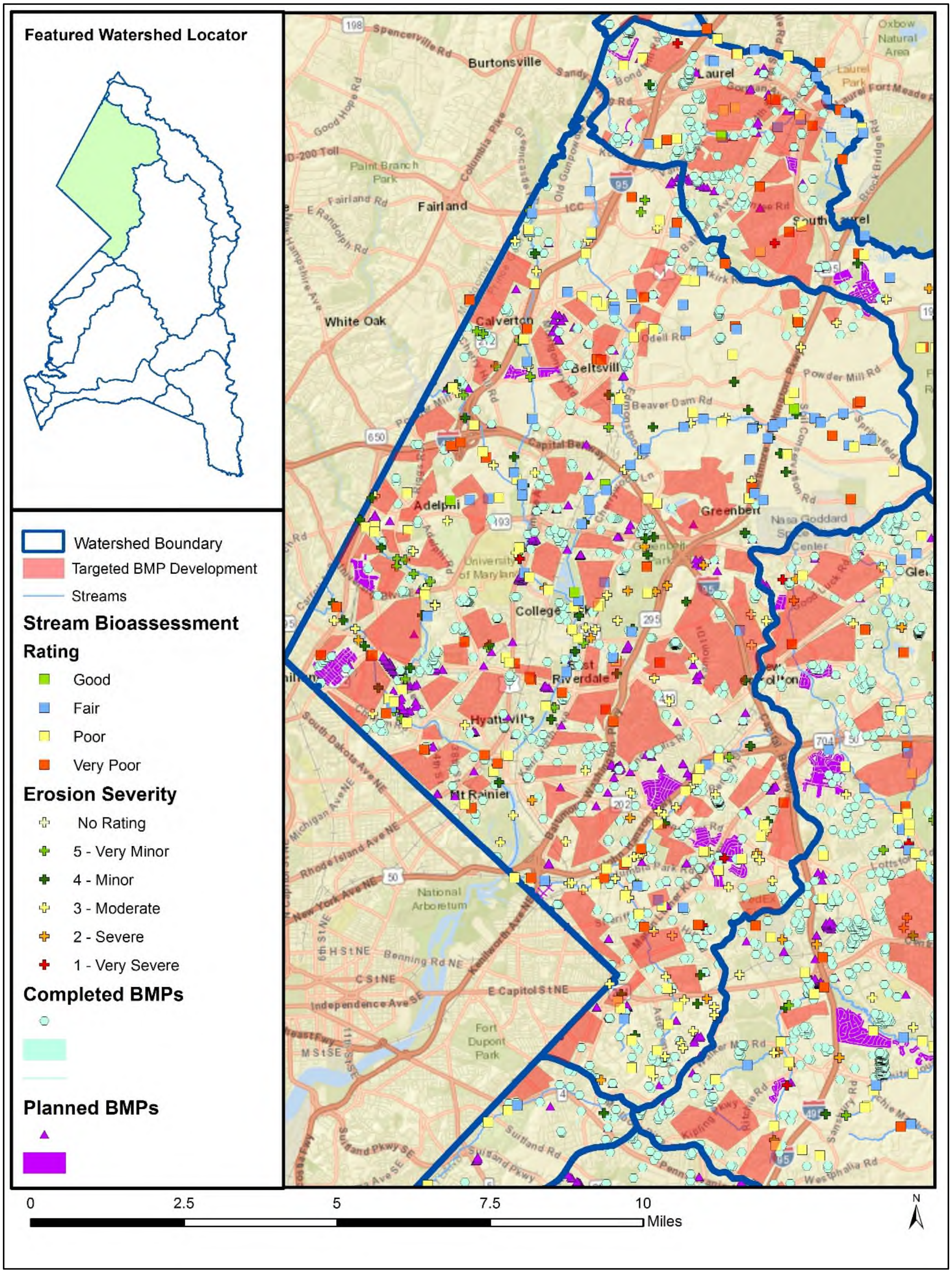


Figure D-1. Areas for BMP prioritization in the Anacostia River watershed.

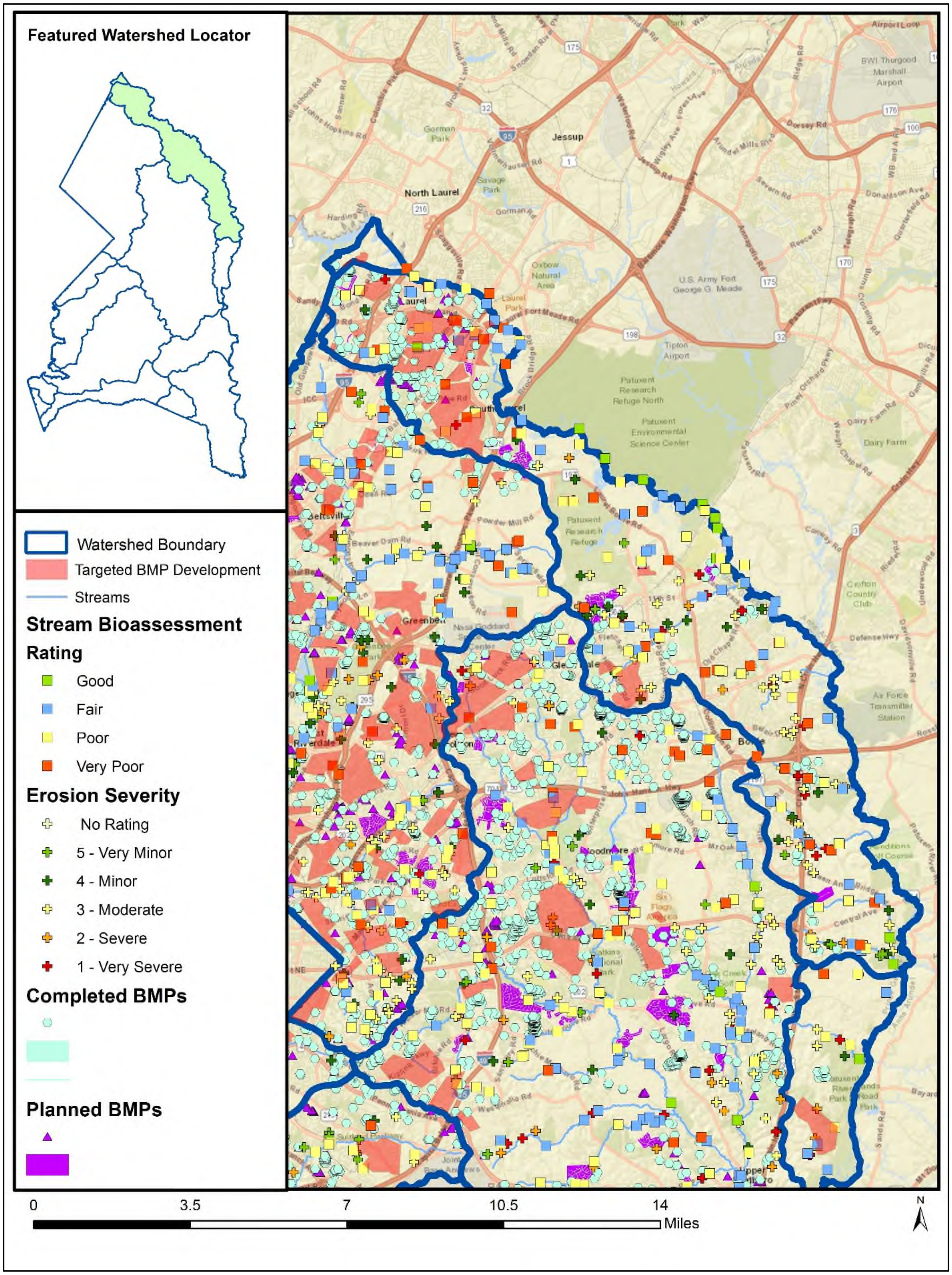


Figure D-2. Areas for BMP prioritization in the Upper Patuxent River and Rocky Gorge Dam watersheds.

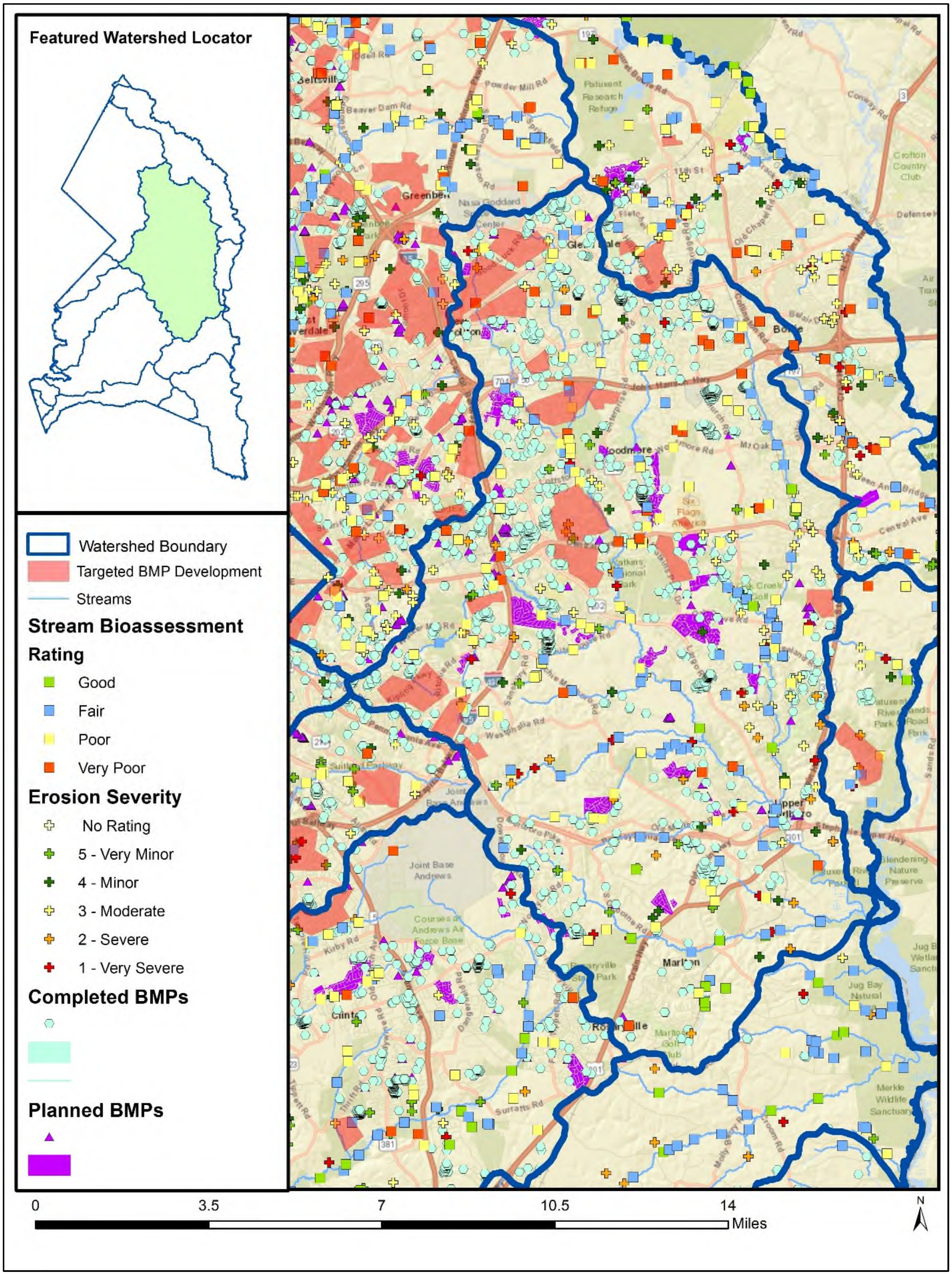


Figure D-3. Areas for BMP prioritization in the Western Branch watershed.

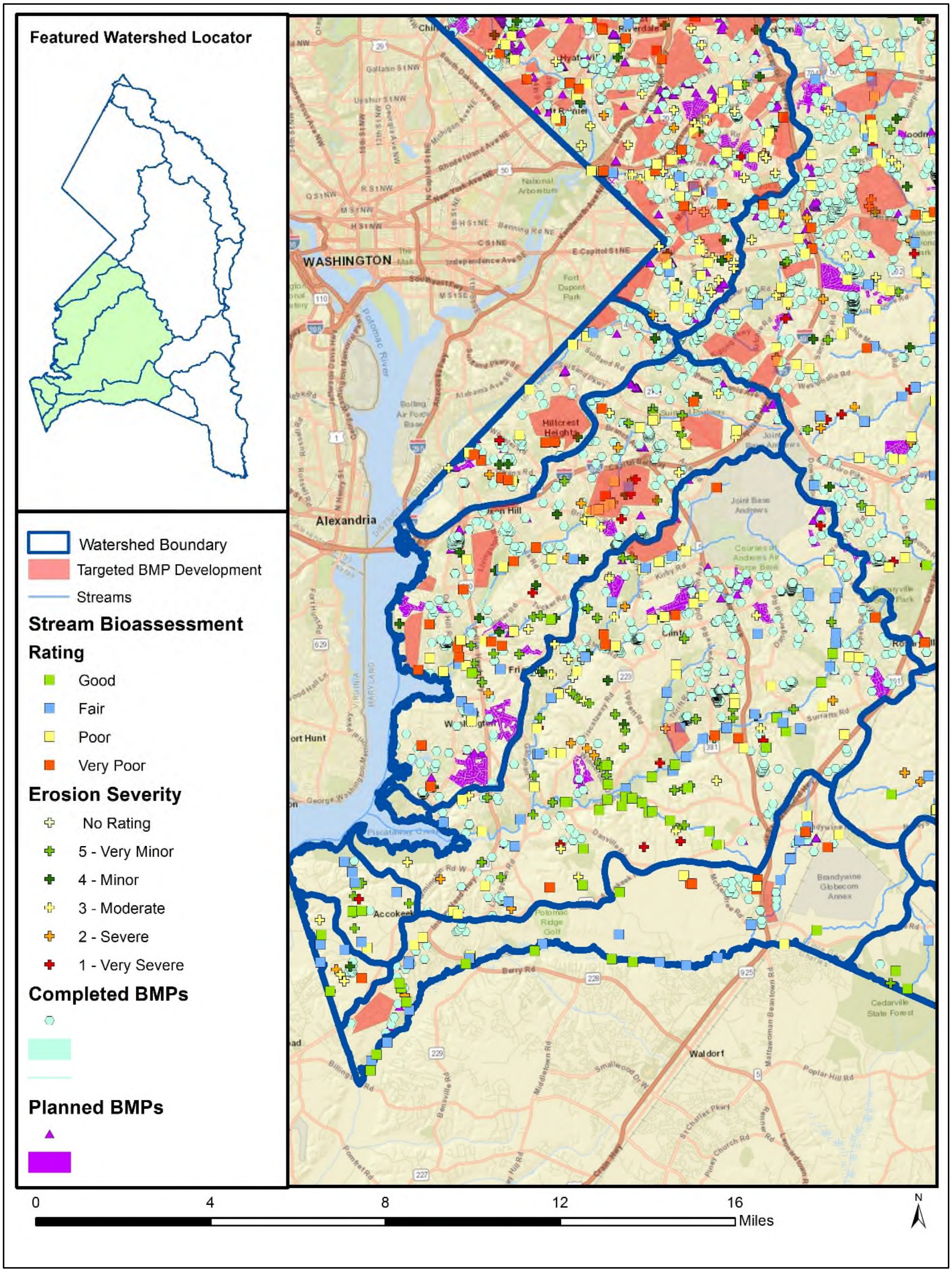


Figure D-4. Areas for BMP prioritization in the Piscataway Creek, Mattawoman Creek, Oxon Hill, and Potomac River watersheds.

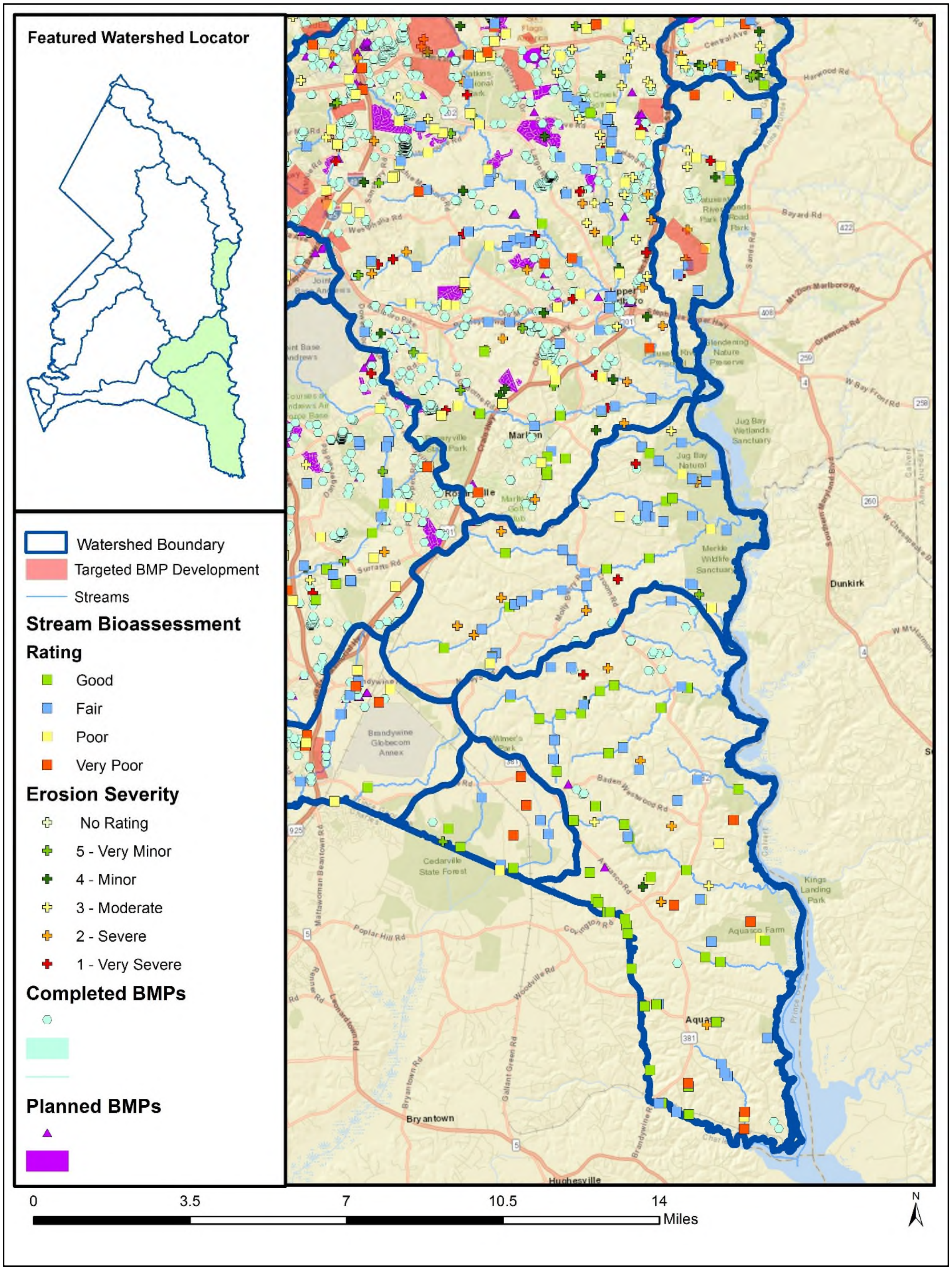


Figure D-5. Areas for BMP prioritization in the Lower Patuxent, Middle Patuxent, and Zekiah Swamp watersheds

APPENDIX E: BIOLOGICAL DEGRADATION AND BMP IMPLEMENTATION

Table E-1. Changes in subwatershed percent biological degradation between rounds and BMPs installed during that period.

Main	Number	Subwatershed	Biological Round	Change in Percent Degradation[a]	ST (imp acres)	RR (imp acres)	SR/OS (LF)	Septic: WWTP /Upgrade (#)
Anacostia River	16	Brier Ditch	R1→R2	33				10
Anacostia River	16	Brier Ditch	R2→R3	-33				3
Anacostia River	7	Indian Creek	R1→R2	-14	93.3	0.6		44
Anacostia River	7	Indian Creek	R2→R3	11	12.4	0.4		13
Anacostia River	22	Lower Anacostia River	R1→R2	-33	21.2	2.0		5
Anacostia River	22	Lower Anacostia River	R2→R3	33			2,201.0	4
Anacostia River	19	Lower Beaverdam Creek	R1→R2	-20	11.8	0.0	506.2	33
Anacostia River	19	Lower Beaverdam Creek	R2→R3	-14	2.5	5.1	167.2	8
Anacostia River	15	Lower Northeast Branch	R1→R2	33				23
Anacostia River	15	Lower Northeast Branch	R2→R3	-33		0.7		5
Anacostia River	9	Northwest Branch	R1→R2	0	4.9	5.0		24
Anacostia River	9	Northwest Branch	R2→R3	0		0.5		8
Anacostia River	5	Paint Branch	R1→R2	63	17.4			10
Anacostia River	5	Paint Branch	R2→R3	-43			1,541.8	7
Anacostia River	14	Sligo Creek	R1→R2	0		0.6		3
Anacostia River	14	Sligo Creek	R2→R3	0		3.5		1
Anacostia River	20	Upper Anacostia River	R1→R2	-33	31.3			5
Anacostia River	20	Upper Anacostia River	R2→R3	33				
Anacostia River	8	Upper Beaverdam Creek	R1→R2	9				3
Anacostia River	8	Upper Beaverdam Creek	R2→R3	-57				3
Anacostia River	12	Upper Northeast Branch	R1→R2	33				1
Anacostia River	12	Upper Northeast Branch	R2→R3	-33				
Mattawoman Creek	31	Mattawoman Creek	R1→R2	-19				27
Mattawoman Creek	31	Mattawoman Creek	R2→R3	7				3

Main	Number	Subwatershed	Biological Round	Change in Percent Degradation[a]	ST (imp acres)	RR (imp acres)	SR/OS (LF)	Septic: WWTP /Upgrade (#)
Oxon Creek	23	Oxon Run	R1→R2	0	30.4	0.6		11
Oxon Creek	23	Oxon Run	R2→R3	-20	0.9			20
Patuxent River lower	36	Black Swamp Creek	R1→R2	100				
Patuxent River lower	36	Black Swamp Creek	R2→R3	-100				
Patuxent River lower	39	Lower Patuxent River	R1→R2	5				
Patuxent River lower	39	Lower Patuxent River	R2→R3	-21				8
Patuxent River lower	32	Spice Creek	R1→R2	17				
Patuxent River lower	32	Spice Creek	R2→R3	-17				
Patuxent River lower	37	Swanson Creek	R1→R2	-27				
Patuxent River lower	37	Swanson Creek	R2→R3	0				1
Patuxent River middle	38	Mataponi Creek	R1→R2	-18				
Patuxent River middle	38	Mataponi Creek	R2→R3	20				2
Patuxent River upper	6	Bear Branch	R1→R2	31		0.2		4
Patuxent River upper	6	Bear Branch	R2→R3	9		2.9	3,620.2	
Patuxent River upper	4	Crow's Branch	R1→R2	31				19
Patuxent River upper	4	Crow's Branch	R2→R3	9				2
Patuxent River upper	10	Horsepen Branch	R1→R2	46		1.3		3
Patuxent River upper	10	Horsepen Branch	R2→R3	-25				3
Patuxent River upper	2	Upper Patuxent River	R1→R2	-7		0.2		14
Patuxent River upper	2	Upper Patuxent River	R2→R3	-8		0.5		6
Patuxent River upper	3	Walker Branch	R1→R2	31				9
Patuxent River upper	3	Walker Branch	R2→R3	9			410.0	1
Piscataway Creek	27	Piscataway Creek	R1→R2	18		0.7		67
Piscataway Creek	27	Piscataway Creek	R2→R3	0			2,472.0	20
Piscataway Creek	25	Tinkers Creek	R1→R2	10		1.9		45
Piscataway Creek	25	Tinkers Creek	R2→R3	14			180.4	11
Potomac River middle tidal	34	Pomonkey Creek	R1→R2	11				

Main	Number	Subwatershed	Biological Round	Change in Percent Degradation[a]	ST (imp acres)	RR (imp acres)	SR/OS (LF)	Septic: WWTP /Upgrade (#)
Potomac River middle tidal	34	Pomonkey Creek	R2→R3	-20				
Potomac River upper tidal	28	Broad Creek	R1→R2	-17		8.9	104.3	16
Potomac River upper tidal	28	Broad Creek	R2→R3	0				6
Potomac River upper tidal	24	Henson Creek	R1→R2	-17		1.0		49
Potomac River upper tidal	24	Henson Creek	R2→R3	0		0.6	503.1	17
Potomac River upper tidal	29	Hunters Mill	R1→R2	-17				3
Potomac River upper tidal	29	Hunters Mill	R2→R3	0				3
Potomac River upper tidal	33	Lower Potomac River	R1→R2	-32				7
Potomac River upper tidal	33	Lower Potomac River	R2→R3	0				2
Potomac River upper tidal	30	Swan Creek	R1→R2	-32				5
Potomac River upper tidal	30	Swan Creek	R2→R3	0				2
Potomac River upper tidal	26	Upper Potomac River	R1→R2	-32				11
Potomac River upper tidal	26	Upper Potomac River	R2→R3	0				2
Western Branch	13	Bald Hill Branch	R1→R2	21				5
Western Branch	13	Bald Hill Branch	R2→R3	2				
Western Branch	42	Charles Branch	R1→R2	20		0.1		13
Western Branch	42	Charles Branch	R2→R3	10				2
Western Branch	40	Collington Branch	R1→R2	-25				12
Western Branch	40	Collington Branch	R2→R3	17				2
Western Branch	11	Folly Branch	R1→R2	21				15
Western Branch	11	Folly Branch	R2→R3	2				6
Western Branch	17	Lottsford Branch	R1→R2	21				1
Western Branch	17	Lottsford Branch	R2→R3	2				
Western Branch	18	Northeast Branch Western Branch)	R1→R2	-17				
Western Branch	18	Northeast Branch Western Branch)	R2→R3	50				
Western Branch	21	Southwest Branch	R1→R2	-43		2.0		32
Western Branch	21	Southwest Branch	R2→R3	43		0.3	297.7	7

Main	Number	Subwatershed	Biological Round	Change in Percent Degradation[a]	ST (imp acres)	RR (imp acres)	SR/OS (LF)	Septic: WWTP /Upgrade (#)
Western Branch	41	Western Branch	R1→R2	2			604.7	11
Western Branch	41	Western Branch	R2→R3	-4			215.9	7
Zekiah Swamp	35	Zekiah Swamp Creek	R1→R2	11				
Zekiah Swamp	35	Zekiah Swamp Creek	R2→R3	-20				

Note:

[a] Green cells (negative percent change) indicate that the percent degradation decreased, meaning there was improvement in the watershed. Red cells indicate that the percent degradation increased.