Volume I
Stressor Analysis Report for the Benthic Macroinvertebrate Impairments in the Accotink Creek Watershed, Fairfax County, Virginia

Prepared for
Virginia Department of Environmental Quality

Prepared by
Interstate Commission on the Potomac River Basin

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Cover Photo

Accotink Creek near Hooes Road, Virginia. 2008. Photo by Virginia Department of Environmental Quality

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Acronyms

AFDM	Ash Free Dry Mass
AHI Trophic Guild	Algivore, Herbivore, and Invertivore Trophic Guild
BMP	Best Management Practices
BRAC	Base Realignment and Closure Act
$CaCO_3$	Calcium Carbonate
CCU	Cumulative Criterion Unit
CEM	Channel Evolution Model
CHLa	Chlorophyll a
CL	Chloride
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DEQ	Virginia Department of Environmental Quality
DO	Dissolved Oxygen
E. coli	Escherichia coli
EMAP	Environmental Monitoring and Assessment Program
EPA	U. S. Environmental Protection Agency
EPT Taxa	Ephemeroptera, Plecoptera, and Trichoptera taxa
FCDPWES	Fairfax County Department of Public Works and Environmental Services
FBNA	Fort Belvoir Northern Area
FNU	Formazin Nephelometric Units
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity
IC25	Inhibition Concentration that causes 25% reduction growth or reproduction
ICPRB	Interstate Commission on the Potomac River Basin
INRMP	Integrated Natural Resource Management Plan
LOEC	Lowest-Observable-Effects-Concentration
LRBS	Log_{10} Relative Bed Stability Index
LWD	Large Woody Debris
MACSW	Mid-Atlantic Coastal Streams Workgroup
MCL	Maximum Contaminant Level
MCPA	4-chloro-2-methylphenoxy acetic acid
MS4	Municipal Separate Storm Sewer Systems
NAWQA	National Water Quality Assessment Program
NED	National Elevation Dataset
NH_3	Ammonia Nitrogen
NO_3	Nitrate
NOEC	No-Observable-Effect-Concentration
NTU	Nephelometric Turbidity Unit
NVSWCD	Northern Virginia Soil and Water Conservation District
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PEC	Probable Effect Concentration
PO_4	Total Orthophosphate
ProbMon	Probabilistic Monitoring Program
R^2	Coefficient of Determination
SC	Specific Conductance
SI	Stressor Identification Analysis

SIC	Standard Industrial Classification Code
SOS	Save Our Streams
SPA	Stream Physical Assessment
SPS	Stream Protection Strategy
SQG	Sediment Quality Guideline
SS	Suspended Sediment
SSURGO	Soil Survey Geographic Database
TDS	Total Dissolved Solids
TEC	Threshold Effect Concentration
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TSV	Tissue Screening Value
TV	Tissue Values
USGS	U. S. Geological Survey
UT	Unnamed tributary
VDOT	Virginia Department of Transportation
VDP	Vision and Development Plan
VPDES	Virginia Pollutant Discharge Elimination System
VSCI	Virginia Stream Condition Index
VSMP	Virginia Stormwater Management Program

Units of Measure

du/ac	Dwelling unit per acre
FNU	Formazin nephelometric units
ft	Foot
km^2	Square kilometer
g/m^2	Grams per square meter
kg/m^3	Kilogram per cubic meter
$kg\text{-}m/s^2$	Kilogram-meter per second squared
m	meter
MGD	Million gallons per day
mg/l	Milligrams per liter
mg/m^2	Milligrams per square meter
mi	Miles
mi^2	Square mile
mm	Millimeter
ng/l	Nanograms per liter
NTU	Nephelometric turbidity unit
ppb	Parts per billion
°C	Degree Celsius
µg/l	Micrograms per liter
µS/cm	Microsiemens per centimeter

Executive Summary

Accotink Creek drains 52 square miles (mi^2) of Northern Virginia before entering first Accotink Bay, then Gunston Cove, an embayment on the tidal Potomac River. **Figure ES-1** shows the location of Accotink Creek. The study area for this project is the watershed draining the non-tidal portion of Accotink Creek upstream of Route 1, as shown in **Figure ES-1**.

The Accotink Creek watershed is highly developed. Overall, 87% of the watershed draining to non-tidal Accotink Creek consists of commercial, industrial, transportation, or residential land. Impervious surface covers 28% of the non-tidal watershed.

Mainstem Accotink Creek and other streams in the Accotink Creek watershed suffer from what Meyer et al. (2005) and Walsh et al. (2005) have called "the urban stream syndrome," which is characterized by the following symptoms:

- Flashier flows
- Elevated nutrient and/or contaminant concentrations
- Fewer smaller streams and lower stream density
- Altered channel morphology
- Reduction in biological diversity with increases in pollution-tolerant taxa

Virginia Department of Environmental Quality (DEQ) uses biological monitoring of benthic macroinvertebrate communities as one way to evaluate the ecological health of wadeable freshwater streams and to help determine whether the Aquatic Life Use is supported. For non-coastal streams, assessment of the benthic macroinvertebrate community is based on the Virginia Stream Condition Index (VSCI). The VSCI is a multi-metric index of the biological integrity of the benthic community (Burton and Gerritsen, 2003). The VSCI is scored on a scale of 0 to 100, where 100 represents the best biological condition and 0 represents the worst. A score of 60 is the threshold for biological impairment.

Using the VSCI, DEQ has conducted biological assessments of the mainstem of Accotink Creek at four locations. The U. S. Environmental Protection Agency (EPA) has also used the VSCI to assess the mainstem of Accotink Creek at four locations. In addition, DEQ has conducted biological assessments in Long Branch (Central), a tributary of Accotink Creek that joins the mainstem just upstream of Lake Accotink, an impoundment on Accotink Creek. **Figure ES-1** shows the location of the biological monitoring stations. All VSCI scores from DEQ and EPA assessments in upper Accotink Creek, lower Accotink Creek, and Long Branch are below 60, the VSCI impairment threshold score.

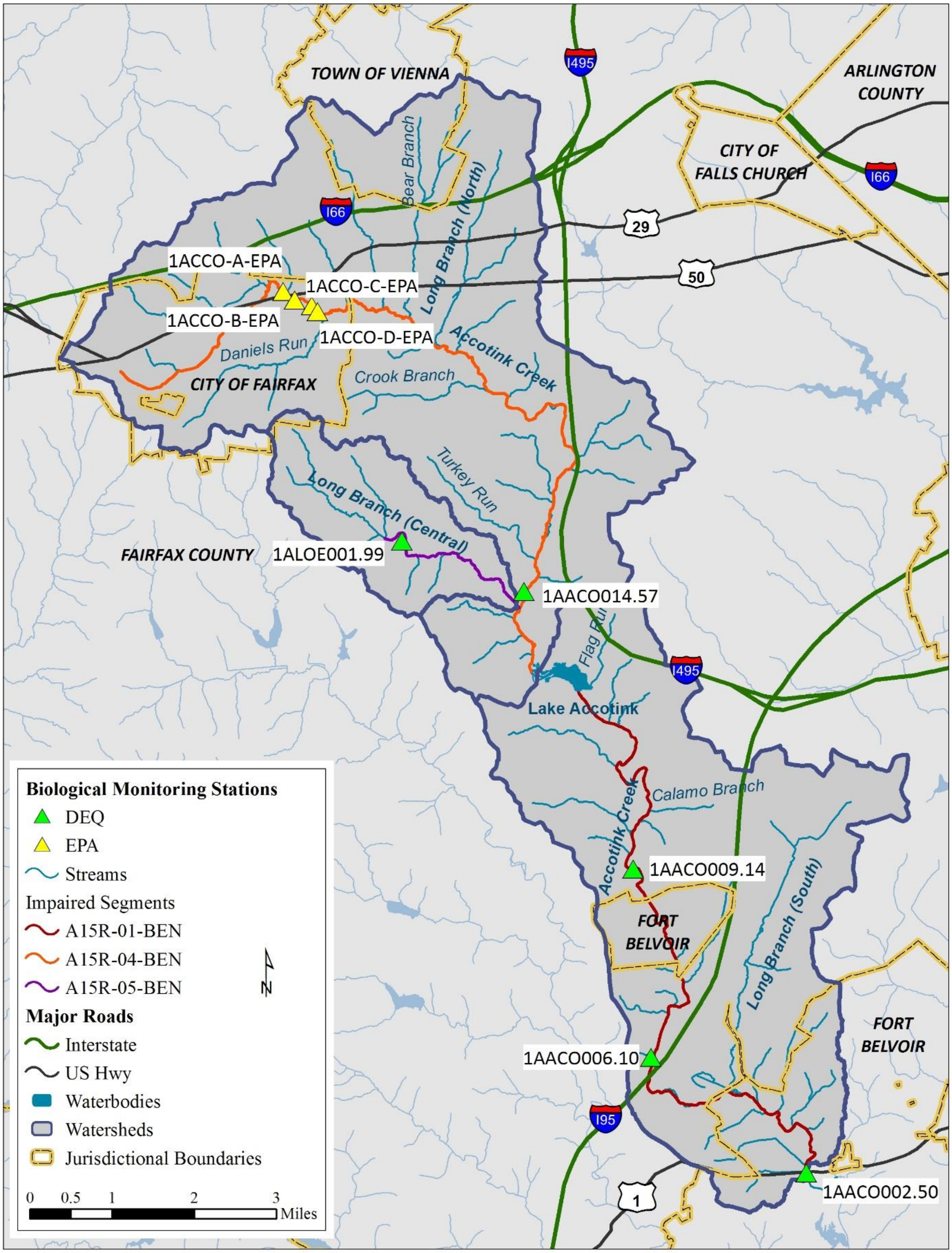

Figure ES-1: Location of the Impaired Segments in Accotink Creek Watershed

Based on benthic macroinvertebrate monitoring and assessments in the Accotink Creek watershed, DEQ has placed Accotink Creek, both above and below Lake Accotink, and Long Branch on Virginia's List of Impaired Waters (Category 5 of the Integrated List) because they are not supporting their Aquatic Life Use. **Figure ES-1** shows the location of the impaired stream segments. Hereafter, impaired segment A15R-01-BEN, as shown in **Figure ES-1**, will be referred to as lower Accotink Creek, segment A15R-04-BEN as upper Accotink Creek, and A15R-05-BEN as Long Branch. **Table ES-1** summarizes the impairment listings for upper Accotink Creek, lower Accotink Creek, and Long Branch in Virginia's 2014 Integrated Report.

Table ES-1: Accotink Creek Benthic Impairments

TMDL Watershed	Stream Name	Cause Group Code 303(d) Impairment ID	Description	Size	Assessment Unit 305(b) Segment ID	Initial Listing
Lower Accotink Creek	Accotink Creek	A15R-01-BEN	Begins at the outlet of Lake Accotink and continues downstream until the tidal waters of Accotink Bay.	10.09 mi	VAN-A15R_ACO01B10 VAN-A15R_ACO01A00	2010 1996
Upper Accotink Creek	Accotink Creek	A15R-04-BEN	Begins at the headwaters of Accotink Creek and continues downstream until the start of Lake Accotink	11.59 mi	VAN-A15R_ACO05A04 VAN-A15R_ACO04A02 VAN-A15R_ACO03A02 VAN-A15R_ACO02A00	2008 2010 2010 2010
Long Branch	Long Branch	A15R-05-BEN	Begins at the confluence with an unnamed tributary (UT) to Long Branch, at the Route 651 (Guinea Road) bridge, and continues downstream until the confluence with Accotink Creek, just below Braddock Road.	2.37 mi	VAN-A15R_LOE01A02	2008

Biological monitoring in the Accotink Creek watershed has determined that these waterbodies are not supporting their Aquatic Life Use, but the biological monitoring does not determine the cause of the biological impairments in these waterbodies. Until the underlying cause(s) of the biological impairments have been determined, there is no way of knowing what actions will most effectively address the impairment. A Stressor Identification Analysis (SI) needs to be performed to determine the stressor(s) to the biological community. The goal of this report is to determine the causes of biological impairment in upper Accotink Creek, lower Accotink Creek, and Long Branch. SI is an analysis of evidence provided by monitoring data and scientific literature that attempts to identify the most likely stressors to the biological community, i.e. the causes of the biological impairment.

Accotink Creek is one of the most extensively monitored watersheds in the region. Four different agencies—DEQ, the U. S. Geological Survey (USGS), EPA, and the Fairfax County Department of Public Works and Environmental Services (FCDPWES)—have collected monitoring data under multiple projects and programs. All four agencies have performed water quality monitoring in the watershed. Constituents analyzed include temperature, pH, dissolved oxygen (DO), specific conductance (SC), total dissolved solids (TDS), chloride (CL), turbidity, total suspended solids (TSS) or suspended sediment (SS), ammonia nitrogen (NH_3), nitrate (NO_3), total Kjeldahl nitrogen (TKN), total nitrogen (TN), total orthophosphate (PO_4), and total phosphorus (TP). DEQ and USGS also performed continuous monitoring of temperature, pH, DO, and other constituents in the Accotink Creek watershed. In addition, biological monitoring of benthic and fish communities, habitat assessments, stream geomorphic assessments, and monitoring of metals and toxics in sediment and fish tissue have all been performed in the mainstem of Accotink Creek and its tributaries. **Table ES-2** shows which agencies performed which types of monitoring and assessments.

Table ES-2: Monitoring Data Collected in Accotink Creek Watershed

Monitoring and Assessment		DEQ	USGS	EPA	FCDPWES
Biological	Benthics	X		X	X
	Fish				X
Habitat		X			X
Geomorphological	Geomorphic	X		X	X
	Stream Survey				X
Flow			X		
Conventional Water Quality		X	X	X	X
Toxicity Test		X			
Metals	Water Column	X			
	Sediment	X			
	Fish Tissue	X			
Toxics	Water Column	X	X		
	Sediment	X	X		
	Fish Tissue	X	X		

The SI for upper Accotink Creek, lower Accotink Creek, and Long Branch examined ten potential stressors to determine the strength of the evidence linking them to the biological impairments in these streams. Based on an evaluation of the monitoring data and the scientific literature, the potential stressors were divided into three categories:

1. **Least Probable Stressors**: Stressors with data indicating normal conditions, without water quality exceedances, or without any observable impacts usually associated with stressors.
2. **Possible Stressors**: Stressors with evidence indicating possible link to the biological impairment, but the evidence is inconclusive.
3. **Most Probable Stressors**: Stressor(s) with the most consistent evidence linking them to the biological impairment.

The following numerical benchmarks were used to help evaluate potential stressors in the SI:

1. When Virginia's water quality standards contained in 9VAC25-260 et seq. (State Water Control Board, 2011) have numerical criteria for a constituent, those criteria were used in the SI. Constituents with explicit numerical criteria include temperature, pH, dissolved oxygen, chloride, ammonia, and most metals.
2. For nutrients and other constituents without numerical criteria, monitoring results were compared to the 90th percentile concentrations observed in the DEQ Probabilistic Monitoring (ProbMon) program dataset from 2001-2012 (Dail et al., 2006). Sample sites for the ProbMon program are chosen at random, so that the collection of sample sites constitutes a random sample of Virginia's streams.
3. The ProbMon program has also adopted thresholds identifying suboptimal conditions for six potential biological stressors that do not have water quality criteria: TN, TP, TDS, the cumulative impact of dissolved metals, habitat degradation, and sedimentation.
4. Sediment samples are screened against Probable Effect Concentrations (PECs) and Threshold Effect Concentrations (TECs) to help assess when metals or toxics are adversely impacting aquatic life. PECs are averages of other thresholds that represent concentrations above which adverse impacts on biota are likely to occur. TECs are averages of other thresholds that represent concentrations below which adverse impacts are unlikely to occur.
5. Fish tissue samples are screened against tissue values (TVs) or tissue screening values (TSVs). These are thresholds for protecting human health under the Fish Consumption Use.

Table ES-3 gives the results of the stressor identification analysis for upper Accotink Creek, lower Accotink Creek, and Long Branch.

Table ES-3: Categorization of Potential Stressors in Accotink Creek Watershed

Category	Stressor	
Least Probable Stressors	Temperature	pH
	Dissolved Oxygen	Metals
Possible Stressors	Nutrients	Toxics
Most Probable Stressors	Chloride	Hydromodification
	Sediment	Habitat Modification

Temperature, pH, DO, and metals are classified as least probable stressors. All of these constituents have water quality criteria to protect aquatic life. Both discrete samples and continuous monitoring data from the Accotink Creek watershed show that temperature, pH, and DO water quality criteria are being met. Observations of metal concentrations in the water column from discrete samples also meet water quality criteria. Observed concentrations of metals in sediments are below the TEC thresholds, indicating that adverse effects on the biota are unlikely.

Nutrients and toxics are categorized as possible stressors because there may be some evidence implicating them in the biological impairments in the Accotink Creek watershed; however, the weight of evidence suggests they are not the primary causes of the impairments.

Continuous monitoring data shows that nutrient concentrations are sufficient to generate enough primary production to cause wide diurnal swings in DO concentrations; however, DO water quality criteria to protect aquatic life are still met.

The impact of toxics on biota was evaluated using the results of toxicity tests, and monitoring in the water column, sediments, and fish tissue. Toxicity tests were performed on water fleas and fathead minnows using two water samples from Accotink Creek. No evidence of chemical toxicity was detected by toxicity tests on water fleas. One toxicity test on minnows had "biologically significant" results, while the other had an ambiguous result. Chlordane, fluoranthene and pyrene, were detected in sediment in lower Accotink Creek at concentrations above the TEC but below the PEC benchmarks, indicating possible adverse effects on aquatic life. Concentrations of polychlorinated biphenyls (PCBs), chlordane, heptachlor epoxide, and dieldrin were measured in fish tissue above their TVs, and lower Accotink Creek is not supporting its Fish Consumption Use because of PCBs measured in fish tissue. Because of the mobility of fish, however, tissue samples may be an imperfect indicator of bioaccumulation of toxics in the location where the fish are found.

Nutrients and toxics, therefore, may be making a contribution to the impairment of the benthic communities in Accotink Creek, at least episodically, but are probably not the primary causes of the impairments.

Chlorides, hydromodification, habitat modification, and sediment have been identified as the most probable stressors of the biological communities in the Accotink Creek watershed.

Monitoring data indicates that Virginia's water quality standards are not met by chloride in upper Accotink Creek, lower Accotink Creek, and Long Branch. Observed chloride concentrations in all three watersheds have exceeded Virginia's chronic chloride criterion to protect aquatic life at least twice in a three year period. Observed chloride concentrations in upper Accotink Creek and lower Accotink Creek also have exceeded the acute chloride criterion at least twice in a three year period. Moreover, chloride concentrations estimated from continuous monitoring of specific conductance, in conjunction with the strong correlation between conductivity and chloride, strongly indicates that in all three watersheds exceedances of the acute and chronic chloride criteria is a frequent occurrence during winter months.

There is also solid evidence that hydromodification, habitat modification, and sediment are adversely impacting the biota in all three waterbodies. Hydromodification refers to altered hydrology, channelization and the replacement of natural headwater streams and tributaries by storm sewers. Developed land accounts for 87% of the Accotink Creek watershed and 28% of the watershed is impervious surface; adverse impacts of imperviousness are likely to occur when impervious cover is greater than 10% (Walsh et al., 2005).

Habitat assessments by DEQ and FCDPWES have documented marginal or inadequate habitat in the Accotink Creek watershed. Bank stability, sedimentation deposition, substrate variety, embeddedness, and bank vegetation have the highest percentage of marginal or poor scores in DEQ assessments. Nine of the 16 habitat assessments performed by DEQ since 2000 have total habitat scores below the ProbMon Suboptimal threshold. The ProbMon program has calculated that VSCI scores below 60 are over four times more likely if habitat is Suboptimal. According to FCDPWES' Stream Physical Assessment (SPA), over two-thirds of the assessed stream miles in the Accotink Creek watershed have fair, poor, or very poor habitat. On average, habitat is in good condition in both the lower mainstem and its tributaries in the Coastal Plain, but in the Piedmont portion of the watershed substrate quality, embeddedness, bank stability, and bank vegetation are the habitat metrics with the lowest scores.

There is ample evidence that in the mainstem of Accotink Creek and its tributaries, sediment is being transported and deposited in sufficient quantities to adversely impact the aquatic community. According to FCDPWES' SPA, the mainstem of Accotink Creek and other streams in the Accotink Creek watershed are actively widening their channels by eroding their banks. Bank stability was assessed as Marginal or Poor in all but one of the sixteen habitat assessments that DEQ performed since 2000 in the Accotink Creek watershed. The degree of sediment deposition is indicated by the embeddedness and sediment deposition habitat metrics. In the habitat assessments DEQ has conducted since 2000, seven of 16 have Marginal or Poor embeddedness scores, and 12 of 16 have Marginal or Poor scores for sediment deposition. The SPA habitat survey confirms these results. The average embeddedness scores were Marginal everywhere in the Piedmont portion of the watershed, except in lower mainstem Accotink Creek and the mainstem of Long Branch.

The adverse effects of hydromodification, habitat modification, and sediment work in concert. Increasing peak flows and frequency of flow disturbances, which are the most noticeable results of hydromodification, reduce the number of sensitive macroinvertebrates. This problem is exacerbated by the lack of macroinvertebrate colonists drifting downstream from headwaters and tributaries. Excess sediment from bank erosion enhances both of these effects. The abrasive action of suspended sediment can also damage stalks and other plant structures, the bodily parts of invertebrates, and the gills of fish.

Channelization leads to a reduction of pool and riffle structure and of the diversity of stream habitat. Poor riparian buffers lead to a shortage of large woody debris and a reduction of the diversity of habitat. Sediment deposition further reduces the quality and variety of habitat. Deposited sediment can cover larger substrate that is favored as habitat by many sensitive macroinvertebrates, fill in spaces between substrate that provide refuge for macroinvertebrates and small fishes, or reduce the supply of gravel or clean substrate necessary for spawning by trout or other species. The reduction in habitat diversity, in turn, contributes to a reduction of diversity in macroinvertebrate taxa.

The reduction of diversity in taxa is also caused by the lack of environmental benefits and services from headwater streams and small tributaries, including a truncation of the processing of terrestrial plant litter, to which poor riparian habitat also contributes. The degraded supply of energy sources cannot support a diverse macroinvertebrate community.

The reduction of biological diversity and increases in pollutant-tolerant taxa are therefore symptoms of the urban stream syndrome, brought about by the urbanization of Accotink Creek watershed and the accompanying changes in watershed hydrology and stream network; poor riparian buffers; and increased erosion, sediment transport, and sediment deposition.

1 Introduction

The Clean Water Act (CWA) requires that all waters of the United States support swimming, sustain and protect aquatic life, and maintain other beneficial uses such as water supply or shellfish propagation and harvest. Virginia has adopted water quality standards to meet the goals of the CWA. These standards specify (1) designated uses for waterbodies, such as a primary contact recreation use, to support swimming, or an aquatic life use, to sustain and protect aquatic life; (2) the water quality criteria necessary to support these uses; and (3) antidegradation policy to preserve existing uses, maintain waters whose quality exceeds standards, and protect waters of exceptional quality. The CWA also requires states to assess their waters to determine if they are meeting water quality standards. Waterbodies not meeting standards, i.e. impaired waterbodies, are documented in a state's biannual Integrated Assessment on the state's Integrated List.

Accotink Creek drains 52 square miles of Northern Virginia before entering first Accotink Bay, then Gunston Cove, on the tidal Potomac River. Long Branch (Central) is a tributary to Accotink Creek, joining it just upstream of Lake Accotink, an impoundment on Accotink Creek. Based on benthic macroinvertebrate monitoring and assessments in the Accotink Creek watershed, the Virginia Department of Environmental Quality (DEQ) has placed Accotink Creek, both above and below Lake Accotink, and Long Branch on Virginia's List of Impaired Waters (Category 5 of the Integrated List) because they are not supporting their Aquatic Life Use. **Figure 1-1** shows the location of the monitoring stations used in the assessment and the impaired stream segments. Hereafter, impaired segment A15R-01-BEN, as shown in **Figure 1-1**, will be referred to as lower Accotink Creek, segment A15R-04-BEN as upper Accotink Creek, and A15R-05-BEN as Long Branch.

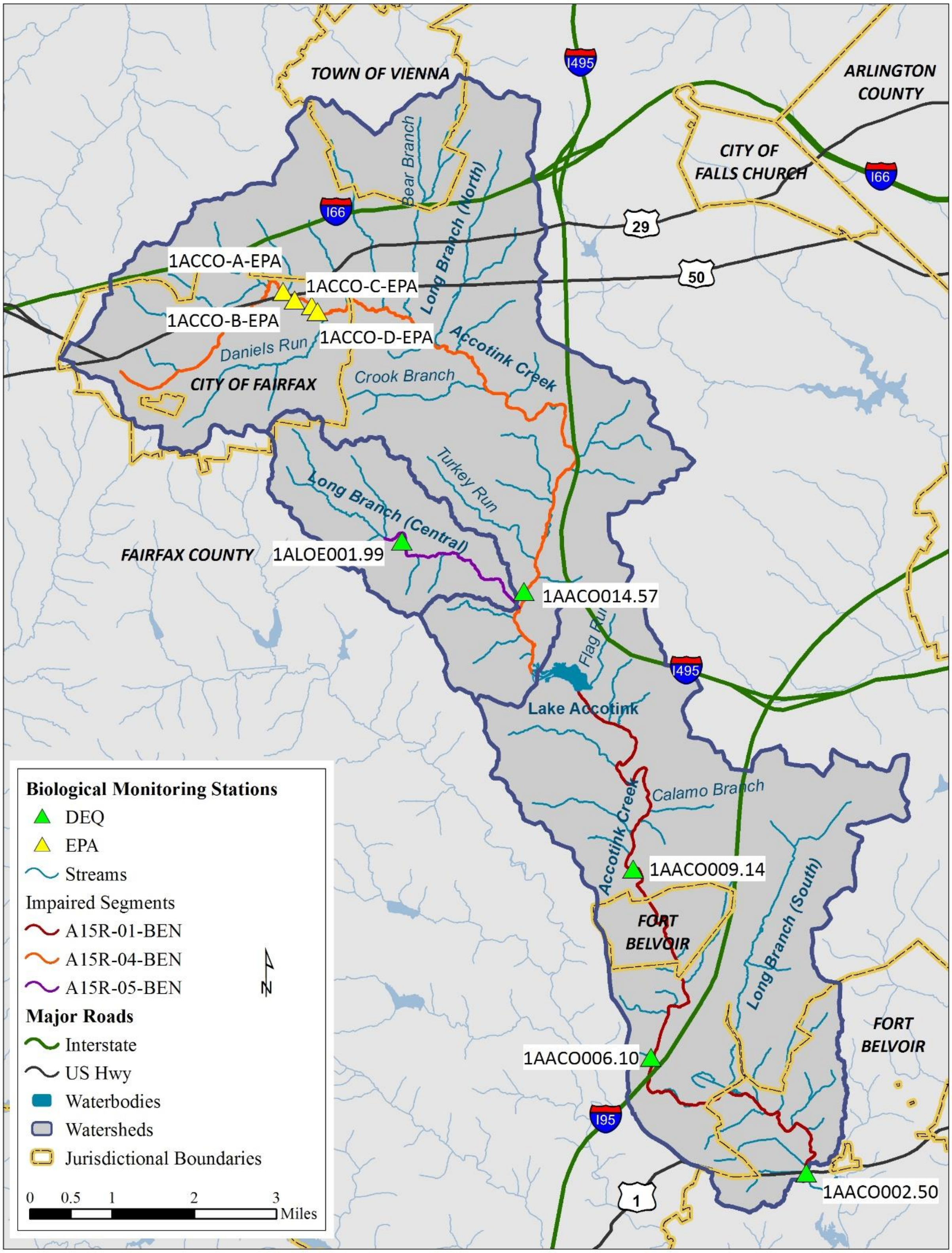

Figure 1-1: Location of the Impaired Segments in Accotink Creek Watershed

The goal of this report is to determine the causes of biological impairment in upper Accotink Creek, lower Accotink Creek, and Long Branch through a Stressor Identification Analysis (SI). SI is an analysis of evidence provided by monitoring data and scientific literature which attempts to identify the most likely stressors to the biological community, i.e. the causes of the biological impairment.

The remainder of this introductory section discusses the regulatory background to listing upper Accotink Creek, lower Accotink Creek, and Long Branch as biologically impaired and the regulatory implications of the SI. **Section 2** characterizes the Accotink Creek watershed in greater detail. **Section 3** reviews existing monitoring data. **Section 4** presents the results of the SI.

1.1 Applicable Water Quality Standards

Virginia's water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. The standards applicable to the impairments in upper Accotink Creek, lower Accotink Creek, and Long Branch are discussed below.

1.1.1 Designated Uses

Designated uses are statutory management objectives for a waterbody. The CWA specifies that all waters must be "fishable and swimmable," that is, support their use for contact recreation and for sustaining a healthy aquatic community. According to Virginia water quality standards (9 VAC 25-260-5):

"all state waters are designated for the following uses: recreational uses (e.g. swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g. fish and shellfish)."

1.1.2 Water Quality Criteria

Water quality criteria can be numerical or narrative. The General Standard defined in Virginia water quality standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standards states:

"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."

1.1.3 Aquatic Life Use

DEQ uses biological monitoring of benthic macroinvertebrate communities as one way to evaluate the ecological health of wadeable freshwater streams and to help determine whether the Aquatic Life Use is supported. For non-coastal streams, assessment of the benthic macroinvertebrate community is based on the Virginia Stream Condition Index (VSCI). The VSCI is a multi-metric index of the biological integrity of the benthic community (Burton and Gerritsen, 2003). The benthic community at a monitoring location is measured against the benthic communities found in reference streams (streams with minimum anthropogenic impacts) using a suite of eight metrics. The VSCI combines these metrics into a single score. The VSCI and its component metrics are discussed in more detail in **Section 3.1**.

Potential VSCI scores range from 0 to 100, with higher scores indicating relatively better ecological health. DEQ has set a score of 60 as the threshold for impairment. Scores below 60 indicate an impaired biological community.

1.2 Impairment Listings

Table 1-1 summarizes the impairment listings for upper Accotink Creek, lower Accotink Creek, and Long Branch in Virginia's 2014 Integrated Report (DEQ, 2016). The lower mainstem of Accotink Creek was first listed in 1996. The initial listing of the impairment started at the confluence of Calamo Branch and included the tidal waters of Accotink Bay. The downstream boundary of this impairment was adjusted in subsequent Water Quality Assessment Reports to cover only the free-flowing portion of the mainstem. The upstream boundary was extended to the outlet of Lake Accotink in 2010. In 2008, a 0.85 mile section of upper Accotink Creek, from an unnamed tributary in Ranger Park to the confluence with Daniels Run, was listed based on benthic macroinvertebrate assessments performed by the U.S. Environmental Protection Agency (EPA) at stations 1ACCO-A-EPA, 1ACCO-B-EPA, 1ACCO-C-EPA, and 1ACCO-D-EPA. The impairment was extended in the 2010 Integrated Report to include all of Accotink Creek from the headwaters to Lake Accotink, based on DEQ's benthic assessments at station 1ACCO014.57. Long Branch was listed in 2008, based on benthic assessments at station 1ALOE001.99.

Table 1-1: Accotink Creek Benthic Impairments

TMDL Watershed	Stream Name	Cause Group Code 303(d) Impairment ID	Description	Size	Assessment Unit 305(b) Segment ID	Initial Listing
Lower Accotink Creek	Accotink Creek	A15R-01-BEN	Begins at the outlet of Lake Accotink and continues downstream until the tidal waters of Accotink Bay.	10.09 mi	VAN-A15R_ACO01B10 VAN-A15R_ACO01A00	2010 1996
Upper Accotink Creek	Accotink Creek	A15R-04-BEN	Begins at the headwaters of Accotink Creek and continues downstream until the start of Lake Accotink	11.59 mi	VAN-A15R_ACO05A04 VAN-A15R_ACO04A02 VAN-A15R_ACO03A02 VAN-A15R_ACO02A00	2008 2010 2010 2010
Long Branch	Long Branch	A15R-05-BEN	Begins at the confluence with an unnamed tributary (UT) to Long Branch, at the Route 651 (Guinea Road) bridge, and continues downstream until the confluence with Accotink Creek, just below Braddock Road.	2.37 mi	VAN-A15R_LOE01A02	2008

Table 1-2 summarizes the VSCI scores from DEQ and EPA benthic assessments in the Accotink Creek watershed. **Figure 1-2** shows the VSCI scores by impairment. Scores from monitoring conducted on the same date in the same impaired waterbody have been averaged. All VSCI scores from sampling in upper Accotink Creek, lower Accotink Creek, and Long Branch are below 60, the VSCI impairment threshold score.

Table 1-2: Accotink Creek Watershed VSCI Scores

Impaired Segment	Date	Station	VSCI
Upper Accotink Creek	11/03/2005	1ACCO-A-EPA	21.2
	11/03/2005	1ACCO-B-EPA	29.1
	11/03/2005	1ACCO-C-EPA	24.3
	11/03/2005	1ACCO-D-EPA	24.0
	11/03/2005	1ACCO-D-EPA	27.8
	12/07/2005	1ACCO-A-EPA	21.5
	12/07/2005	1ACCO-B-EPA	25.1
	12/07/2005	1ACCO-C-EPA	30.7
	12/07/2005	1ACCO-D-EPA	23.1
	12/07/2005	1ACCO-D-EPA	28.0
	03/13/2006	1ACCO-A-EPA	25.2
	03/13/2006	1ACCO-B-EPA	23.9
	03/13/2006	1ACCO-C-EPA	26.3
	03/13/2006	1ACCO-D-EPA	28.7
	03/13/2006	1ACCO-D-EPA	25.6
	05/23/2007	1AACO014.57	31.6
	11/07/2007	1AACO014.57	30.9
Lower Accotink Creek	11/04/1994	1AACO006.10	38.3
	05/18/1995	1AACO006.10	38.9
	11/29/1995	1AACO006.10	30.6
	05/30/1996	1AACO006.10	38.2
	11/18/1996	1AACO006.10	28.3
	06/01/2006	1AACO002.50	35.3
	06/01/2006	1AACO006.10	24.3
	11/21/2006	1AACO002.50	26.6
	11/21/2006	1AACO006.10	41.9
	04/30/2007	1AACO002.50	33.5
	04/30/2007	1AACO006.10	36.6
	11/01/2007	1AACO002.50	28.3
	11/01/2007	1AACO006.10	29.7
	05/30/2008	1AACO006.10	25.7
	05/30/2008	1AACO009.14	22.8
	10/31/2008	1AACO006.10	35.9
	10/31/2008	1AACO009.14	30.7
Long Branch	06/01/2006	1ALOE001.99	29.5
	09/19/2006	1ALOE001.99	24.5

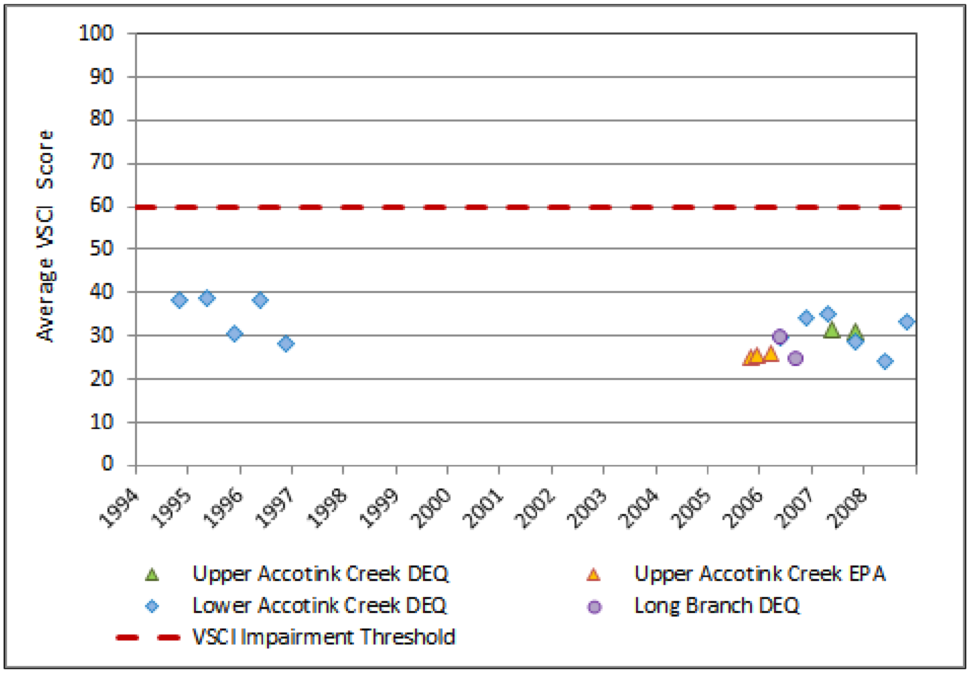

Figure 1-2: Average VSCI Scores for Upper Accotink Creek, Lower Accotink Creek, and Long Branch

The 2014 Integrated Report identifies other impairments in the Accotink Creek watershed. Lake Accotink is not meeting its Fish Consumption Use because of mercury and polychlorinated biphenyls (PCBs) in fish tissue. Both of these impairments were first listed in 2010. Accotink Creek from the outlet of Lake Accotink downstream to tidal waters is also not meeting its Fish Consumption Use because of PCBs in fish tissue. This impairment was also first listed in 2010. The Fish Consumption Use impairments in Lake Accotink and lower Accotink Creek have not yet been addressed.

Other impairments, identified in previous Assessment Reports, have already been addressed. Total Maximum Daily Loads (TMDLs) have been developed for fecal coliform in upper Accotink Creek and *E. coli* in lower Accotink Creek to address Recreational Use impairments. The impaired segment in upper Accotink Creek was first listed in 1998. It extended from the confluence with Crook Branch to Lake Accotink. The TMDL for fecal coliform was approved by the EPA in 2002. The impairment in lower Accotink Creek extended from Calamo Branch to tidal waters. It was first listed in 2004. The EPA approved the TMDL for *E. coli* in 2008. Tidal Accotink Creek, which was not meeting its Fish Consumption Use because of PCBs in fish tissue, was included in an interstate TMDL developed to address PCB impairments in the tidal Potomac River and its embayments. That TMDL was approved by the EPA in 2007.

1.3 Goals of Stressor Identification Analysis

Section 303(d) of the CWA and the EPA's Water Quality Planning and Management Regulations (40 CFR part 130) generally require states to develop TMDLs for waterbodies that are not meeting water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. Impaired waterbodies requiring TMDLs are listed in Category 5 of the Integrated Report. Currently, upper Accotink Creek, lower Accotink Creek, and Long Branch are listed in Category 5 on Virginia's Integrated Report.

Biological monitoring in the Accotink Creek watershed has determined that these waterbodies are not supporting their Aquatic Life Use, but the biological monitoring does not determine the cause of the biological impairments in these waterbodies. Until the underlying cause(s) of the biological impairments have been determined, there is no way of knowing what actions will most effectively address the impairment. A SI needs to be performed to determine the stressor(s) to the biological community. Once the stressor(s) have been identified, TMDLs can be developed for any pollutant identified as a stressor of the biological community.

Not all stressors are pollutants amenable to TMDL development. The CWA distinguishes the general class of pollution, defined as "the man-made or man-induced alteration of physical, biological, chemical, and radiological integrity of water and other media (CWA, Section 502, General Definitions)," from pollutants, which are restricted to "[d]redged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dust and industrial, municipal, and agricultural waste discharge into water (CWA, Section 502, General Definitions)." TMDLs can only be developed for pollutants. If a stressor is not a pollutant, EPA guidance (EPA, 2005) provides an alternative category in the Integrated List, 4C, for waterbodies impaired by pollution not caused by a pollutant.

The goal of SI, therefore, is to identify the stressors of the biological communities in upper Accotink Creek, lower Accotink Creek, and Long Branch. If the stressors are pollutants, then TMDLs should be developed for those pollutants. If the stressors are due to natural causes, or if all stressors are pollution but not pollutants, then the impairment listings should be revised in the next Integrated Report. Stressors which are not pollutants can be addressed by means other than a TMDL, such as a watershed plan.

2 Watershed Description

This section describes the Accotink Creek watershed in greater detail. **Section 2.1** discusses topography, hydrogeomorphic regions, soils, land use, population, and housing. **Section 2.2** describes permitted facilities, regulated stormwater, and waste disposal.

2.1 Watershed Description and Identification

Accotink Creek drains approximately 52 mi^2 of Northern Virginia. **Figure 2-1** shows the location of Accotink Creek and its watershed. The mainstem of Accotink Creek begins in the City of Fairfax and flows southeast through Fairfax County and Fort Belvoir[1] before entering first Accotink Bay and then Gunston Cove, an embayment on the tidal Potomac River. Seventy-seven percent of the Accotink Creek watershed is in Fairfax County; the remainder is in the City of Fairfax (11%), Fort Belvoir (8%), and the Town of Vienna (4%). The headwaters of Accotink Creek are along Interstate 66. Most of the watershed is just outside the Capital Beltway. Accotink Creek crosses Interstate 95 near Springfield, VA, before entering the main post of Fort Belvoir.

The Accotink Creek watershed is highly developed. Overall, according to the analysis of zoning and planimetric data described in **Section 2.1.4**, 87% of the Accotink Creek watershed draining to the impaired segments consists of commercial, industrial, transportation, or residential land, and impervious surface covers 28% of the watershed draining to impaired segments.

[1] Fort Belvoir is a U.S. Army installation that is the headquarters of the National Geospatial-Intelligence Agency and many other Defense Department agencies. It is divided into two sections: Fort Belvoir North Area (803 acres) and the main post (9,530 acres). Under the 2005 Base Realignment and Closure (BRAC) Act, many defense department agencies were relocated to Fort Belvoir. It is currently one of the largest employers in Fairfax County and is expected to generate extensive development in the surrounding area (Fairfax County, 2013).

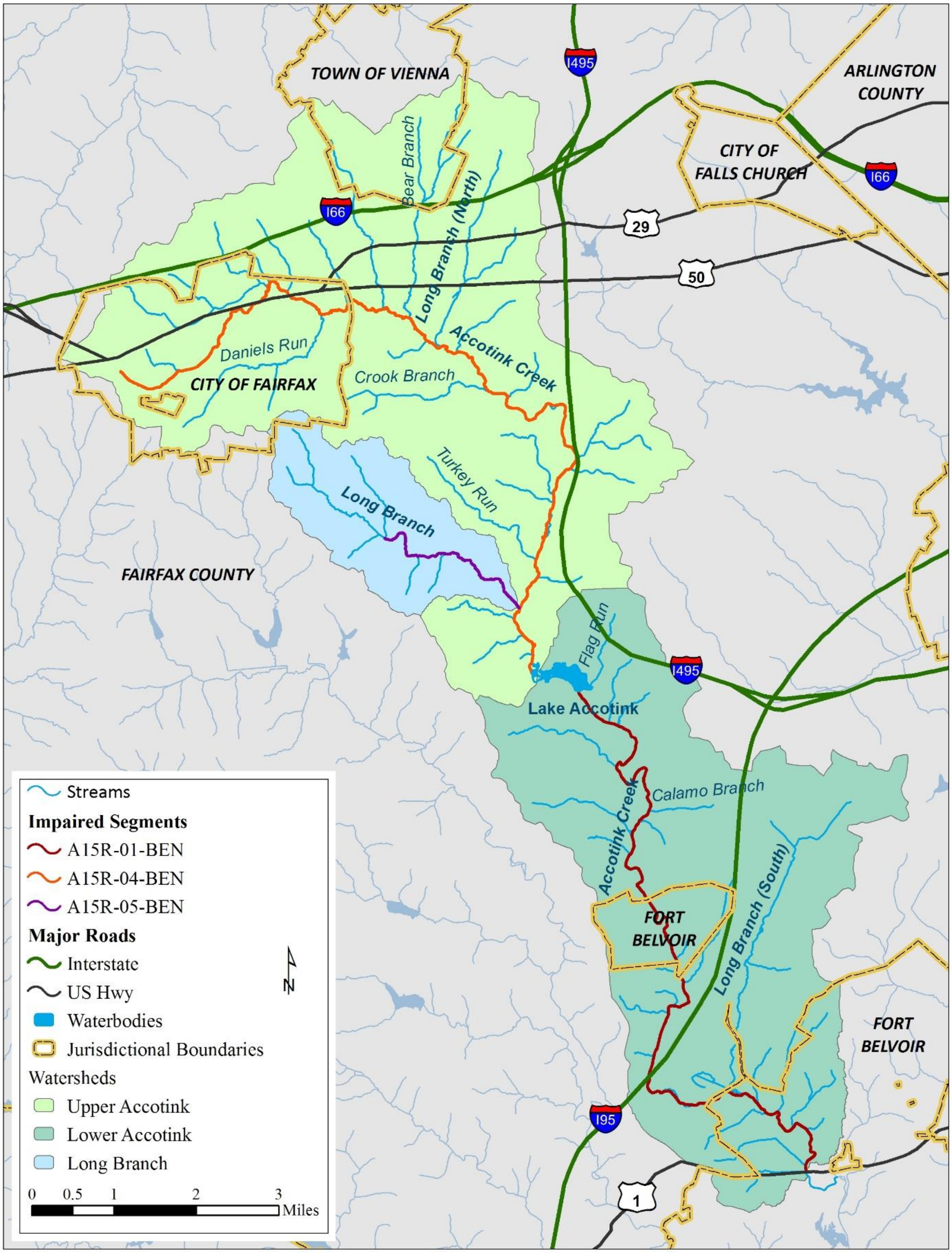

Figure 2-1: Location and Boundaries of the Accotink Creek Watersheds

Lake Accotink is a 55 acre impoundment on Accotink Creek in the middle of the watershed (Fairfax County, 2014). It was originally built in the 1940's as a drinking water reservoir for Fort Belvoir. The army stopped using it as a source of drinking water in the 1960's (Fairfax County Public Schools, 1976), and it is currently operated by the Fairfax County Parks Authority for recreational use as part of the 493 acre Lake Accotink Park.

Figure 2-1 shows the impaired sections of Accotink Creek and Long Branch. Lake Accotink separates the two impaired sections of the mainstem Accotink Creek, A15R-01-BEN and A15R-04-BEN, which will be referred to as "lower Accotink Creek" and "upper Accotink Creek," respectively. **Figure 2-1** also shows the drainage areas associated with the two impairments. The drainage area for the upper Accotink Creek impairment terminates at the inlet to Lake Accotink. The drainage area for the lower Accotink Creek impairment includes the upper Accotink Creek drainage, the drainage of the tributaries to Lake Accotink, and direct drainage to the lake. The drainage areas above and below the inlet to Lake Accotink will also be referred to as the upper Accotink Creek watershed and the lower Accotink Creek watershed, respectively.

In addition, **Figure 2-1** shows the impaired section of Long Branch and the Long Branch watershed. There are two other tributaries to Accotink Creek named Long Branch: one has its headwaters north of Interstate 66, and the other runs parallel to Interstate 95 until it joints with Accotink Creek in Fort Belvoir (see **Figure 2-1**). These will be referred to as "Long Branch North" and "Long Branch South," respectively, while "Long Branch" will always refer to the impaired segment and its watershed.

2.1.1 Topography

A National Elevation Dataset (NED) was used to characterize the topography in the watershed (USGS, 1999). NED data obtained from the United States Geological Survey (USGS) show that elevation in the upper Accotink watershed, excluding the Long Branch watershed, ranges from approximately 184 to 492 ft above mean sea level, with an average elevation of 343 ft above mean sea level, while the elevation in the lower Accotink Creek watershed below Lake Accotink ranges from approximately eight to 384 ft above mean sea level, with an average elevation of 194 ft. The elevation in the Long Branch watershed ranges from 186 to 462 ft above mean sea level, with an average elevation of 337 ft.

2.1.2 Hydrogeomorphic Regions

The USGS has divided the Chesapeake Bay watershed into hydrogeomorphic regions, based on physiography or geological structure, and underlying rock type (USGS, 2000). **Figure 2-2** shows the hydrogeomorphic regions in the Accotink Creek watershed. Three hydrogeomorphic regions are found in the watershed, Piedmont Crystalline, Coastal Plain Dissected Uplands, and Coastal Plain Lowlands.

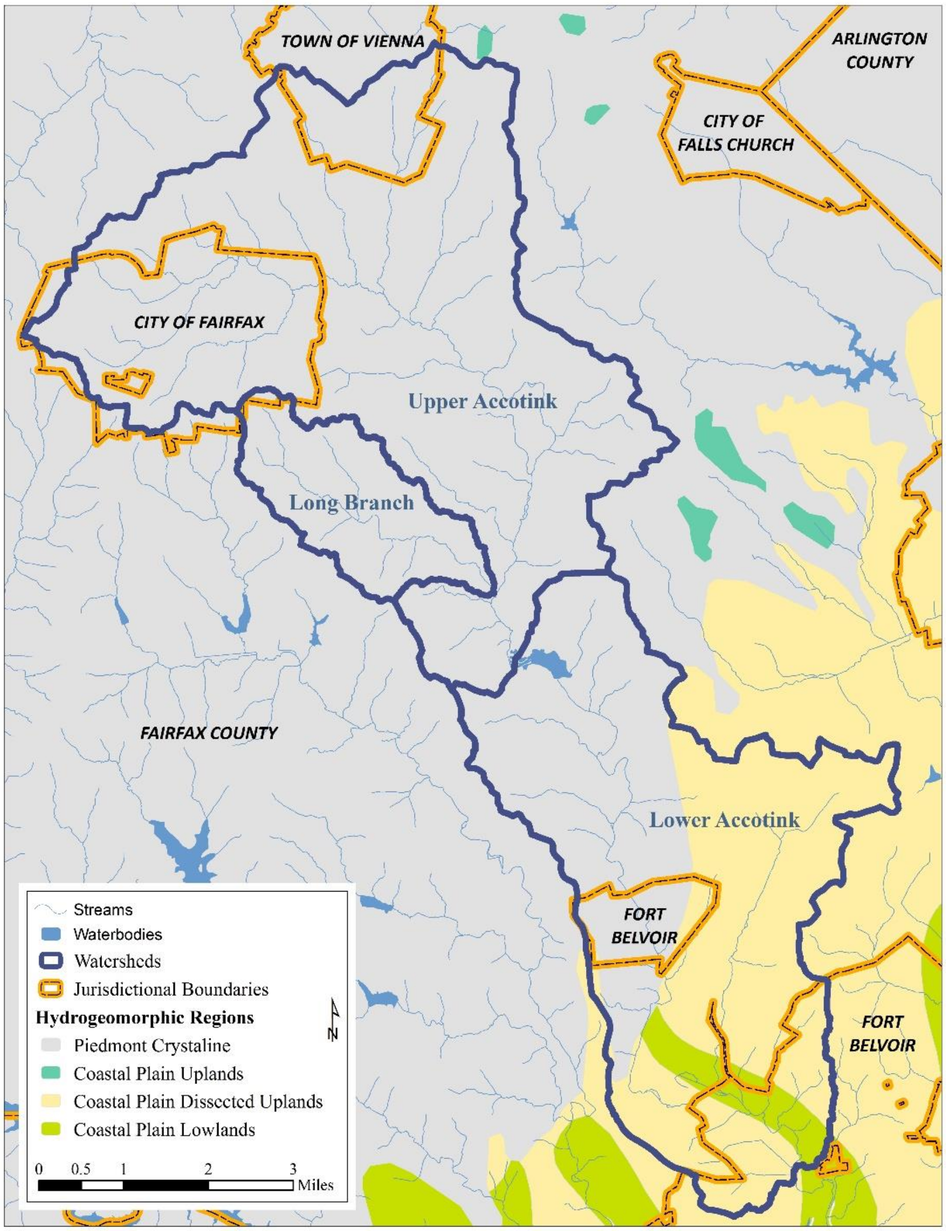

Figure 2-2: Accotink Creek Watersheds with Hydrogeomorphic Regions

The watershed of upper Accotink Creek, including Long Branch, is entirely within the Piedmont Crystalline region, as is 44% of the lower Accotink Creek watershed. Fifty percent of the lower Accotink Creek watershed is in the dissected uplands of the Coastal Plain; the remainder is in the Coastal Plain Lowlands.

2.1.3 Soils

The soil characterization of the Accotink Creek watershed was based on data obtained from the Soil Survey Geographic (SSURGO) database (NRCS, 2015). According to SSURGO, there are 63 soil series represented in the watershed (**Table 2-1**).

Table 2-1: Soils Series in Accotink Creek Watersheds

Soil Name	Upper Accotink[1]		Lower Accotink[2]		Long Branch	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
Barkers Crossroads loam	156	1.0%	100	0.8%	2	0.1%
Barkers Crossroads-Nathalie complex	73	0.4%	622	5.1%	40	1.6%
Barkers Crossroads-Rhodhiss complex	47	0.3%	441	3.6%	9	0.3%
Barkers Crossroads-Rhodhiss-Rock outcrop complex	0	0.0%	0	0.0%	1	0.0%
Beltsville silt loam	15	0.1%	390	3.2%	0	0.0%
Codorus and Hatboro soils	763	4.7%	1,181	9.6%	193	7.8%
Codorus silt loam	484	3.0%	54	0.4%	22	0.9%
Downer loamy sand	0	0.0%	10	0.1%	0	0.0%
Elkton silt loam	0	0.0%	29	0.2%	0	0.0%
Elsinboro loam	21	0.1%	1	0.0%	0	0.0%
Fairfax loam	46	0.3%	75	0.6%	15	0.6%
Glenelg silt loam	1,576	9.7%	144	1.2%	288	11.7%
Grist Mill sandy loam	0	0.0%	251	2.0%	0	0.0%
Grist Mill-Matapeake complex	0	0.0%	19	0.2%	0	0.0%
Grist Mill-Mattapex complex	0	0.0%	12	0.1%	0	0.0%
Gunston silt loam	0	0.0%	111	0.9%	0	0.0%
Hatboro silt loam	150	0.9%	94	0.8%	5	0.2%
Hattontown - Elbert complex	0	0.0%	0	0.0%	0	0.0%
Hattontown - Orange complex	23	0.1%	0	0.0%	0	0.0%
Hattontown silt loam	2	0.0%	0	0.0%	0	0.0%
Hattontown-Haymarket complex	4	0.0%	0	0.0%	1	0.0%
Hattontown-Orange complex	9	0.1%	0	0.0%	0	0.0%
Haymarket silt loam	0	0.0%	0	0.0%	3	0.1%
Kingstowne sandy clay loam	1	0.0%	295	2.4%	0	0.0%
Kingstowne-Beltsville complex	70	0.4%	125	1.0%	1	0.0%
Kingstowne-Danripple complex	7	0.0%	77	0.6%	0	0.0%
Kingstowne-Sassafras-Marumsco complex	0	0.0%	291	2.4%	0	0.0%
Kingstowne-Sassafras-Neabsco complex	0	0.0%	1,168	9.5%	0	0.0%
Kingstowne-Sassfras complex	0	0.0%	4	0.0%	0	0.0%
Lunt-Marumsco complex	0	0.0%	117	0.9%	0	0.0%
Matapeake silt loam	0	0.0%	43	0.4%	0	0.0%

Soil Name	Upper Accotink[1] Acres	Upper Accotink[1] Percent of Total	Lower Accotink[2] Acres	Lower Accotink[2] Percent of Total	Long Branch Acres	Long Branch Percent of Total
Mattapex loam	0	0.0%	128	1.0%	0	0.0%
Meadowville loam	155	0.9%	46	0.4%	16	0.7%
Meadowville silt loam	5	0.0%	0	0.0%	0	0.0%
Nathalie gravelly loam	87	0.5%	206	1.7%	3	0.1%
Orange silt loam	9	0.1%	0	0.0%	0	0.0%
Pits	0	0.0%	6	0.0%	0	0.0%
Rhodhiss sandy loam	72	0.4%	436	3.5%	0	0.0%
Rhodhiss-Rock outcrop complex	1	0.0%	27	0.2%	0	0.0%
Sassafras sandy loam	0	0.0%	79	0.6%	0	0.0%
Sassafras-Marumsco complex	0	0.0%	1,021	8.3%	0	0.0%
Sassafras-Neabsco complex	0	0.0%	123	1.0%	0	0.0%
Sumerduck loam	112	0.7%	1	0.0%	18	0.7%
Sumerduck silt loam	17	0.1%	0	0.0%	0	0.0%
Urban land	2,898	17.8%	2,710	22.0%	135	5.5%
Urban land-Barker Crossroads complex	184	1.1%	43	0.3%	0	0.0%
Urban land-Grist Mill	0	0.0%	67	0.5%	0	0.0%
Urban land-Kingstowne complex	42	0.3%	471	3.8%	0	0.0%
Urban land-Wheaton complex	1,230	7.5%	0	0.0%	46	1.9%
Water	20	0.1%	81	0.7%	0	0.0%
Wheaton - Codorus complex	55	0.3%	0	0.0%	0	0.0%
Wheaton - Fairfax complex	23	0.1%	0	0.0%	0	0.0%
Wheaton - Glenelg complex	1,533	9.4%	0	0.0%	8	0.3%
Wheaton - Meadowville complex	112	0.7%	0	0.0%	0	0.0%
Wheaton - Sumerduck complex	73	0.4%	0	0.0%	0	0.0%
Wheaton loam	308	1.9%	4	0.0%	55	2.2%
Wheaton-Codorus complex	160	1.0%	115	0.9%	59	2.4%
Wheaton-Fairfax complex	302	1.8%	165	1.3%	198	8.0%
Wheaton-Glenelg complex	4,879	29.9%	606	4.9%	1,140	46.4%
Wheaton-Hatboro complex	6	0.0%	0	0.0%	2	0.1%
Wheaton-Meadowville complex	442	2.7%	209	1.7%	106	4.3%
Wheaton-Sumerduck complex	142	0.9%	4	0.0%	90	3.7%
Woodstown sandy loam	0	0.0%	116	0.9%	0	0.0%
Total	**16,317**	**100.0%**	**12,321**	**100.0%**	**2,457**	**100.0%**

[1]Excluding Long Branch
[2]Excluding Upper Accotink Creek

Hydrologic soil groups represent different levels of infiltration capacity of the soils. Descriptions of the hydrologic soil groups are presented in **Table 2-2**. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. More rainfall becomes surface water runoff when soils are poorly drained. The acreage of each hydrologic soil group in Accotink Creek is presented in **Table 2-3**. **Figure 2-3** also shows the hydrological soil groups in the Accotink Creek watershed. As **Table**

2-3 and **Figure 2-3** show, soils in the watersheds of the impaired waterbodies in Accotink Creek are predominately soils of hydrologic group C, or have been disturbed by development.

Table 2-2: Descriptions of Soil Hydrologic Groups

Soil Hydrologic Group	Description
A	High infiltration rates. Soils are deep, well-drained to excessively-drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have a high water table, or shallow to impervious cover.

Table 2-3: Soil Hydrologic Groups in Accotink Creek Watersheds

Hydrologic Group – Dominant Condition	Upper Accotink[1]		Lower Accotink[2]		Long Branch	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
A	233	1.4%	519	4.2%	17	0.7%
B	1,730	10.6%	1,925	15.6%	306	12.4%
B/D	1,397	8.6%	1,329	10.8%	220	8.9%
C	8,573	52.5%	5,031	40.8%	1,733	70.6%
C/D	0	0.0%	141	1.1%	0	0.0%
D	9	0.1%	0	0.0%	0	0.0%
Pits/Gravel[3]	0	0.0%	6	0.0%	0	0.0%
Urban Land[4]	4,354	26.7%	3,290	26.7%	181	7.4%
Water	20	0.1%	81	0.7%	0	0.0%
Total	**16,317**	**100.0%**	**12,321**	**100.0%**	**2,457**	**100.0%**

[1]Excluding Long Branch
[2]Excluding Upper Accotink Creek
[3] "Pits are open excavations from which soil and commonly underlying material have been removed, exposing either rock or other material" (NRCS 1993).
[4] "Urban land is land mostly covered by streets, parking lots, buildings, and other structures of urban areas" (NRCS 1993). Here, this category also includes several urban land-soil complexes (e.g., Urban land-Barker Crossroads complex and others listed **Table 2-1**), which have no assigned soil hydrologic group.

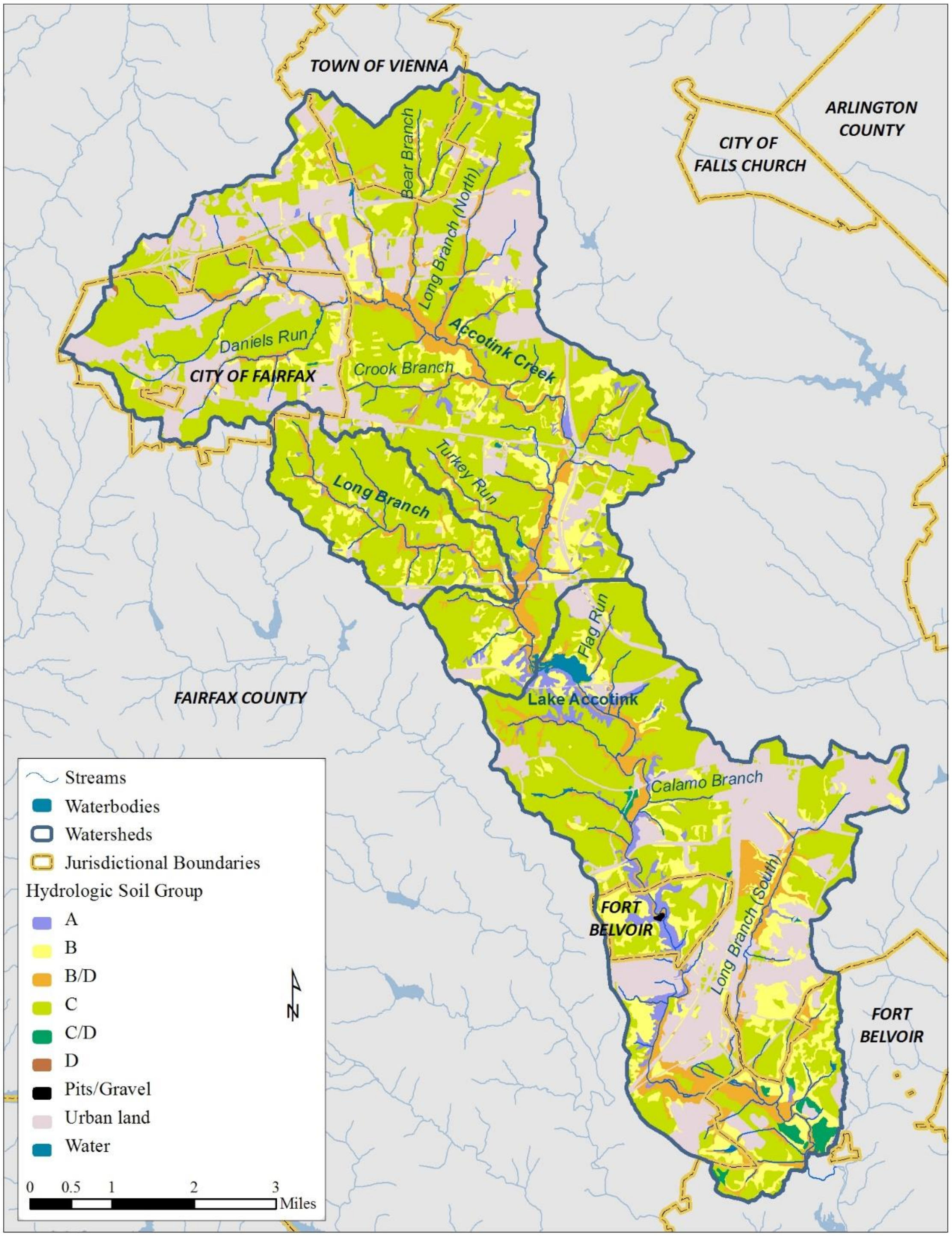

Figure 2-3: Soil Hydrologic Groups in Accotink Creek Watersheds

2.1.4 Land Use

The land use characterization for the Accotink Creek watershed, excluding Fort Belvoir, was based on (1) Fairfax County geospatial zoning data provided by K. Bennett (FCDPWES. Personal communication, 2009) and (2) City of Fairfax geospatially represented existing land use (ELU) and zoning data made available by Maurice Riou (GIS Manager, City of Fairfax, VA. Personal communication, 12/16/2015). The zoning codes and ELU were combined into a set of four major land use categories—commercial, industrial, residential, and open space—and subdivided into seven minor categories as shown in **Tables 2-4 and 2-5** for Fairfax County and the City of Fairfax data respectively.

Table 2-4: Classification of Land Use Categories based on Fairfax County Zoning

Zone Type	Zoning Code	Short Description	Land Use Category	Land Use Type
Commercial	C-1	Office commercial district	Commercial	Commercial
	C-2	Retail commercial district		
	C-3	General commercial district		
	C-4	High intensity office district		
	C-5	Neighborhood retail commercial district		
	C-6	Community retail commercial district		
	C-7	Regional retail commercial district		
	C-8	Highway commercial district		
Industrial	I-2	Industrial research district	Industrial	Industrial
	I-3	Light intensity industrial district		
	I-4	Medium intensity industrial district		
	I-5	General industrial district		
	I-6	Heavy industrial district		
Residential	R-C	Residential-conservation district	Residential	Low Density
	R-1	Residential district for single family dwelling types at a density not to exceed 1 dwelling unit per acre (du/ac)		
	R-2	Residential district for single family dwelling types at a density not to exceed 2du/ac		
	R-3	Residential district for single family dwelling types at a density not to exceed 3 du/ac		Medium Density
	R-4	Residential district for single family dwelling types at a density not to exceed 4 du/ac		
	R-5	Residential district for single family dwelling types at a density not to exceed 5 du/ac		
	R-8	Residential district for a mixture of single family residential dwelling types at a density not to exceed 8 du/ac		High Density
	R-12	Residential district for a mixture of residential dwelling types at a density not to exceed 12 du/ac		
	R-16	Residential district for a mixture of residential dwelling types at a density not to exceed 16 du/ac		
	R-20	Residential district for a mixture of residential		

Zone Type	Zoning Code	Short Description	Land Use Category	Land Use Type
		dwelling types at a density not to exceed 20 du/ac		
	R-30	Residential district for multiple family dwellings at a density not to exceed 30 du/ac		
	RTH	Townhouse district		
	RM-2	Multifamily district		
Planned Units	CPD	Commercial planned development district	Commercial	Commercial
	PDC	Planned development commercial district		
	PDH-2	Planned development housing district residential district for single family dwelling types at a density not to exceed 2du/ac	Residential	Low Density
	PDH-3	Planned development housing district residential district for single family dwelling types at a density not to exceed 3 du/ac		Medium Density
	PDH-4	Planned development housing district residential district for single family dwelling types at a density not to exceed 4 du/ac		
	PDH-5	Planned development housing district residential district for single family dwelling types at a density not to exceed 5 du/ac		
	PDH-8	Residential district for a planned mixture of single family residential dwelling types at a density not to exceed 8 du/ac		High Density
	PDH-12	Residential district for a planned mixture of residential dwelling types at a density not to exceed 12 du/ac		
	PDH-16	Residential district for a planned mixture of residential dwelling types at a density not to exceed 16 du/ac		
	PDH-20	Residential district for a planned mixture of residential dwelling types at a density not to exceed 20 du/ac		
	PDH-30	Residential district for a planned mixture of residential dwelling types at a density not to exceed 30 du/ac		
	PDH-40	Residential district for a planned mixture of residential dwelling types at a density not to exceed 40 du/ac		
	PRC	Planned residential community district		
	PRM	Planned residential mixed use district		Mixed Use
Other	PR	Other	Open Space	Open Space

Table 2-5: Classification of Land Use Categories based on the City of Fairfax Existing Land Use

Existing Land Use (ELU)	Land Use Category	Land Use Type
Auto Dealer	Commercial	Commercial
Auto Repair		
Commercial - Lodging		
Commercial - Office		
Commercial - Retail		
Institutional - City of Fairfax		
Institutional - General		
Industrial	Industrial	Industrial
Open Space - Preserved	Open Space	Open Space
Open Space - Recreation & Historic		
Open Space - Undesignated		
Vacant		
Residential - Multifamily	Residential	High Density
Residential - Single Attached		Medium Density[1]
Residential - Single Detached		
Residential - Single Attached		Low Density[1]
Residential - Single Detached		

[1]The distinction between medium density and low density residential was based on zoning codes

Additional geospatial data, including parkland (PARKS_FCPA, PARKS_NON_FCPA layers) and open water (extracted from the HYDRO_AREAS_4000 layer), were downloaded from the Fairfax Geoportal (http://www.fairfaxcounty.gov/maps/data.htm). Major paved transportation areas were also provided by K. Bennett (FCDPWES. Personal communication, 2009). Using standard GIS tools and procedures, parkland, which was used as a surrogate for open space, open water, and paved major transportation areas were combined with the zoning layer to yield the overall land use for the Accotink watershed, excluding Fort Belvoir, as shown in **Figure 2-4** and summarized in **Tables 2-6 through 2-8** for the upper Accotink, lower Accotink, and Long Branch watersheds respectively.

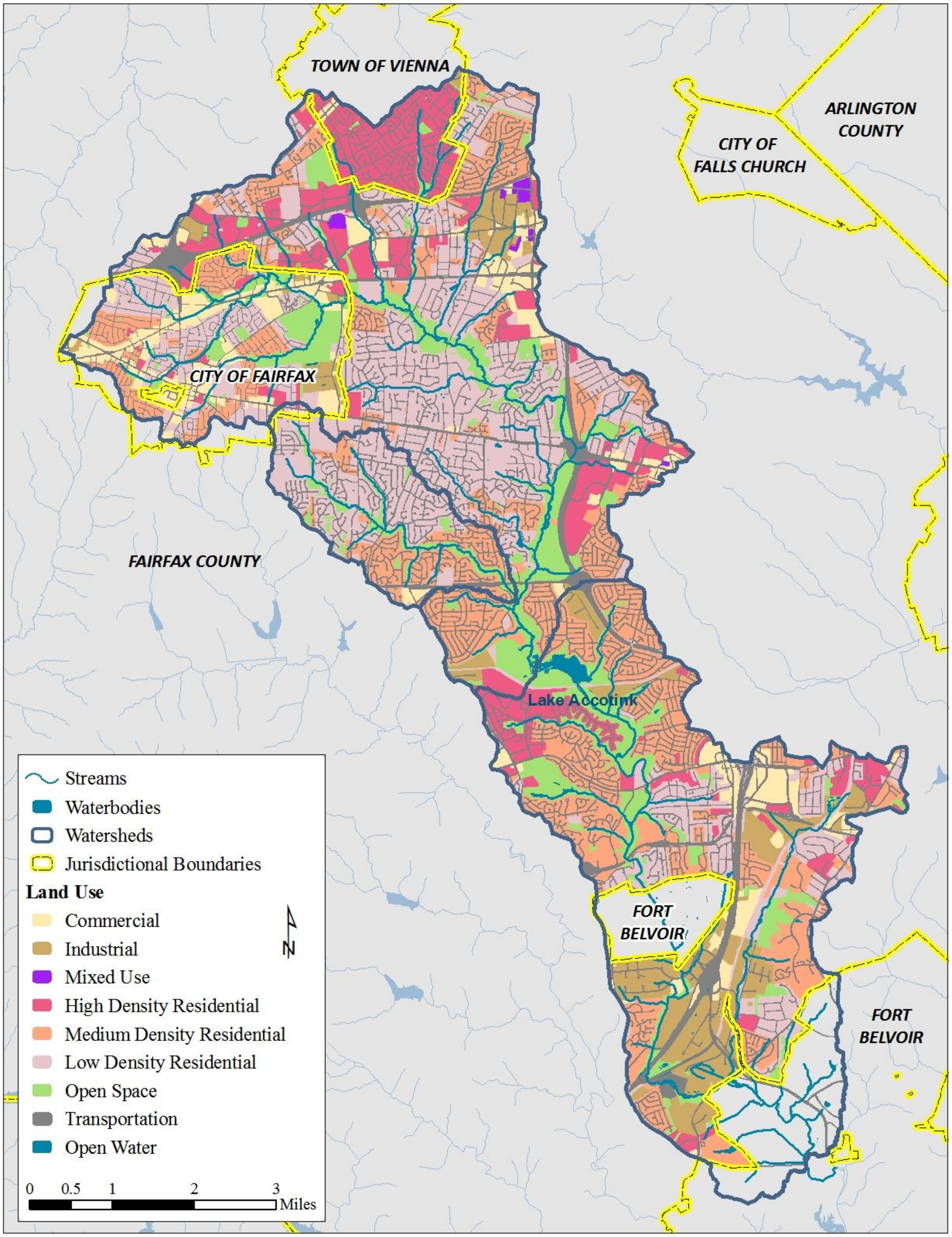

Figure 2-4: Land Use in Accotink Creek Watershed

Table 2-6. Land Use in Upper Accotink Creek Watershed[1]

Land Use Category	Zoning Category	City of Fairfax		Fairfax County		Town of Vienna		Total	
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Commercial	Commercial	739	21%	593	5%	28	2%	1,360	8%
Industrial	Industrial	127	4%	363	3%	19	2%	509	3%
Residential	Mixed Use	0	0%	76	1%	0	0%	76	0%
	Low Density	876	25%	4,282	37%	1	0%	5,159	32%
	Medium Density	627	18%	2,232	19%	2	0%	2,861	18%
	High Density	98	3%	1,305	11%	895	78%	2,298	14%
Transportation	Transportation	503	14%	1,463	13%	135	12%	2,101	13%
Open Space	Open Space	518	15%	1,294	11%	61	5%	1,873	11%
Water	Water	17	0%	70	1%	0	0%	88	1%
Total		**3,505**	**100%**	**11,679**	**100%**	**1,142**	**100%**	**16,326**	**100%**

[1]Excluding Long Branch

Table 2-7. Land Use in Lower Accotink Creek Watershed[1]

Land Use Category	Zoning Category	Fairfax County		Fort Belvoir		Total	
		Acres	Percent	Acres	Percent	Acres	Percent
Commercial	Commercial	530	5%	956	41%	1,487	12%
Industrial	Industrial	1,538	15%	0	0%	1,538	12%
Residential	Low Density	1,511	15%	0	0%	1,511	12%
	Medium Density	2,986	30%	0	0%	2,986	24%
	High Density	794	8%	0	0%	794	6%
Transportation	Transportation	1,297	13%	90	4%	1,387	11%
Open Space	Open Space	1,180	12%	1,273	54%	2,453	20%
Water	Water	145	1%	27	1%	173	1%
Total		**9,981**	**100%**	**2,348**	**100%**	**12,328**	**100%**

[1]Excluding Upper Accotink Creek

Table 2-8. Land Use in Long Branch Watershed

Land Use Category	Zoning Category	City of Fairfax		Fairfax County		Total	
		Acres	Percent	Acres	Percent	Acres	Percent
Commercial	Commercial	11	22%	27	1%	37	2%
Residential	Low Density	21	46%	1,222	51%	1,243	51%
	Medium Density	0	0%	629	26%	629	26%
	High Density	4	8%	0	0%	4	0%
Transportation	Transportation	11	24%	266	11%	277	11%
Open Space	Open Space	0	0%	257	11%	257	10%
Water	Water	0	0%	10	0%	10	0%
Total		**47**	**100%**	**2,411**	**100%**	**2,458**	**100%**

The watersheds are highly developed with developed land accounting for 88% of the upper Accotink watershed, 87% of lower Accotink watershed, and 89% of the Long Branch watershed. Residential land use comprises the largest category of land use in the upper Accotink (64%), lower Accotink (58%), and Long Branch (76%) watersheds. Transportation is the next largest category of land use in upper Accotink and Long Branch watersheds, accounting for about 13% and 11% of the watersheds, respectively, whereas industrial land use (12%) is the second largest category in the lower Accotink watershed, followed by open space (12%) and transportation (11%).

An estimation of the impervious area within each watershed was based on planimetric data provided by Fairfax County, VA (K. Bennett, FCDPWES. Personal communication, 2009). Polygon and line geospatial data representing building footprints, building additions, and paved areas (e.g. roads, parking lots, driveways, and sidewalks) were combined using standard GIS tools and procedures to obtain a representation of the impervious area in each subwatershed as shown in **Table 2-9.**

Table 2-9: Percent Imperviousness by Watershed and Jurisdiction

Jurisdiction	Watershed			Total
	Upper Accotink[1]	Lower Accotink[2]	Long Branch	
City of Fairfax	35.7%		47.9%	35.8%
Fairfax County	27.5%	31.2%	21.6%	28.5%
Fort Belvoir		10.8%		10.8%
Town of Vienna	30.8%			30.8%
Total	**29.5%**	**27.4%**	**22.1%**	**28.1%**

[1]Excluding Long Branch
[2]Excluding Upper Accotink Creek

Land use for Fort Belvoir was not available in a GIS representation, so the land use was determined based on Fairfax County planimetric data, the Fort Belvoir Integrated Natural Resource Management Plan (INRMP) (Horne Engineering Services, Inc., 2001), and Fort Belvoir Real Master Property Plan Installation Vision and Development Plan (VDP) (Atkins, 2014). The INRMP reported acres of impervious surface, open space, forest, and wetlands for the Fort Belvoir Northern Area (FBNA) and for the Accotink Creek drainage on the main base. The Accotink Creek drainage on the main base includes tidal waters outside of the impairment, so the acreage could not be used directly. The acreages represent conditions prior the Base Realignment and Closure Act (BRAC) of 2005, which transferred many military functions to Fort Belvoir and led to additional development on the base. The VDP includes projections of impervious areas in 2017 for the FBNA and the drainage on the main base.

Based on information in the VDP, the Fairfax County planimetric data has a representation of the impervious surfaces in Fort Belvoir prior to the BRAC. Impervious surfaces in the FBNA, based on the planimetric data, were adjusted to match the INRMP. It was assumed that the open space reported in the INRMP was developed pervious land, and that the ratio of impervious surface to open space was characteristic of Fort Belvoir development. Using this ratio, the amount of pervious developed land prior to the BRAC could be estimated for FBNA and the portion of the main base within the impaired watershed. The remainder of the land was assumed to be forest. To get the final Fort Belvoir land use representing current conditions, the percent change in impervious area from the INRMP to the VDP was calculated, and that ratio applied to the pre-BRAC estimates of developed pervious and impervious developed land to get current estimates of their acreage. The change in acreage was subtracted from the pre-BRAC estimate of forested land.

All developed land in Fort Belvoir except transportation was classified as commercial. The forested land was classified as open space. The resulting land use is shown in **Table 2-7**.

2.1.5 Population and Households

Spatial data at the Virginia state level that incorporates the 2010 Census block geography and the 2010 Census population and housing unit counts were downloaded from the Fairfax Geoportal (http://www.fairfaxcounty.gov/maps/data.htm). The aerial extent of census blocks located within or intersecting a watershed were determined using routine GIS analysis. The fraction of each census block within a watershed was calculated and then used to obtain an area-weighted number of households for each watershed. Summaries of the population and household estimates for the Accotink Creek watershed are presented in **Table 2-10**.

Table 2-10: 2010 Census Data Summary for the Accotink Creek Watersheds

Watershed	Estimated Households	Estimated Population
Upper Accotink[1]	44,439	116,554
Lower Accotink	20,954	55,633
Long Branch	4,581	13,319
Total	69,973	185,506

[1]Excluding Long Branch

2.2 Permitted Facilities

DEQ issues Virginia Pollutant Discharge Elimination System (VPDES) permits for all point source discharges to surface waters, to dischargers of stormwater from Municipal Separate Storm

Sewer Systems (MS4s), and to dischargers of stormwater from Industrial Activities. DEQ issues Virginia Stormwater Management Program (VSMP) permits to dischargers of stormwater from Construction Activities. There are two broad types of discharge permits; individual permits and general permits.

DEQ issues individual permits to both municipal and industrial facilities. Permit requirements, special conditions, effluent limitations and monitoring requirements are determined for each facility on a site specific basis in order to meet applicable water quality standards. General permits are written for a general class of dischargers where operations and activities are similar. These permits are also prepared to protect and maintain applicable water quality standards. In Virginia, general permits are adopted as regulations.

There are four types of permits issued in the Accotink Creek watershed: (1) individual Virginia Pollutant Discharge Elimination System (VPDES) permits; (2) general VPDES permits; (3) municipal separate storm sewer system (MS4) permits; and (4) general construction stormwater control permits. These are discussed in subsequent sections.

Most of the watershed is served by sanitary sewers. The wastewater treatment plant discharges into a different watershed than Accotink Creek.

2.2.1 Facilities with Individual Permits

Individual VPDES permits have conditions that apply to a specific facility, including effluent limits and monitoring requirements. There are five, individual industrial permits authorizing discharge in the Accotink Creek watershed. Four of them are issued to bulk petroleum storage operations; these are classified as minor permits. They are listed in **Table 2-11**, along with their receiving stream and their discharge flows, where applicable. In addition, Fort Belvoir has an individual VPDES permit for industrial stormwater. It is classified as a major permit. The average flow for Fort Belvoir industrial VPDES permit, shown in **Table 2-11,** was based on results from the Generalized Watershed Loading Functions (GWLF) model, used in the development of the Accotink Creek sediment TMDLs (See **Section 3**). **Figure 2-5** shows the location of these facilities.

Table 2-11: Individual VPDES Permitted Facilities within Accotink Creek Watershed

Watershed	Permit No	Facility Name	Major/ Minor	Municipal/ Industrial	Discharge Source	Receiving Stream	Average Flow (MGD)
Upper Accotink	VA0001872	Joint Basin Corporation – Fairfax Terminal Complex	Minor	Industrial	Process Wastewater and Stormwater	Daniels Run, UNT	0.100
	VA0002283	Motiva Enterprises LLC – Fairfax	Minor	Industrial	Process Wastewater and Stormwater	Crook Branch	0.048
Lower Accotink	VA0001945	Kinder Morgan Southeast Terminals LLC-Newington	Minor	Industrial	Process Wastewater and Stormwater	Accotink Creek, UNT	0.176
	VA0001988	Kinder Morgan Southeast Terminals LLC-Newington 2	Minor	Industrial	Process Wastewater and Stormwater	Accotink Creek, UNT	0.036
	VA0092771	Fort Belvoir	Major	Industrial	Stormwater	Accotink Creek	0.322[1]

[1]Based on results from GWLF model, Volume II, Section 3.

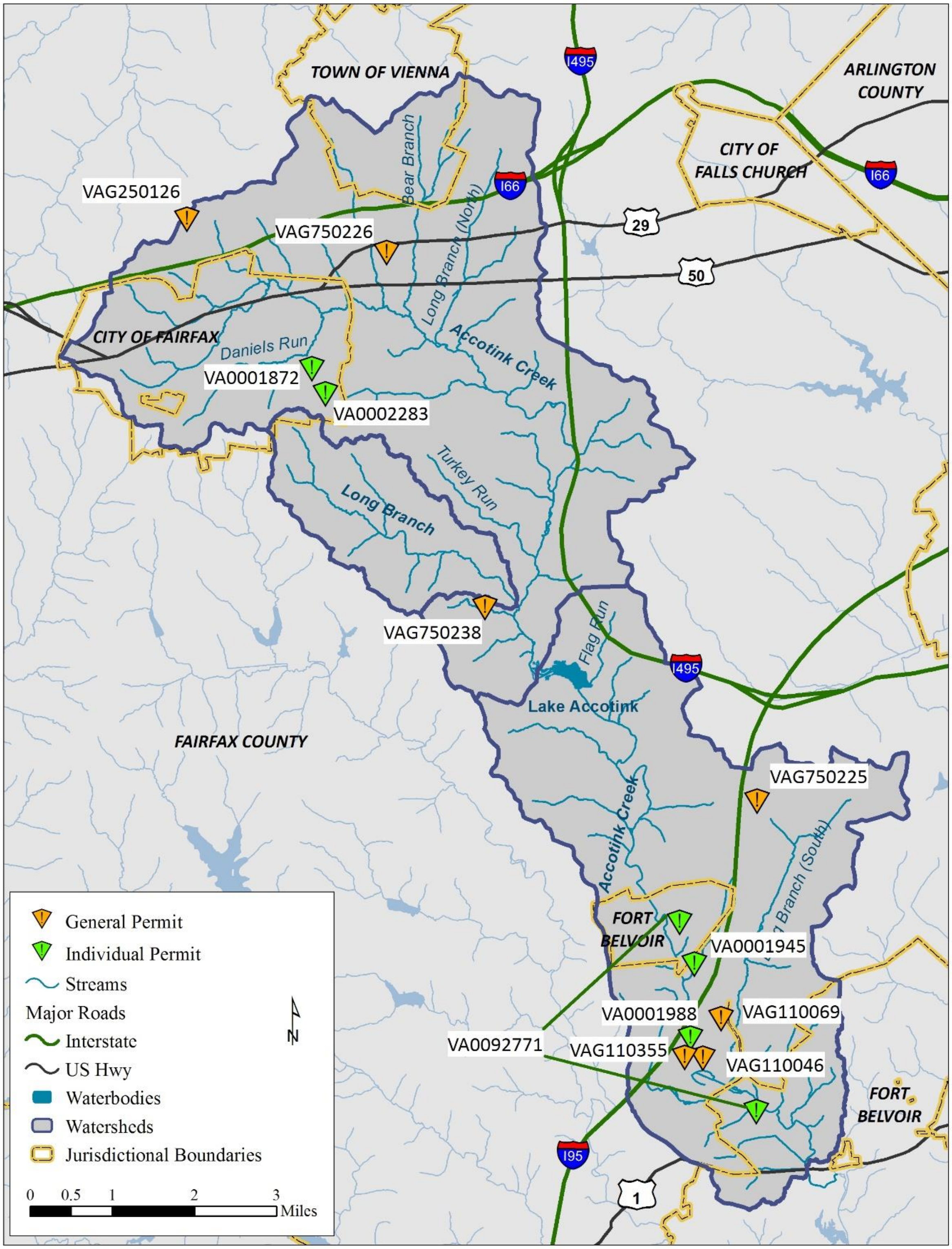

Figure 2-5: Location of Facilities with Individual and General VPDES Permits within Accotink Watershed

2.2.2 Facilities with General Permits

General permits apply to a class of dischargers. Facilities in Accotink Creek watershed are registered under the following general permits, excluding the MS4 general permit:

- three (3) Vehicle Wash and Laundry facilities;
- one (1) Non-contact Cooling Water permittees;
- three (3) Concrete Products Facilities;
- two (2) permittees under the Domestic Sewage Discharge of Less Than or Equal to 1,000 Gallons per Day;
- two (2) facilities authorized under the permit for Petroleum Contaminated Sites and Hydrostatic Tests;
- twelve (12) permits for Discharges of Stormwater Associated with Industrial Activity;

Table 2-12 shows the facilities in Accotink Creek registered under these general permits, not including discharges of industrial stormwater, the two domestic sewage dischargers, or the two permits for petroleum contaminated sites and hydrostatic tests. **Figure 2-5** shows the location of facilities with general permits that are identified in **Table 2-12**. The twelve facilities registered under the general permit for industrial stormwater are identified in **Table 2-13** with their locations shown in **Figure 2-6**. One household under the general domestic sewage permit for discharges less than 1,000 gallons per day is in the upper Accotink Creek watershed, and the other is in the Long Branch watershed. Facilities authorized to discharge under the general permit for petroleum contaminated sites, groundwater remediation and/or hydrostatic testing are not presented in the referenced maps or tables. These permits may be short-lived, depending on the specific activity. Additionally, a registration statement is not required for certain activities, such as short-term projects and hydrostatic testing discharges. Because of the nature of permitting these sources and because these are insignificant sources of sediment, they are not presented in the referenced maps or tables. Nonetheless, the two permits that were active at the time of writing this report were both located in the upper Accotink Creek watershed. Permits for discharge of stormwater from construction activities are discussed in **Section 2.2.4**.

Table 2-12: Cooling Water, Car Wash and Concrete General VPDES Permitted Facilities within Accotink Creek Watershed

Watershed	Permit No	Facility Name	Type
Upper Accotink	VAG250126	AT&T Oakton Office Park	Cooling Water
	VAG750226	Enterprise Rent A Car - 3055 Nutley St	Car Wash
	VAG750238	Ravensworth Collision Center	Car Wash
Lower Accotink	VAG110046	Virginia Concrete Company Inc - Newington Plant 1	Concrete
	VAG110069	VA Concrete Co - Mid Atlantic Materials-Newington	Concrete
	VAG750255	Enterprise Rent A Car – 6701Loisdale Rd	Car Wash
	VAG110355	Superior Concrete	Concrete

Table 2-13: Industrial Stormwater General VPDES Permitted Facilities within Accotink Creek Watershed

Watershed	Permit No	Facility	Area of Industrial Activity (Acres)	SIC (Standard Industrial Classification Code) Description
Upper Accotink	VAR051066	US Postal Service – Merrifield Vehicle Maintenance	2	United States Postal Service
	VAR051770	Fairfax County – Jermantown Maintenance Facility	12.4	Local and Suburban Transit
	VAR052188	Milestone Metals	1.5	Scrap and Waste Materials
Lower Accotink	VAR051042	SICPA Securink Corporation	1.1	Printing Ink
	VAR051047	Fairfax County – Connector Bus Yard	6.25	Local and Suburban Transit
	VAR051565	Rolling Frito Lay Sales LP – South Potomac DC	1.2	Trucking, Except Local
	VAR051771	Fairfax County – Newington Maintenance Facility	25.4	Local and Suburban Transit
	VAR051772	Fairfax County-DVS – Alban Maintenance Facility	5.5	Local and Suburban Transit
	VAR051795	HD Supply-White Cap	1	Brick, Stone, and Related Materials
	VAR051863	United Parcel Service – Newington	9.1	Courier Services, Except Air
	VAR052223	Newington Solid Waste Vehicle Facility	4.9	Local Trucking without Storage
	VAR052366	Ready Refresh by Nestle - Lorton Branch	3.0	Local Trucking with Storage

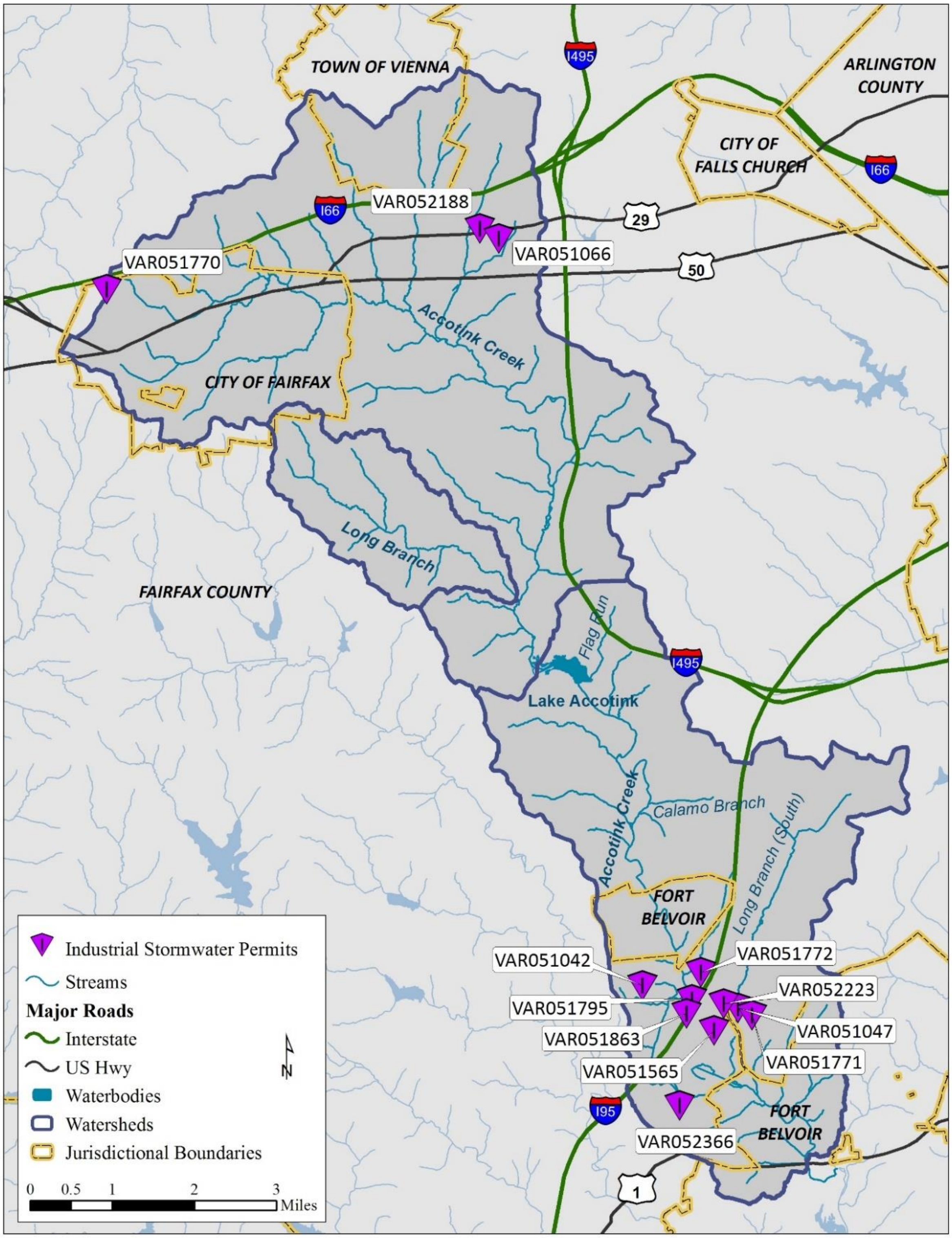

Figure 2-6: Location of Industrial Stormwater General Permits within Accotink Watershed

2.2.3 Municipal Separate Storm Sewer Systems (MS4s)

MS4 permits in the Accotink Creek watershed are listed in **Table 2-14**. Fairfax County has a Phase I, individual permit and it is anticipated that VDOT will have an individual MS4 by completion of this TMDL study. While VDOT remains a Phase II MS4 entity, DEQ is preparing an individual permit to govern its operations. The rest of the MS4s have Phase II, general permits. **Table 2-14** also shows the watershed of the impaired segment associated with the MS4s.

Table 2-14: MS4 Permits within Accotink Creek Watershed

Watershed	Permit No	Facility Name	Phase
All	VA0088587	Fairfax County	I
All	VA0092975	Virginia Department of Transportation	II
All	VAR040104	Fairfax County Public Schools	II
Long Branch & Upper Accotink	VAR040064	City of Fairfax	II
Upper Accotink	VAR040066	Town of Vienna	II
Lower Accotink	VAR040093	Fort Belvoir	II
	VAR040095	Northern Virginia Community College	II

A MS4 can be defined by its service area, which represents the drainage areas of the sewers and outfalls operated by the MS4. Service areas can overlap. **Figure 2-7** shows the overlapping service areas in one portion of the Accotink Creek watershed. In particular, the service area for the Virginia Department of Transportation (VDOT) has significant overlap with jurisdictional MS4s like Fairfax County, the Town of Vienna, or the City of Fairfax.

VDOT, Fairfax County, the Town of Vienna, Fort Belvoir, and the Fairfax County Public School System all provided GIS representations of their service areas. Service areas for the City of Fairfax and the Northern Virginia Community College, Annandale Campus, were digitized from maps documented in the City of Fairfax Chesapeake Bay Action Plan (City of Fairfax, 2015) and the Municipal Separate Storm Sewer System (MS4) Manual (NOVA, 2014), respectively. Because of the overlap in service areas, it is sometimes more useful to consider the combined service area, that is the area drained by the storm sewer system of at least one MS4, if not more. **Figure 2-8** shows the combined MS4 service area in the Accotink Creek watershed.

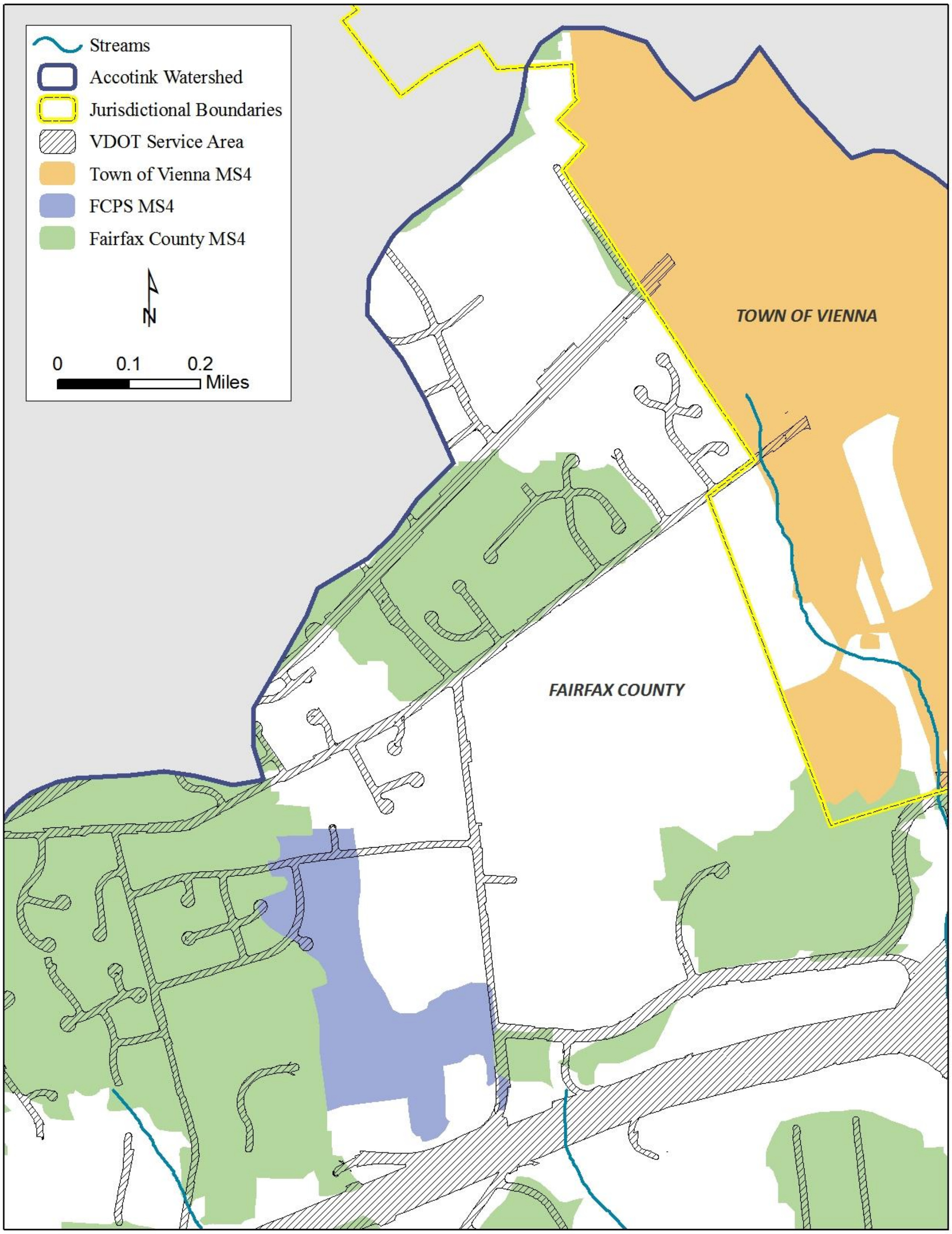

Figure 2-7: Individual MS4 Service Areas

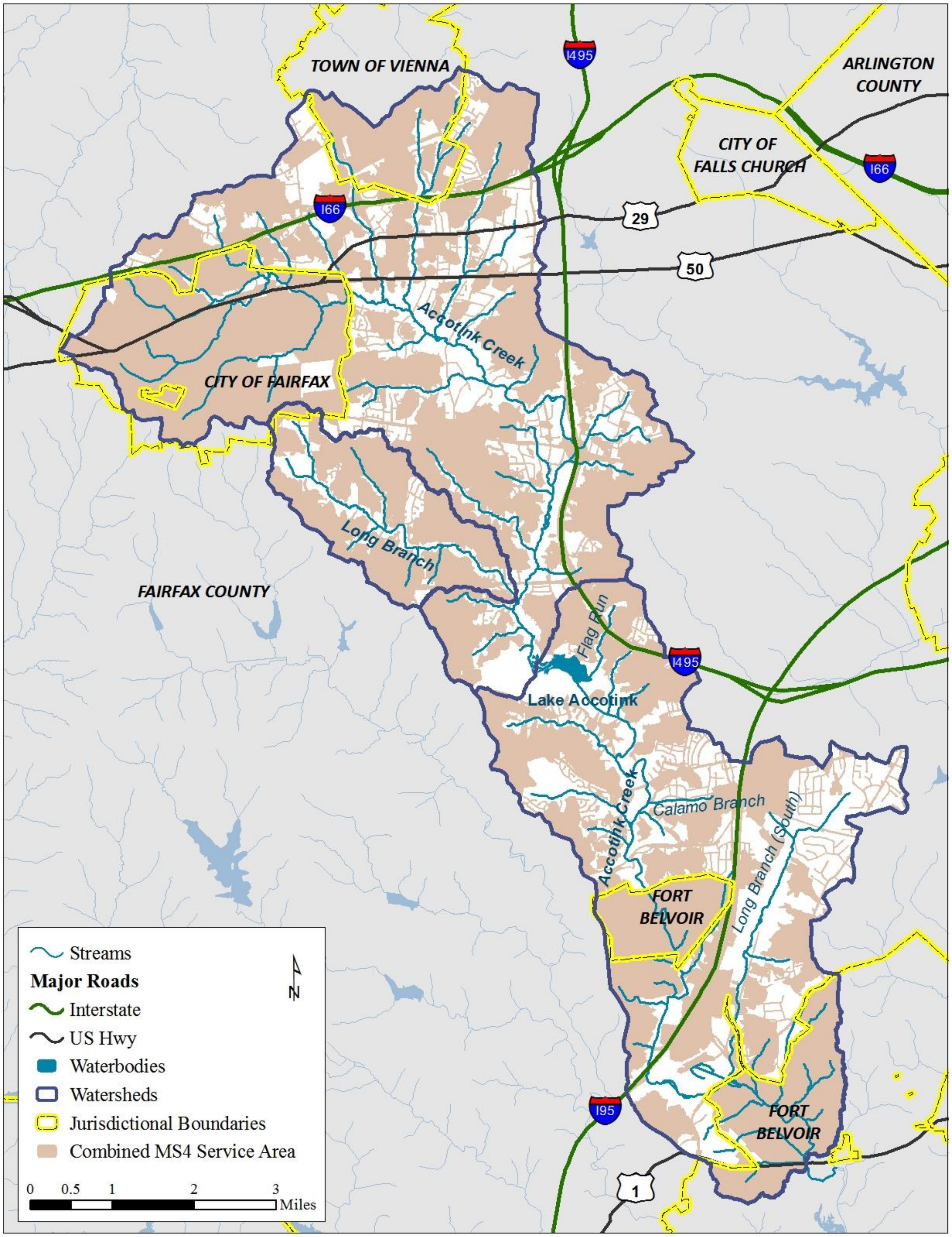

Figure 2-8: Combined MS4 Service Areas

Under the VSMP, DEQ also issues general permits to control stormwater from construction sites. **Table 2-15** summarizes the number of active construction permits in the Accotink Creek watershed, the total acreage under development, and the total disturbed area at the inception of this project in December, 2014. Information on current construction permits can be obtained from an on-line database on the VSMP website, which is currently available at the following: http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/VSMPPermits/ConstructionGeneralPermit.aspx

Table 2-15: Construction Stormwater Permits within Accotink Creek Watershed (December, 2014)

Watershed	Number of Permits	Total Area of Sites (acres)	Total Disturbed Area (acres)
Upper Accotink[1]	44	704	315
Lower Accotink[2]	33	648	265
Long Branch	1	11	5

[1]Excludes Long Branch
[2]Excludes upper Accotink Creek and Long Branch

2.2.5 Sewers

The population in Accotink Creek watershed is primarily served by sanitary sewers. Most of the wastewater is treated at Fairfax County's Norman J. Cole Jr. Pollution Control Plant, which discharges into Pohick Creek, which is the watershed adjacent to Accotink Creek.

3 Analysis of Monitoring Data

This section reviews and analyzes the available monitoring data for Accotink Creek. Accotink Creek is one of the most extensively monitored watersheds in the region. Four different agencies—DEQ, the USGS, the EPA, and the FCDPWES—have collected monitoring data under multiple projects and programs. Conventional water quality monitoring, biological monitoring of benthic and fish communities, habitat assessments, stream geomorphic assessments, and monitoring of metals and toxics in sediment and fish tissue have all been performed in the mainstem of Accotink Creek and its tributaries. **Table 3-1** shows which agencies performed which types of monitoring and assessments.

Table 3-1: Monitoring Data Collected in Accotink Creek Watershed

Monitoring and Assessment		DEQ	USGS	EPA	FCDPWES
Biological	Benthics	X		X	X
	Fish				X
Habitat		X			X
Geomorphological	Geomorphic	X		X	X
	Stream Survey				X
Flow			X		
Conventional Water Quality		X	X	X	X
Toxicity Test		X			
Metals	Water Column	X			
	Sediment	X			
	Fish Tissue	X			
Toxics	Water Column	X	X		
	Sediment	X	X		
	Fish Tissue	X	X		

In anticipation of the SI, the analysis of monitoring data has been organized in the following manner: **Section 3.1** discusses the biological monitoring in the Accotink Creek watershed; **Section 3.2** reviews habitat assessments and the results of stream surveys; **Section 3.3** discusses stream geomorphic assessments; **Section 3.4** describes the available flow data; **Section 3.5** analysis analyzes water column monitoring data for pH, DO, specific conductance, turbidity, suspended sediment, nutrients, and other conventional pollutants; **Section 3.6** reviews the results of toxicity tests and monitoring data on metals and toxic chemicals in the water column, sediment, and fish tissue; and **Section 3.7** discusses the available data on periphyton.

3.1 Analysis of Biological Monitoring Data

Three agencies have performed biological monitoring in the Accotink Creek watershed: DEQ, EPA, and FCDPWES.

3.1.1 DEQ Benthic Monitoring

DEQ has monitored and evaluated the state of the benthic macroinvertebrate community at five locations in the Accotink Creek watershed. The locations of the five biological monitoring stations are shown on **Figure 3-1**. Station 1AACO006.10, at Alban Road, was monitored first in the fall of 1994 and was monitored a total of eleven times. A second station in the lower Accotink Creek, 1AACO002.50, at Route 1, was assessed four times in 2006 and 2007. The third station in lower Accotink Creek, 1AACO009.14, upstream of Hooes Road was assessed spring and fall in 2008. One site in upper Accotink Creek, 1AACO014.57, at Braddock Road, was assessed spring and fall in 2007. There is one DEQ biological monitoring station in Long Branch, 1ALOE001.99, near Guinea Road, which was monitored spring and fall in 2006. All of the monitoring locations in Accotink Creek were sampled using the "single habitat approach" (DEQ, 2008) where sampling is performed in riffles with cobble substrate.

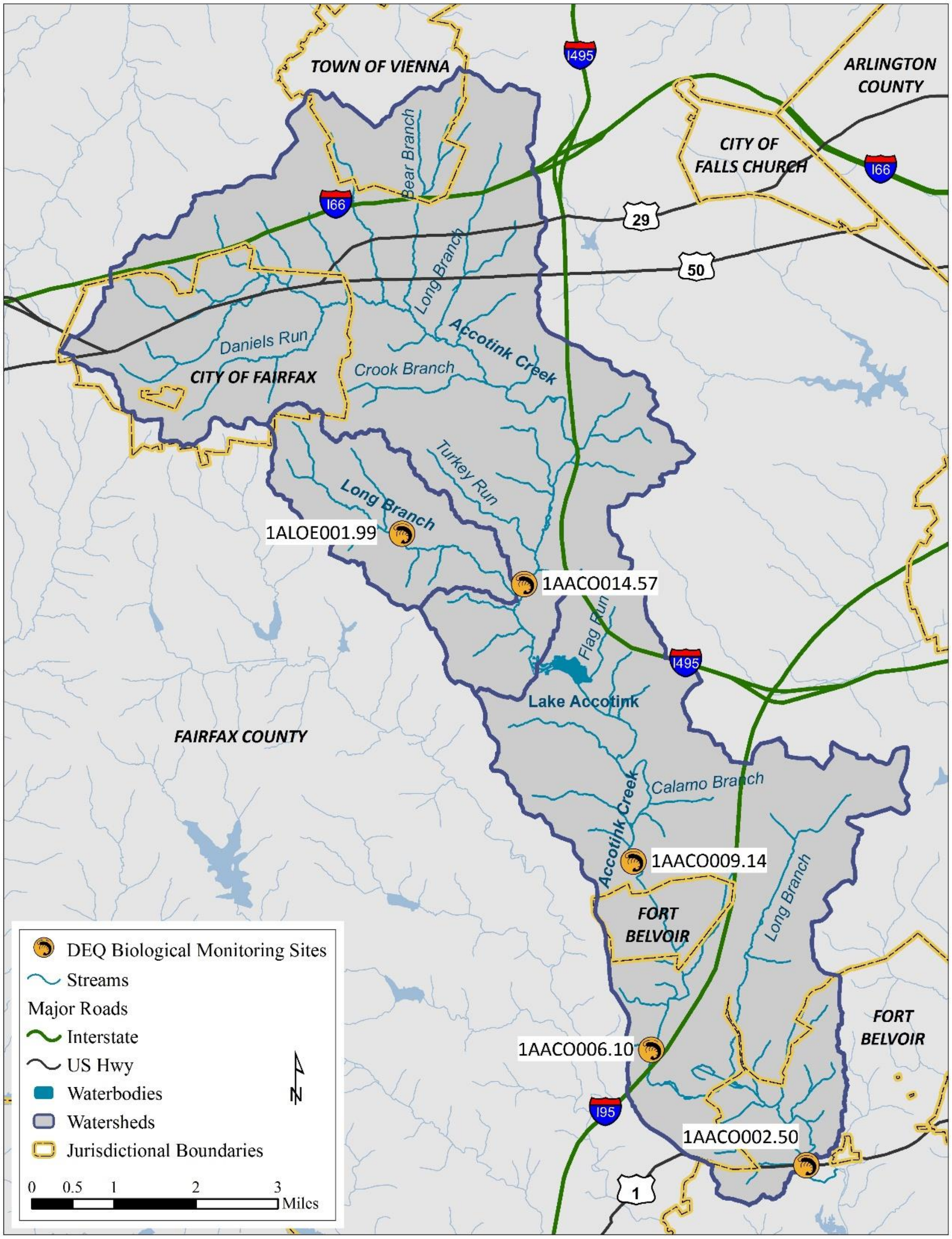

Figure 3-1: DEQ Biological Monitoring Stations

The health of the benthic biological community is measured using the VSCI (Burton and Gerritsen, 2003). The VSCI is scored on a scale of 0 to 100, where 100 represents the best biological condition and 0 represents the worst. A score of 60 is the threshold for biological impairment. All 21 assessments in Accotink Creek and Long Branch had scores below 60.

The VSCI is a multi-metric index composed of eight biological metrics. Each of these eight metrics measures an aspect of the benthic macroinvertebrate community, such as diversity, intolerance to pollution, or a balance in the structure and function of taxa. **Table 3-2** lists the composite metrics in the VSCI and what they measure. The metrics are given scores on a scale from 0 to 100 based on a comparison with reference sites. Reference sites are sites relatively free of anthropogenic influence and are intended to represent minimally disturbed conditions. **Table 3-3** lists all of the benthic taxa observed in Accotink Creek, as well as their functional feeding group and tolerance values. The tolerance values shown for each family are used by DEQ to calculate scores for the modified Hilsenhoff Biotic Index (HBI), one of the metrics in the VSCI. Potential tolerance values range from one to ten, with one indicating the intolerance to pollution and ten indicating tolerance to pollution.

Table 3-2: Component Metrics of Virginia Stream Condition Index

Metric	Description	Measures…	Response to Pollution
Total Taxa	Number of distinct taxa	overall variety of macroinvertebrate assemblage	Decrease
% Top Two Taxa	Percent of individuals from two most dominant taxa	diversity of benthic community	Increase
EPT Taxa	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa	prevalence of pollutant-sensitive mayflies, stoneflies, and caddis flies	Decrease
% PT (excluding Hydropsychidae)	Percent individuals of Plecoptera, and Trichoptera, excluding Hydropsychidae	pollutant-sensitive stoneflies and caddis flies without counting pollution-insensitive net-spinning caddis flies	Decrease
% Ephemeroptera	Percent of individuals Ephemeroptera	pollutant-sensitive mayflies	Decrease
% Chironomidae	Percent of individuals Chironomidae	pollution-tolerant midge larvae	Increase
HBI (family level)	Family-level Hilsenhoff Biotic Index	average tolerance to pollution of benthic community, weighted by abundance	Increase
% Scrapers	Percent individuals from scraper functional feeding group	macroinvertebrates which graze on substrate- or periphyton-attached algae	Decrease

Table 3-3: Benthic Taxa Identified in Accotink Creek Watershed

Class	Order	Family	Functional Feeding Group	DEQ Tolerance Value
Hirudinea	unknown	unknown		
	Arhynchobdellida	Hirudinidae	Predator	7
Oligochaeta	unknown	unknown	Collector	6
	Haplotaxida	Lumbricidae	Collector	10
	Lumbriculida	Lumbriculidae	Collector	8
	Tubificida	Naididae	Collector	8
Insecta	Coleoptera	Dryopidae	Shredder	5
	Coleoptera	Dytiscidae	Predator	6
	Coleoptera	Elmidae	Scraper	4
	Diptera	Chironomidae (A)	Collector	6
	Diptera	Chironomidae (B)	Collector	9
	Diptera	Empididae	Predator	6
	Diptera	Muscidae	Predator	8
	Diptera	Simuliidae	Filterer	6
	Diptera	Tipulidae	Shredder	3
	Ephemeroptera	Baetidae	Collector	4
	Ephemeroptera	Caenidae	Collector	4
	Ephemeroptera	Heptageniidae	Scraper	4
	Hemiptera	Gerridae	Predator	8
	Hemiptera	Veliidae	Predator	6
	Megaloptera	Corydalidae	Predator	5
	Odonata	Aeshnidae	Predator	3
	Odonata	Calopterygidae	Predator	5
	Odonata	Coenagrionidae	Predator	9
	Odonata	Corduliidae	Predator	5
	Odonata	Gomphidae	Predator	1
	Plecoptera	Nemouridae	Shredder	2
	Trichoptera	Hydropsychidae	Filterer	6
Malacostraca	Amphipoda	Crangonyctidae	Collector	6
	Amphipoda	Gammaridae	Collector	6
	Decapoda	Cambaridae	Shredder	5
	Isopoda	Asellidae	Collector	8
Bivalvia	Veneroida	Corbiculidae	Filterer	8
	Veneroida	Sphaeriidae	Filterer	8
Clitellata	Haplotaxida	Tubificidae	Collector	10
Gastropoda	Basommatophora	Ancylidae	Scraper	6
	Basommatophora	Physidae	Scraper	8
	Basommatophora	Planorbidae	Scraper	7
	Neotaenioglossa	Hydrobiidae	Scraper	3
Turbellaria	Tricladida		Collector	8

Table 3-4 shows the component metric scores and overall VSCI for each assessment. The low VSCI scores are due to the lack of pollutant-sensitive individuals, taxa in the Ephemeroptera, Plecoptera, and Trichoptera (EPT) orders, and scrapers. Component scores for the EPT Taxa, Percent Ephemeroptera, and Percent Plecoptera plus Trichoptera (excluding Hydropsychidae) are

frequently less than 10, as are the scores for Percent Scrapers. Metrics that measure diversity, such as Total Taxa or the Percent Two Dominant Taxa, while not as poor as the EPT-associated metrics, also contribute to lowering VSCI scores below the 60 threshold. The Two Dominant Taxa account for over 70% of the individuals in more than half the assessments and half the individuals in more than 80% of the assessments.

Table 3-4: Virginia Stream Condition Index and Component Metric Scores in Accotink Creek Watershed at DEQ Monitoring Locations

Station	Collection Date	Sample Season	Rep Num	Total Taxa	EPT Tax	% Ephem	% PT – Hydropsychidae	% Scrap	% Chiro	% 2Dom	HBI	Richness Score	EPT Score	% Ephem Score	% PT-H Score	% Scraper Score	% Chironomidae Score	% 2Dom Score	%MFBI Score	VSCI
1AACO002.50	06/01/2006	Spring	1	17	2	0.92	0	6.42	22.02	72.48	6.24	77.27	18.18	1.5	0	12.45	77.98	39.77	55.32	35.31
	11/21/2006	Fall	1	8	1	0	0	0	16.9	80.28	6.23	36.36	9.09	0	0	0	83.1	28.49	55.51	26.57
	04/30/2007	Spring	1	10	3	11.7	2.1	5.32	53.19	65.96	5.68	45.45	27.27	19.09	5.98	10.31	46.81	49.19	63.52	33.45
	11/01/2007	Fall	1	8	1	0	0	1.32	1.32	75	7.07	36.36	9.09	0	0	2.55	98.68	36.13	43.15	28.25
1AACO006.10	11/04/1994	Fall	1	10	1	0	0	12.96	3.7	44.44	6.61	45.45	9.09	0	0	25.12	96.3	80.28	49.84	38.26
	05/18/1995	Spring	1	13	2	1.3	0	6.49	19.48	32.47	7.22	59.09	18.18	2.12	0	12.58	80.52	97.59	40.87	38.87
	11/29/1995	Fall	1	10	1	0	0	0	17.65	50	7.59	45.45	9.09	0	0	0	82.35	72.25	35.47	30.58
	05/30/1996	Spring	1	12	2	2.94	0	11.76	26.47	41.18	6.84	54.55	18.18	4.8	0	22.8	73.53	85.01	46.5	38.17
	11/18/1996	Fall	1	9	1	0	0	0	34.21	55.26	6.89	40.91	9.09	0	0	0	65.79	64.65	45.67	28.26
	06/01/2006	Spring	1	5	1	0	0	0.86	3.45	93.97	6.24	22.73	9.09	0	0	1.67	96.55	8.72	55.27	24.25
	11/21/2006	Fall	1	20	2	0.89	0	2.68	12.5	46.43	6.29	90.91	18.18	1.46	0	5.19	87.5	77.42	54.52	41.9
	04/30/2007	Spring	1	12	2	20	0	10	44	64	5.9	54.55	18.18	32.63	0	19.38	56	52.02	60.31	36.63
	11/01/2007	Fall	1	10	1	0	0	2.67	0	82.67	6.43	45.45	9.09	0	0	5.17	100	25.05	52.46	29.65
	05/30/2008	Spring	1	8	2	1.0	0	1.0	50.5	72.4	6.1	36.4	18.2	1.6	0.0	1.8	49.5	39.9	58.0	25.7
	10/31/2008	Fall	1	12	2	1.27	0	5.06	10.13	59.49	6.33	54.55	18.18	2.06	0.00	9.81	89.87	58.54	53.98	35.87
1AACO009.14	05/30/2008	Spring	1	6	1	0.0	0	0.0	47.7	74.8	6.1	27.3	9.1	0.0	0.0	0.0	52.3	36.5	57.3	22.8
	10/31/2008	Fall	1	11	1	0.00	0	2.63	6.14	81.58	5.89	50.00	9.09	0.00	0.00	5.10	93.86	26.62	60.50	30.65
1AACO014.57	05/23/2007	Spring	1	9	2	4.59	0	0	17.43	69.72	5.95	40.91	18.18	7.48	0	0	82.57	43.75	59.5	31.55
	11/07/2007	Fall	1	9	1	0	0	4.04	3.03	74.75	6.21	40.91	9.09	0	0	7.83	96.97	36.49	55.7	30.87
1ALOE001.99	06/01/2006	Spring	1	9	3	6.67	0	1.9	34.29	81.9	5.84	40.91	27.27	10.88	0	3.69	65.71	26.15	61.2	29.48
	09/19/2006	Fall	1	6	2	1.04	0	2.08	22.92	94.79	5.9	27.27	18.18	1.7	0	4.04	77.08	7.53	60.36	24.52

Table 3-5 shows the total number of individuals found in each waterbody, classified, in most cases, at the family level. **Figure 3-2** shows the percent composition of each assessment by major taxa. In all of the impaired segments, Hydropsychidae has the largest number of individuals, followed by Chironomidae. One of these two taxa is the dominant taxa in each of the 21 assessments, with Hydropsychidae the dominant taxon in over three-quarters of the assessments. In seven out of 21 assessments, Hydropsychidae and Chironomidae are the two most dominant taxa. Only once in the remaining 14 cases, when Chironomidae and Baetidae were dominant, is Hydropsychidae or Chironomidae replaced in the dominant two taxa by a more pollutant intolerant taxon.

Table 3-5: Macroinvertebrates Observed in Accotink Creek Watershed by DEQ

Class	Order	Family	Upper Accotink	Lower Accotink	Long Branch	Total
Bivalvia	Veneroida	Corbiculidae	9	62	0	71
Bivalvia	Veneroida	Sphaeriidae	0	12	0	12
Clitellata	Haplotaxida	Tubificidae	0	36	0	36
Gastropoda	Basommatophora	Ancylidae	0	20	0	20
Gastropoda	Basommatophora	Physidae	1	15	0	16
Gastropoda	Basommatophora	Planorbidae	0	3	0	3
Gastropoda	Neotaenioglossa	Hydrobiidae	0	4	0	4
Hirudinea			0	1	0	1
Hirudinea	Arhynchobdellida	Hirudinidae	0	1	0	1
Insecta	Odonata	Coenagrionidae	0	47	0	47
Insecta	Coleoptera	Dryopidae	0	2	0	2
Insecta	Coleoptera	Dytiscidae	1	0	0	1
Insecta	Coleoptera	Elmidae	3	10	3	16
Insecta	Diptera	Chironomidae (A)	22	305	55	382
Insecta	Diptera	Chironomidae (B)	0	23	3	26
Insecta	Diptera	Empididae	0	1	0	1
Insecta	Diptera	Muscidae	0	0	1	1
Insecta	Diptera	Simuliidae	38	82	3	123
Insecta	Diptera	Tipulidae	5	21	5	31
Insecta	Ephemeroptera	Baetidae	5	32	7	44
Insecta	Ephemeroptera	Caenidae	0	1	0	1
Insecta	Ephemeroptera	Heptageniidae	0	5	1	6
Insecta	Hemiptera	Gerridae	0	21	0	21
Insecta	Hemiptera	Veliidae	0	2	0	2
Insecta	Megaloptera	Corydalidae	5	9	0	14
Insecta	Odonata	Aeshnidae	0	5	0	5
Insecta	Odonata	Calopterygidae	0	8	0	8
Insecta	Odonata	Corduliidae	0	1	0	1
Insecta	Odonata	Gomphidae	0	2	0	2
Insecta	Plecoptera	Nemouridae	0	2	0	2
Insecta	Trichoptera	Hydropsychidae	103	559	122	784
Malacostraca	Amphipoda	Crangonyctidae	0	1	0	1
Malacostraca	Amphipoda	Gammaridae	0	53	0	53

Class	Order	Family	Upper Accotink	Lower Accotink	Long Branch	Total
Malacostraca	Decapoda	Cambaridae	0	18	1	19
Malacostraca	Isopoda	Asellidae	0	1	0	1
Oligochaeta				14	0	14
Oligochaeta	Haplotaxida	Lumbricidae	0	11	0	11
Oligochaeta	Lumbriculida	Lumbriculidae	13	58	0	71
Oligochaeta	Tubificida	Naididae	0	12	0	12
Turbellaria	Tricladida		3	3	0	6

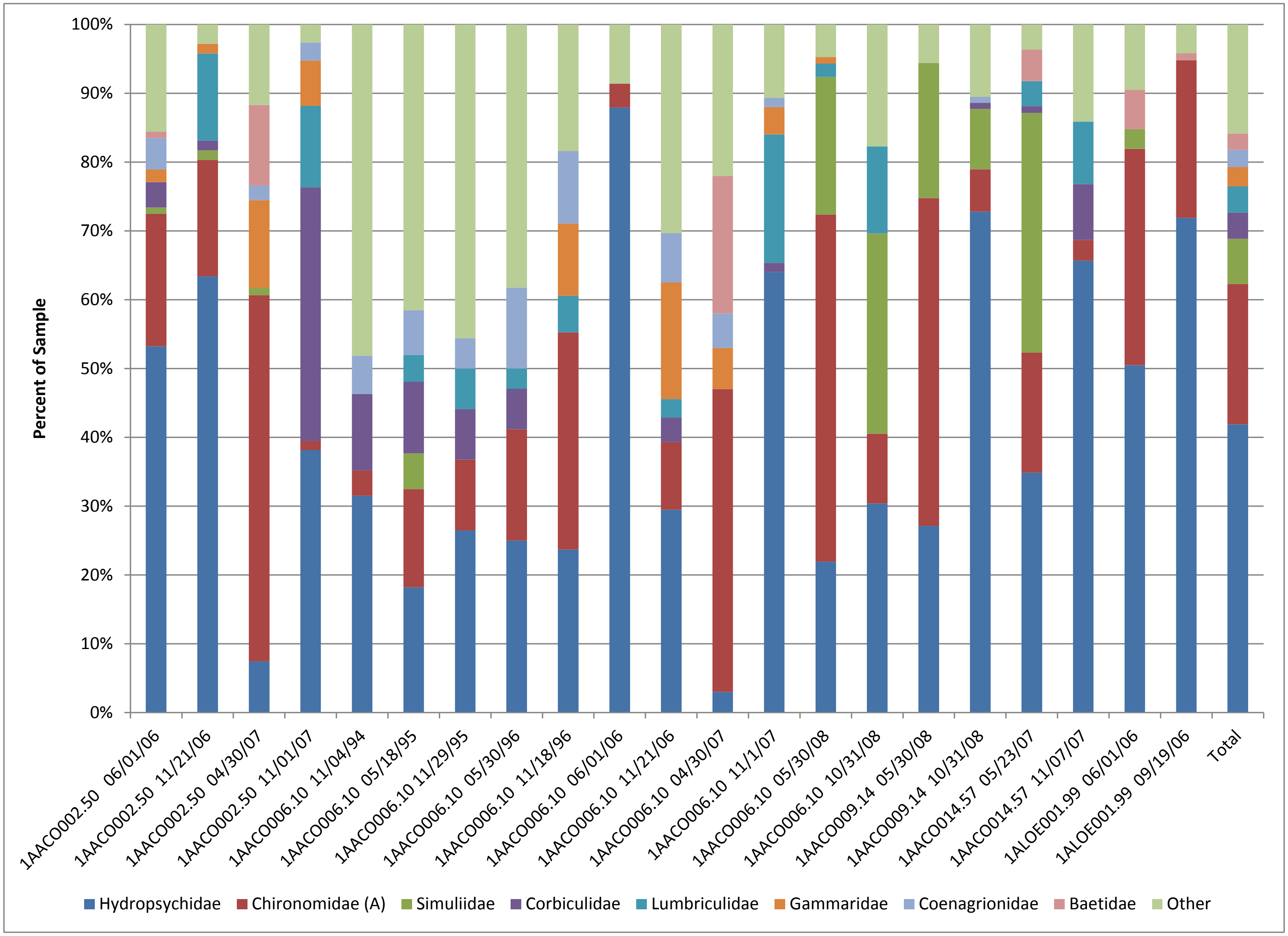

Figure 3-2: Distribution of Taxa in DEQ Assessments in Accotink Creek

3.1.2 EPA Biological Monitoring

The EPA (Selvakumar et al., 2008) performed a study in Accotink Creek to determine the impact of stream restoration on water quality and the health of the biological community. The opportunity for the study was provided by the City of Fairfax's stream restoration project on Accotink Creek, constructed from March to May in 2006, which restored 1,800 linear feet of the stream from Lee Highway to Old Lee Highway. **Figure 3-3** shows the location of the restored section. The restoration included (1) bank stabilization with coir fiber logs, erosion control fabrics, and willow stakes; (2) improvement of the vegetative stream buffer with dense planting and seeding of native vegetation; and (3) placement of rocks to divert flow to the center of the stream, reduce slope, and form step pools. The EPA, in conjunction with the USGS, began biological and water quality monitoring in December 2005, before construction began, and continued monitoring until January 2008, approximately a year and a half after the completion of the stream restoration. The objective of the EPA study was to compare monitoring results before and after stream restoration to test whether water quality, the benthic macroinvertebrate community, and physical habitat changed.

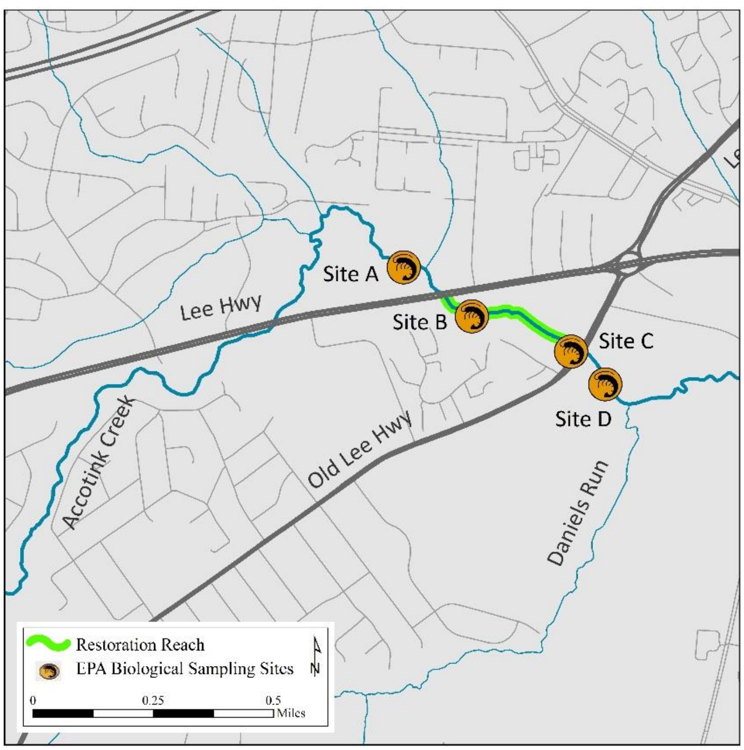

Figure 3-3: EPA Biological Monitoring Stations

Macroinvertebrate sampling was performed at four sites in the vicinity of the restoration project: one site (A) upstream of the restoration, two sites (B and C) within the restored reach, and a fourth site (D) downstream of the restoration project. The locations of these sites are shown in **Figure 3-3**. A fifth site in a restored park upstream of the project (RUP) was also monitored as a control. Selvakumar et al. (2008) do not identify its location. The sites were sampled three times (twice for RUP) before the restoration was started and five times after it was completed. Sites B and C within the restored reach had to be moved slightly from their original locations because the restoration made the original sites inappropriate for benthic sampling.

Selvakumar et al. (2008) calculated a VSCI score for each sample. **Table 3-6** shows the metric scores and the VSCI scores taken in the pre-restoration period. Selvakumar et al. (2008) discuss post-restoration VSCI scores and other results, but outside of their discussion the post-restoration monitoring results and metric scores were not available for analysis. Selvakumar et al. (2008) report that the metrics for EPT Taxa, Percent Ephemeroptera, Percent Plecoptera, and Trichoptera (excluding Hydropsychidae), and Percent Scrapers all score poorly, both before and after restoration. All but one of the VSCI scores is below 30. **Table 3-7** shows the number of individuals found by taxa at the family level in the pre-restoration period. The two most prevalent taxa are Chironomidae and Hydropsychidae. Selvakumar et al. (2008) noted that in the pre-restoration period Chironomidae were dominant while post-restoration Hydropsychidae were dominant. They speculated that stream restoration may be responsible for the change in dominance, but the change in dominance happened at both the control site (RUP) and the upstream site A, making it unlikely that the stream restoration explains the change in the dominant taxon.

Selvakumar et al. (2008) did detect a small but statistically significant improvement in VSCI scores at all sites before and after restoration. They also detected statistically significant improvements in the HBI and EPT Taxa metrics for all sites. They suggested that it might take longer than two years of post-restoration monitoring for stream restoration to have a greater positive impact on the biological community. They also suggested that control of stormwater volume and pollutants associated with stormwater may be necessary to restore the health of the benthic community.

Table 3-6: Virginia Stream Condition Index and Component Metric Scores in Accotink Creek Watershed at EPA Monitoring Locations

Site	Date	% Ephem	% Top Two Taxa	% Chiron	EPT Taxa	% PT - H	% HBI	Total Taxa	% Scrap	VSCI
A	03/13/2006	0	76.50	47.06	9.09	0	46.14	22.73	0	25.2
A	11/03/2005	0	41.29	33.61	9.09	0	60.18	22.73	2.7	21.2
A	12/07/2005	0	71.59	10.09	9.09	0	58.42	22.73	0	21.5
B	03/13/2006	0	59.50	52.94	9.09	0	46.71	22.73	0	23.9
B	11/03/2005	4.37	60.64	59.82	18.18	0	60.79	27.27	1.4	29.1
B	12/07/2005	0	80.28	32.10	9.09	0	56.28	22.73	0	25.1
C	3/13/2006	0	85.39	34.55	9.09	0	51.07	27.27	2.9	26.3
C	11/03/2005	0	68.94	33.94	9.09	0	59.78	22.73	0	24.3
C	12/07/2005	0	97.72	38.10	9.09	0	58.40	40.91	1.5	30.7
D	03/13/2006	0	95.31	48.94	0.00	0	51.31	27.27	6.8	28.7
D	03/13/2006	0	76.27	38.89	9.09	0	49.02	18.18	13.4	25.6
D	11/03/2005	0	31.57	78.99	9.09	0	58.58	13.64	0	24.0
D	11/03/2005	0	73.99	56.80	9.09	0	57.41	22.73	2.5	27.8
D	12/07/2005	0	57.80	42.50	9.09	0	57.35	13.64	4	23.1
D	12/07/2005	0	100.00	30.16	9.09	0	56.49	27.27	1.2	28.0
RUP	03/13/2006	0	61.26	25.00	9.09	0	56.86	36.36	5.2	24.2
RUP	12/07/2005	0	94.72	36.13	9.09	0	59.57	27.27	1.3	28.5

Table 3-7: Macroinvertebrates Observed in Accotink Creek Watershed at EPA Monitoring Sites before Stream Restoration

Phylum	Class	Order	Family	Total
Annelida	Oligochaeta			21
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	55
Annelida	Oligochaeta	Tubificida	Naididae	50
Arthropoda	Insecta	Coleoptera	Elmidae	2
Arthropoda	Insecta	Coleoptera	Psephenidae	1
Arthropoda	Insecta	Diptera	Ceratopogonidae	1
Arthropoda	Insecta	Diptera	Chironomidae	925
Arthropoda	Insecta	Diptera	Empididae	6
Arthropoda	Insecta	Diptera	Sciaridae	1
Arthropoda	Insecta	Diptera	Tipulidae	24
Arthropoda	Insecta	Diptera		1
Arthropoda	Insecta	Ephemeroptera	Baetidae	3
Arthropoda	Insecta	Odonata	Calopterygidae	1
Arthropoda	Insecta	Trichoptera	Hydropsychidae	433
Arthropoda	Malacostraca	Amphipoda		1
Mollusca	Gastropoda	Basommatophora	Ancylidae	3
Mollusca	Gastropoda	Basommatophora	Physidae	7
Nematoda				6
Nemertea				16

3.1.3 Fairfax County Biological Monitoring

Fairfax County began biological monitoring in 1999 during the development of the county's Stream Protection Strategy (SPS) (FCDPWES, 2001). The goals of the SPS were to (1) determine the baseline condition of Fairfax County streams; and (2) develop a strategy for their protection and restoration. Biological assessment was a key component of the strategy. Benthic macroinvertebrates and fish were sampled at 114 locations throughout the county, including twelve sites in the Accotink Creek watershed. **Figure 3-4** shows the location of these monitoring sites.

Benthic macroinvertebrates were sampled using the Mid-Atlantic Coastal Streams Workgroup (MACSW) "multi-habitat" method, in which undercut banks, aquatic vegetation, sand, cobble, and snags are sampled in proportion to their presence in the sampled reach (FCDPWES, 2006). Benthic samples were assessed at the genus level using a ten metric Index of Biotic Integrity (IBI) in the Piedmont and a five metric IBI in the Coastal Plain. **Table 3-8** lists the component metrics of the IBIs. Each metric is scored on a scale from one to ten, and the metrics are summed to a composite score. Component scores from the Coastal Plain are doubled before being rated, to account for the use of only five metrics. Samples with a composite score of 80-100 were rated Excellent; 60-80, Good; 40-60, Fair; 20-40, Poor; and 0-20, Very Poor. Fish samples were assessed based on taxa richness (the number of distinct species).

Table 3-9 summarizes the SPS assessments. The benthic IBI at all assessed sites were rated Poor or Very Poor, except for one site on the upper Accotink Creek mainstem which was rated Fair. All sites in the lower Accotink Creek watershed with the exception of a site on Long Branch South were rated Moderate for Fish Taxa Richness. Sites on Long Branch and upper mainstem Accotink Creek were also rated Moderate for Fish Taxa Richness, except for the uppermost site on the mainstem, which was rated Low. Sites on upper Accotink Creek tributaries, however, were all rated Low or Very Low.

Originally, FCDPWES planned to continue biological monitoring at the SPS sites on a five-year rotation, sampling approximately 20-25 of sites each year. A second round of sampling was performed on the Accotink Creek mainstem in 2001, and the results of those assessments are also shown in **Table 3-9**. In 2004, however, FCDPWES switched to a probabilistic monitoring strategy in which biological monitoring locations were randomly selected according to a stratified sampling scheme based on stream order. The locations of the probabilistic monitoring strategy sites are shown in **Figure 3-5**. A fish IBI was also developed. **Table 3-10** shows the component metrics for the fish IBI. Two different scoring criteria were used for the metrics, depending on whether the watersheds were less than or greater than 50 km^2. **Table 3-11** gives the rating for the composite scores of the metrics. Monitoring of the fish community was restricted to streams second order or larger.

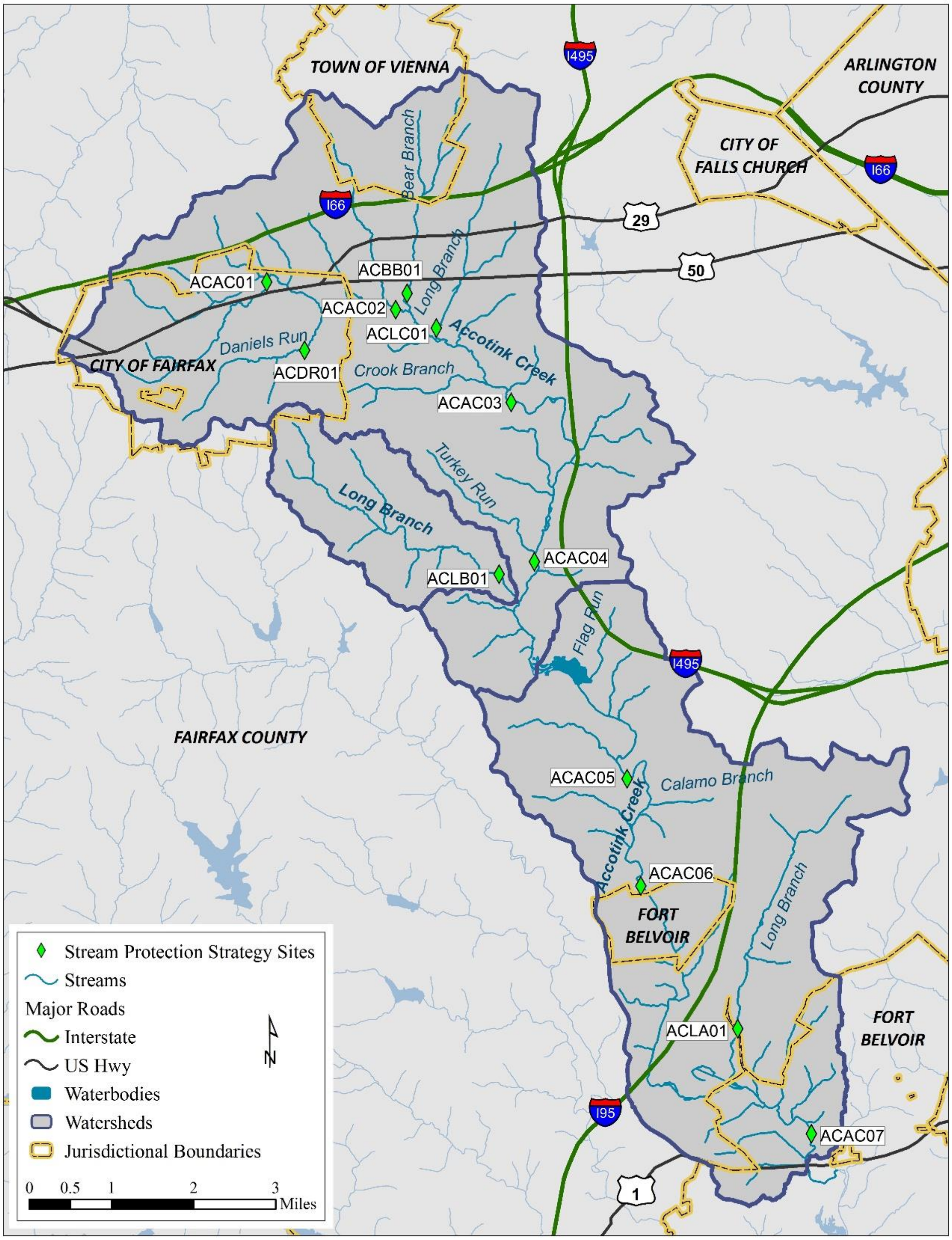

Figure 3-4: Location of Fairfax County Stream Protection Strategy Sites

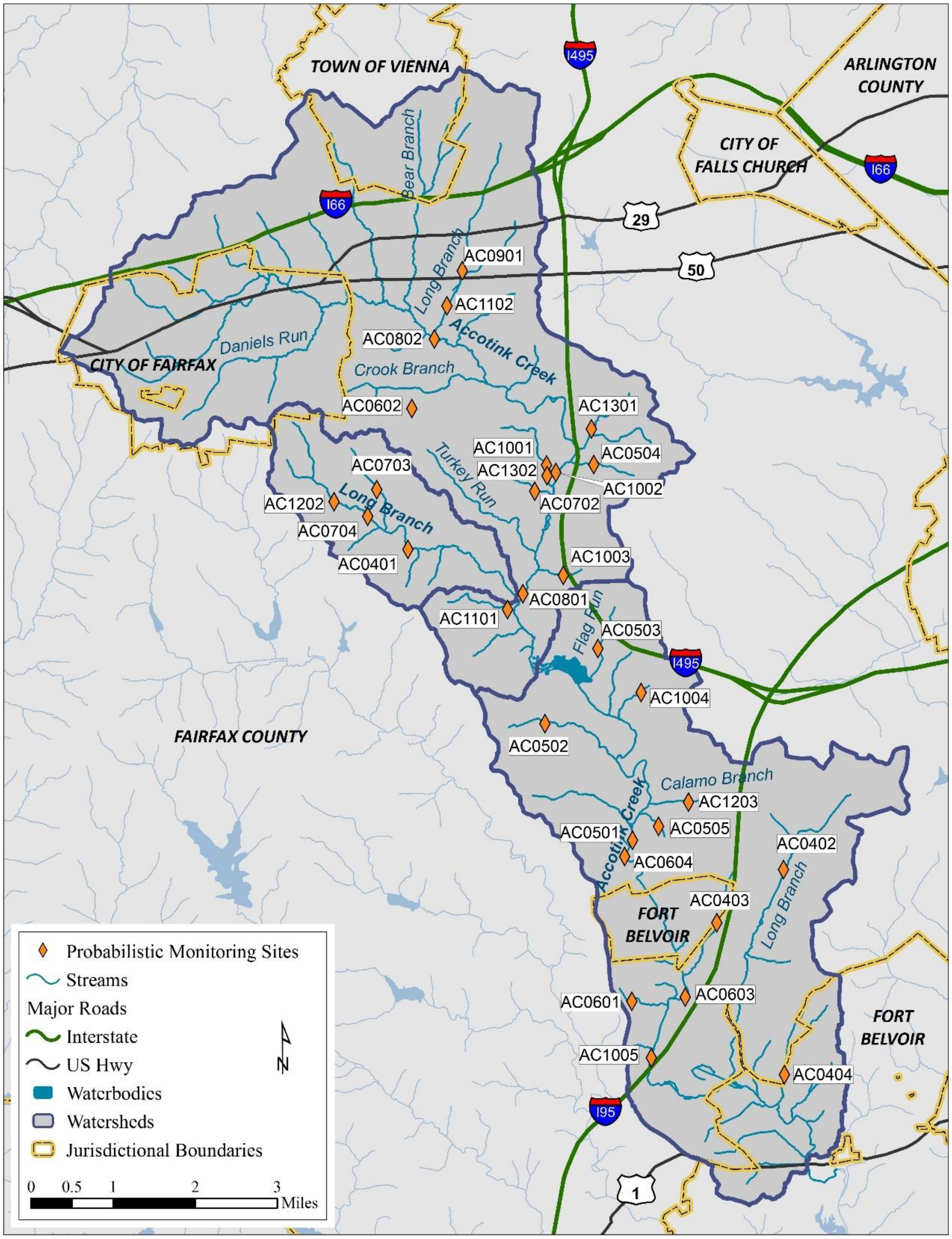

Figure 3-5: Location of Fairfax County Probabilistic Monitoring Sites

Table 3-8: Component Metrics of Fairfax County's Macrobiotic Index of Biotic Integrity

Metric	Description	Piedmont	Coastal Plain
Taxa Richness	Number of taxa	X	X
EPT Taxa	Number of Mayfly, Stonefly, and Caddisfly taxa	X	X
Percent EPT	Percent of Mayfly, Stonefly, and Caddisfly taxa (excluding tolerant net-spinning Caddisflies)	X	
Percent Ephemeroptera	Percent of individuals that are Mayflies		X
Percent Trichoptera w/o Hydropsychidae	Percent of individuals that are Caddisflies (excluding tolerant net-spinning Caddisflies)	X	
Percent Coleoptera	Percent of individuals that are beetles	X	
Family Biotic Index	General tolerance of sample	X	
Hilsenhoff Biotic Index	General tolerance of sample		X
Percent Dominance	Percent of individuals belonging to the dominant taxa	X	
Percent Clingers	Percent of individuals whose habitat type is clingers		X
Percent Clingers + Percent Plecoptera	Percent of individuals whose habitat type is clingers plus percent of individuals which are stoneflies but not clingers	X	
Percent Shredders	Percent of individuals whose primary functional feeding group is shredders	X	
Percent Predators	Percent of individuals whose primary functional feeding group is predators	X	

Table 3-9: Summary of Fairfax County Biological Assessments for the Stream Protection Strategy

Watershed/ Waterbody	Site ID	Year	Physiographic Province	Benthic IBI	Benthic Rating	Fish Taxa Richness
Upper Mainstem	ACAC01	1999	Piedmont	13.11	Poor	Low
	ACAC02	1999	Piedmont	24.16	Fair	Moderate
	ACAC03	1999	Piedmont	2.64	Poor	Moderate
	ACAC04	1999	Piedmont	13.70	Poor	Moderate
	ACAC02	2001	Piedmont	5.63	Very Poor	Moderate
	ACAC03	2001	Piedmont	11.26	Very Poor	Moderate
Upper Tributary	ACBB01	1999	Piedmont	5.84	Very Poor	Low
	ACDR01	1999	Piedmont	3.43	Very Poor	Very Low
	ACLC01	1999	Piedmont	2.42	Very Poor	Low
Lower Mainstem	ACAC05	1999	Piedmont	16.23	Very Poor	Moderate
	ACAC06	1999	Piedmont	10.54	Poor	Moderate
	ACAC07	1999	Coastal Plain	13.61	Poor	Moderate
	ACAC05	2001	Piedmont	24.15	Poor	Moderate
	ACAC07	2001	Coastal Plain	37.33	Poor	Moderate
Lower Tributary	ACLA01	1999	Coastal Plain	22.05	Poor	Low
Long Branch	ACLB01	1999	Piedmont	13.49	Poor	Moderate

Table 3-10: Component Metrics of Fairfax County Fish Index of Biotic Integrity

Metric	Description
Number of Species	Number of species
Number of Darter Species	Number of species that are darters
Percent Tolerant	Percent of individuals classified as pollution tolerant
Number of Intolerant Species	Number of species classified as intolerant to pollution
Percent Generalists (AHI)	Percent of individuals in algivore/herbivore/invertivore (AHI) trophic guild
Percent Benthic Invertivores	Percent of individuals whose primary trophic guild is benthic invertivores
Percent Lithophils – Tolerants	Percent of individuals spawning on clean gravel who are pollutant tolerant

Table 3-11: Fairfax County Fish IBI Ratings

Ratings	Fish IBI Score
Excellent	>29
Good	23-28
Fair	18-22
Poor	13-17
Very Poor	<13

Table 3-12 summarizes the results of the probabilistic biological assessment. There was only one site assessed on the upper Accotink Creek mainstem, and its rating was Poor for benthic macroinvertebrates and Good for fish. Benthics were assessed at twelve sites on upper mainstem tributaries; two sites were rated Fair and the rest were rated Poor or Very Poor. Six sites on upper mainstem tributaries were all rated Poor or Very Poor for fish. Benthics were assessed at four sites in the Long Branch watershed, and all were rated Poor or Very Poor. Fish assessments were performed at three sites; two were rated Poor or Very Poor and the third Fair. The benthic communities in lower mainstem tributaries were also rated Poor or Very Poor at the seven sites sampled. Of the four sites assessed for fish, one was rated Fair and the rest Poor or Very Poor. The health of the biological community was somewhat better in the lower mainstem. Benthics and fish were assessed at four sites on the lower Accotink Creek mainstem. Three of the four were rated Fair for benthics; the other site was rated Very Poor. Two of the four sites assessed by the fish IBIs were rated Good and the other two were rated Fair.

Table 3-12: Fish and Benthic Ratings for Fairfax County Probabilistic Monitoring Program

Watershed/ Waterbody	Site ID	Year	Physiographic Province	Stream Order	Drainage Area (mi²)	Benthic IBI	Benthic Rating	Fish IBI	Fish Rating
Upper Mainstem	AC1002	2010	Piedmont	4	0.52	23.2	Poor	71.4	Good
Upper Tributary	AC0504	2004	Piedmont	1	0.25	10	Very Poor	N/A	N/A
	AC0602	2006	Piedmont	1	0.03	28	Poor	N/A	N/A
	AC0702	2007	Piedmont	1	0.35	18	Very Poor	N/A	N/A
	AC0801	2008	Piedmont	4	3.9	42.4	Fair	36	Poor
	AC0802	2008	Piedmont	3	12.28	15.6	Very Poor	36	Poor
	AC0901	2009	Piedmont	1	1.3	14.4	Very Poor	35.7	Poor
	AC1001	2010	Piedmont	2	20.55	43.4	Fair	7.1	Very Poor
	AC1003	2010	Piedmont	1	0.03	20.4	Poor	N/A	N/A
	AC1101	2011	Piedmont	1	0.41	15.7	Very Poor	28.6	Poor
	AC1102	2011	Piedmont	2	2.22	39.4	Poor	N/A	N/A
	AC1301	2013	Piedmont	2	0.44	16.2	Very Poor	N/A	N/A
	AC1302	2013	Piedmont	2	0.53	16.9	Very Poor	21.4	Poor
Lower Mainstem	AC0501	2005	Piedmont	4	35.55	45	Fair	25	Fair
	AC0603	2006	Piedmont	4	38.34	6.3	Very Poor	33	Good
	AC0604	2006	Piedmont	4	35.9	41.5	Fair	25	Fair
	AC1005	2010	Coastal Plain	4	39.29	54.3	Fair	57.1	Good
Lower Tributary	AC0402	2004	Coastal Plain	3	2.65	23.8	Poor	0	Very Poor
	AC0403	2004	Piedmont	1	0.35	31.9	Poor	N/A	N/A
	AC0404	2004	Coastal Plain	2	0.74	18.2	Very Poor	21.4	Poor
	AC0502	2005	Piedmont	2	0.4	29	Poor	23	Poor
	AC0503	2005	Piedmont	1	0.49	10	Very Poor	27	Fair
	AC0505	2005	Piedmont	1	0.09	33	Poor	N/A	N/A
	AC0601	2006	Coastal Plain	1	0.02	15.8	Very Poor	N/A	N/A
Long Branch	AC0401	2004	Piedmont	3	2.57	21.5	Poor	14.3	Very Poor
	AC0703	2007	Piedmont	1	0.37	16	Very Poor	N/A	N/A
	AC0704	2007	Piedmont	2	1.19	29	Poor	43	Fair
	AC1202	2012	Piedmont	2	0.92	16.3	Very Poor	28.6	Poor

Table 3-13 summarizes, mostly at the family level, the benthic taxa identified by FCDPWES in the Accotink Creek watershed from 1999-2013. In all Accotink Creek samples, the two most prevalent taxa found by FCDPWES are Oligochaeta and Chironomidae, where Oligochaeta are somewhat more prevalent in the mainstem Accotink Creek and Chironomidae are more prevalent in the tributaries, including Long Branch. The pollutant tolerant caddisfly, Hydropsychidae, is found in numbers an order of magnitude less than the two most prevalent taxa. All other taxa are found in numbers another order of magnitude less than Hydropsychidae, demonstrating the prevalence of the dominant two taxa and how few sensitive taxa are found in the Accotink Creek

watershed. Over the period 1999-2013, only 15 mayflies (Ephemeroptera) and 17 stoneflies (Plecoptera) were identified.

Table 3-13: Macroinvertebrates Observed in Accotink Creek Watershed at FCDPWES Monitoring Sites

Class	Order	Family	Upper Mainstem	Upper Tributary	Lower Mainstem	Lower Tributary	Long Branch	Total
Arachnida	Trombidiformes	Lebertiidae	0	0	0	4	2	6
Arachnida	Trombidiformes	Sperchonidae	0	0	2	0	0	2
Arachnida	Trombidiformes		0	1	0	0	0	1
Arachnida	Trombidiformes	Unionicolidae	0	0	0	1	0	1
Bivalvia	Veneroida	Corbiculidae	2	5	12	2	0	21
Bivalvia	Veneroida	Sphaeriidae	0	7	13	2	0	22
Gastropoda	Basommatophora	Ancylidae	3	4	0	3	0	10
Gastropoda	Basommatophora	Lymnaeidae	0	1	2	3	0	6
Gastropoda	Basommatophora	Physidae	0	10	3	9	1	23
Gastropoda	Basommatophora	Planorbidae	0	2	1	17	0	20
Gastropoda	Heterostropha	Valvatidae	0	0	12	0	0	12
Gastropoda			0	1	0	0	0	1
Hirudinea			0	5	0	0	0	5
Hirudinea	Rhynchobdellida	Glossiphoniidae	0	0	2	0	0	2
Insecta	Coleoptera	Dryopidae	0	1	0	1	0	2
Insecta	Coleoptera	Dytiscidae	0	1	0	3	0	4
Insecta	Coleoptera	Elmidae	6	8	30	0	1	45
Insecta	Coleoptera	Hydrophilidae	0	0	5	1	0	6
Insecta	Diptera	Ceratopogonidae	0	1	0	0	1	2
Insecta	Diptera	Chironomidae	201	1,498	475	759	697	3,630
Insecta	Diptera	Dixidae	0	1	0	0	0	1
Insecta	Diptera	Empididae	1	5	0	0	1	7
Insecta	Diptera	Psychodidae	0	2	0	0	0	2
Insecta	Diptera	Simuliidae	1	2	5	1	31	40
Insecta	Diptera	Stratiomyidae	0	1	0	0	0	1
Insecta	Diptera	Tipulidae	2	22	3	10	1	38
Insecta	Diptera	Unidentified	0	2	2	0	3	7
Insecta	Ephemeroptera	Baetidae	0	3	0	0	0	3
Insecta	Ephemeroptera	Caenidae	0	0	0	5	0	5
Insecta	Ephemeroptera	Ephemerellidae	0	0	1	0	0	1
Insecta	Ephemeroptera	Heptageniidae	1	0	4	0	0	5
Insecta	Ephemeroptera	Leptophlebiidae	0	1	0	0	0	1
Insecta	Lepidoptera	Pyralidae	0	1	0	2	0	3
Insecta	Lepidoptera	Unidentified	0	1	0	0	0	1
Insecta	Megaloptera	Corydalidae	0	2	2	3	0	7
Insecta	Odonata	Calopterygidae	0	2	10	5	0	17
Insecta	Odonata	Coenagrionidae	0	6	27	0	0	33
Insecta	Odonata	Unidentified	0	0	0	2	0	2
Insecta	Plecoptera	Nemouridae	0	15	1	1	0	17
Insecta	Trichoptera	Hydropsychidae	57	188	44	72	46	407
Insecta	Trichoptera	Limnephilidae	0	0	0	0	1	1
Insecta	Trichoptera	Philopotamidae	0	22	0	0	1	23
Malacostraca	Amphipoda	Crangonyctidae	0	10	16	9	0	35
Malacostraca	Amphipoda	Gammaridae	0	25	1	1	0	27

Class	Order	Family	Upper Mainstem	Upper Tributary	Lower Mainstem	Lower Tributary	Long Branch	Total
Malacostraca	Amphipoda	Unidentified	0	0	0	1	0	1
Malacostraca	Decapoda	Cambaridae	0	1	0	1	2	4
Malacostraca	Isopoda	Asellidae	0	4	0	9	1	14
Oligochaeta			777	995	792	758	362	3,684
Turbellaria	Tricladida	Planariidae	2	0	2	0	0	4
Turbellaria			0	0	0	0	3	3
Unidentified			2	1	0	0	0	3

Table 3-14 summarizes the fish taxa identified by FCDPWES in the Accotink Creek watershed from 1999-2013. The distribution of taxa is different in the lower mainstem of Accotink Creek than the other areas. The blacknose dace (*Rhinichthys atratulus*), the most prevalent fish elsewhere in the watershed, is observed far less frequently in the lower mainstem. The rosyside dace (*Clinostomus funduloides*) is absent from the lower mainstem, although it is not uncommon in the rest of the watershed. Conversely, the common shiner (*Luxilus cornutus*) is found in the lower mainstem, but not elsewhere in the watershed. Three fish species, the blacknose dace, the white sucker (*Catostomus commersoni*), and the tessellated darter (*Etheostoma olmstedi*), account for over 70% of the identified species outside of the lower mainstem. All three of these species are tolerant of pollution. The blacknose dace and the white sucker also belong to the algivore/herbivore/invertivore (AHI) trophic guild. The lower mainstem of Accotink Creek is more diverse. Six taxa account for approximately 70% of the fish identified there: the tessellated darter, satinfin shiners (Cyprinella spp)[2], the white sucker, the swallowtail shiner (*Notropis procne*), the American eel *(Anguilla rostrata*), and the redbreast sunfish (*Lepomis auritus*). The swallowtail shiner, the American eel, satinfin shiners , and the redbreast sunfish have a Moderate tolerance rating. The white sucker is the only member of the AHI trophic guild of the six prevalent taxa in the lower mainstem of Accotink Creek.

Lake Accotink acts as a fish migration barrier and may contribute to patterns of distribution or abundance of fish in the Accotink Creek watershed.

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[2] Includes satfin shiner (*Cypinella analostana*) and spotfin shiner (*Cypinella spiloptera*). http://www.fairfaxcounty.gov/dpwes/stormwater/fish/minnows2.htm#satinfin

Table 3-14: Fish Observed in Accotink Creek Watershed at FCDPWES Monitoring Sites

Species	Upper Mainstem	Upper Tributaries	Lower Mainstem	Lower Tributaries	Long Branch	Total
Rhinichthys atratulus	379	1,916	22	945	1,079	4,341
Etheostoma olmstedi	349	283	808	15	93	1,548
Catostomus commersoni	385	387	313	47	267	1,399
Cyprinella spp	262	201	501	14	12	990
Notropis procne	312	259	289	15	2	877
Semotilus atromaculatus	291	197	138	31	45	702
Lepomis macrochirus	38	141	138	4	6	327
Clinostomus funduloides	58	145	0	14	70	287
Lepomis auritus	0	2	179	73	0	254
Anguilla rostrata	4	4	188	15	10	221
Lepomis cyanellus	44	66	80	9	14	213
Rhinichthys cataractae	0	0	156	0	0	156
Ameiurus natalis	36	50	62	4	2	154
Luxilus cornutus	0	0	151	0	0	151
Erimyzon oblongus	54	3	6	1	5	69
Semotilus corporalis	0	1	9	55	0	65
Nocomis micropogon	0	0	54	0	0	54
Lepomis gibbosus	6	4	38	0	1	49
Micropterus salmoides	0	6	26	0	0	32
Gambusia holbrooki	3	1	2	9	0	15
Hypentelium nigricans	0	0	13	0	0	13
Notemigonus crysoleucas	4	0	3	0	0	7
Cyprinus carpio	0	0	5	0	1	6
Ameiurus nebulosus	1	0	4	0	0	5
Umbra pygmaea	0	0	0	5	0	5
Ictalurus punctatus	0	0	4	0	0	4
Fundulus heteroclitus	0	3	0	0	0	3
Hybognathus regius	0	0	3	0	0	3
Percina peltata	0	0	3	0	0	3
Fundulus diaphanus	0	0	2	0	0	2
Lepomis megalotis	0	1	1	0	0	2
Carassius auratus	0	0	0	0	1	1
Dorosoma cepedianum	0	0	1	0	0	1
Etheostoma blennioides	0	0	1	0	0	1
Lampetra aepyptera	0	0	0	1	0	1
Lepomis microlophus	0	0	0	0	1	1
Notropis hudsonius	0	0	1	0	0	1
Perca flavescens	0	0	1	0	0	1

3.1.4 Volunteer Monitoring

The Northern Virginia Soil and Water Conservation District (NVSWCD) sponsors a volunteer monitoring program in Fairfax County. NVSWCD trains volunteers in the Virginia Save Our Streams (SOS) monitoring protocol and coordinates the efforts of the volunteers. Monitoring results are submitted to both DEQ and FCDPWES, and supplement state and county assessments by (1) identifying streams of exceptional water quality, (2) identifying streams in poor health which may have water quality problems, and (3) measuring in the impact of best management practices (BMPs) or other pollution control measures.

Volunteer citizen monitoring data, collected in the Accotink Creek watershed 2003-2012, was submitted to DEQ from nine sites in the Accotink Creek watershed for the 2010, 2012, and 2014 Integrated Assessments. The sites are shown in **Figure 3-6**. SOS has separate protocols for hard-bottom and muddy-bottom streams, but all sites in the Accotink Creek watershed were assessed using the hard-bottom protocol. Under the SOS (2007) hard-bottom protocols, benthic macroinvertebrates are sampled in riffles and identified into 19 taxa at the family, order, or class level. **Table 3-15** shows the total number of individuals identified by taxa under the SOS protocol for each waterbody sampled in the Accotink Creek watershed, 2003-2012. Very few individuals from pollutant-sensitive taxa were found. The dominant taxa are worms (Oligocheata), common netspinners (Hydropyschidae), and midges (Chironomidae).

Under the SOS protocol, six metrics are calculated based on the benthic macroinvertebrate classification and combined in a multi-metric index. The average metric and index scores for each waterbody are also shown in **Table 3-15**. The ecological condition is classified as Acceptable if the multi-metric score is nine to twelve, and Unacceptable if the score is from zero and seven, while a score of eight represents a "Grey Zone" where the ecological condition cannot be determined. Average multi-metric scores for Accotink Creek waterbodies are all in the Unacceptable range. Of the 52 SOS assessments performed in the Accotink Creek watershed, one multi-metric score was in the Grey Zone and the rest were in the Unacceptable range.

Table 3-15: Summary of Volunteer Monitoring Results in Accotink Creek Watershed

Waterbody	Upper Accotink Creek	Lower Accotink Creek	Long Branch	Daniels Run	Calemo Branch
Stations	4	1	2	1	1
Samples	34	2	7	6	3
Worms	2,607	226	552	90	28
Flatworms	30	33	9	1	3
Leeches	33	1	3	0	0
Crayfish	18	0	11	0	0
Sowbugs	3	0	0	1	0
Scuds	4	0	20	1	1
Stoneflies	3	0	0	0	0
Mayflies	197	0	29	0	0
Dragonflies and Damselflies	30	0	5	0	0
Hellgrammites, Fishflies, and Alderflies	6	3	2	0	0
Common Netspinners	3,743	43	400	1,020	117
Most Caddisflies	93	0	0	1	0
Beetles	44	8	14	17	0
Midges	1,884	88	294	503	29
Blackflies	214	0	125	71	2
Most True Flies	183	0	37	17	12
Gilled Snails	8	2	3	0	0
Lunged Snails	15	0	9	8	14
Clams	146	15	10	0	0
Other Organisms	0	0	0	0	0
Define Other Organism	0	0	0	0	0
Total Organisms	9,261	419	1,523	1,731	206
Average Metric 1: Percent Mayflies, Stoneflies, and Most Caddisflies	3.3	0.0	1.8	0.0	0.0
Average Metric 2: Percent Common Netspinners	36.5	10.2	53.7	53.7	61.4
Average Metric 3: Percent Lunged Snails	0.4	0.0	0.8	0.5	7.5
Average Metric 4: Percent Beetles	0.8	1.9	1.5	0.4	0.0
Average Metric 5: Percent Tolerant	54.7	86.6	37.7	44.2	30.6
Average Metric 6: Percent Non-Insect	35.7	66.2	20.8	9.3	20.2
Average Multi-Metric Score	3.9	4.5	4.3	5.0	2.3

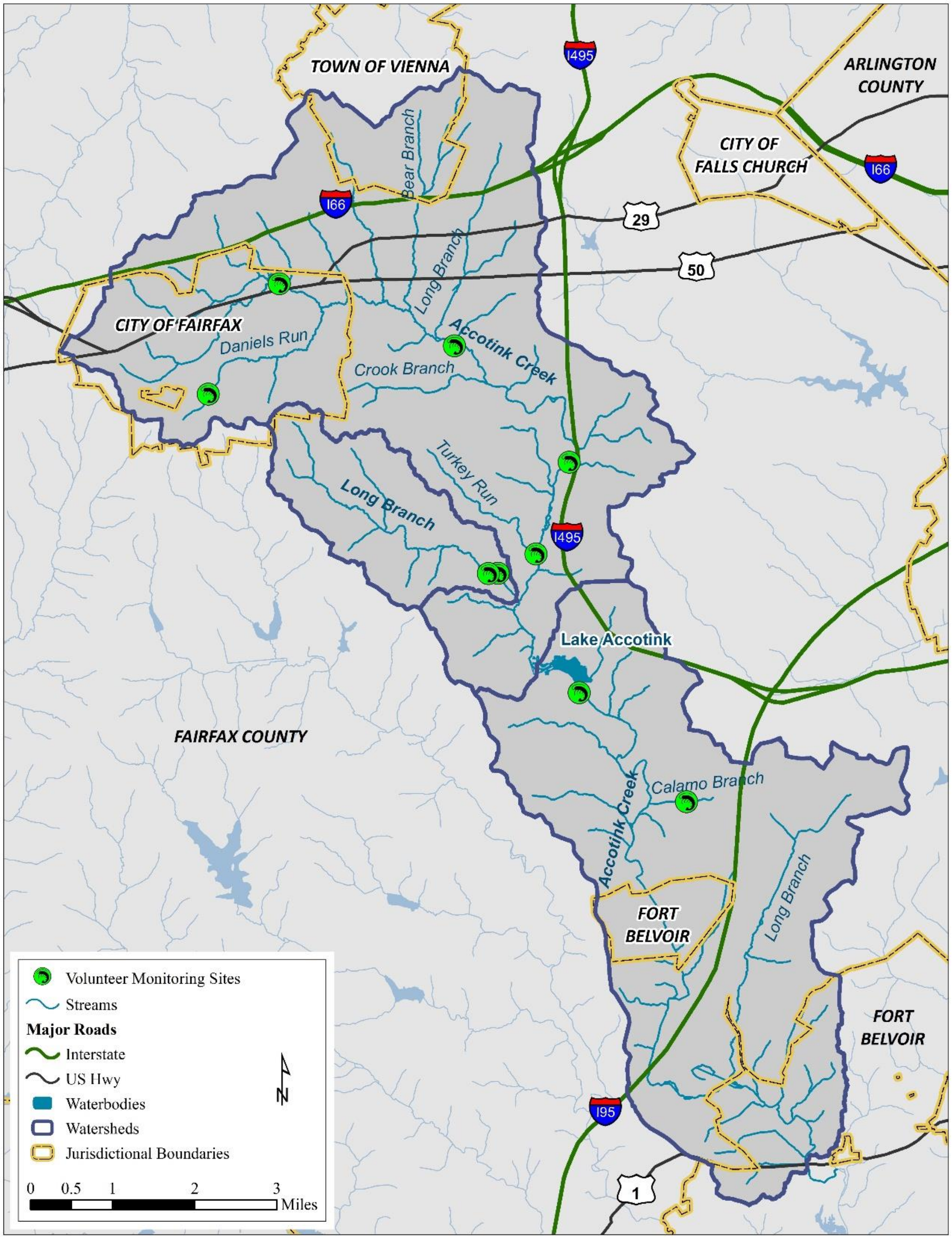


Figure 3-6: Location of Volunteer Monitoring Sites

3.1.5 Summary of Biological Monitoring in the Accotink Creek Watershed

Although the methods of assessment used by FCDPWES or volunteer monitors differ from the methods used by DEQ and EPA, all biological monitoring programs agree that the health of the aquatic community in the Accotink Creek watershed may be in fair condition at best, but is frequently in poor condition. Monitoring by FCDPWES and volunteers show that unhealthy biological communities are not confined to DEQ and EPA sampling locations on the impaired segments of mainstem Accotink Creek or Long Branch, but can be found on other Accotink Creek tributaries and in all stream orders.

3.2 Habitat Assessment

DEQ and FCDPWES have performed habitat assessments in the Accotink Creek watershed.

3.2.1 DEQ Habitat Assessment

DEQ routinely performs a habitat assessment of the biological monitoring site as part of its biological assessment. Habitat is evaluated using ten metrics[3], each scored on a scale from 0 to 20. Scores from 0 to 5 are considered Poor, between 6 and 10 are Marginal, 11 to 15 are Suboptimal, and 16 through 20 are Optimal. **Table 3-16** defines the habitat metrics and describes the metrics under Optimal and Poor conditions. Virginia's Probabilistic Monitoring Program (ProbMon) has adopted condition thresholds for biological stressors that do not have water quality criteria, including habitat degradation. According to the ProbMon analysis, overall habitat scores greater than 150 indicate Optimal conditions and overall scores less than 120 indicate Suboptimal conditions. (The ProbMon program is discussed in greater detail in **Section 3.5**.)

[3] Two additional metrics were originally used: COVER, which measures instream cover for fish, and GRAZE, which measures grazing or mowing of riparian vegetation (Burton and Gerritsen, 2003). These metrics were not used in the Accotink Creek watershed after 1996 and have been excluded from the analysis to facilitate comparison.

Table 3-16: Habitat Metrics (Burton and Gerritsen, 2003)

Metric	Definition	Optimal Conditions	Poor Conditions
ALTER	Channel Alteration	Not channelized	Extensively channelized
BANKS	Bank stability	Low erosion	High erosion
BANKVEG	Bank vegetative protection	Well-armored banks	No bank protection
EMBED	Embeddedness	Little or no fine sediment	Abundant fine sediment
FLOW	Channel flow	Channel filled	Low wetted width
RIFFLES	Frequency of riffles	Frequent riffle/run sequence	Infrequent riffles
RIPVEG	Riparian vegetation zone width	>18 meter width	<6 meter width
SEDIMENT	Sediment deposition	No sediment deposition	High deposition
SUBSTRATE	Epifaunal substrate	Mixed rubble, extensive	Rubble lacking
VELOCITY	Velocity/depth regimes	Diverse velocity/depth regimes	One regime (slow/deep)

Table 3-17 shows the habitat assessment scores for Accotink Creek, corresponding to the biological assessments at the sites shown in **Figure 3-1**. As **Table 3-17** shows, most of the habitat assessments were performed in the lower portion of the Accotink Creek mainstem, and most of those were performed at Station 1AACO006.10. Five of the assessments at 1AACO006.10 were performed in the mid-1990's. The results from these assessments are distinctly different from those performed in 2006-2008. Only one of the five earlier assessments was Suboptimal, and one assessment was Optimal, while none of the later assessments were Optimal, and three of the six assessments were Suboptimal. The later assessments have Marginal scores half the time or more for Banks, Bank Vegetation, Embeddedness, Sediment, and Substrate, while the earlier assessments did not have Marginal scores for the first three metrics. It is not clear, whether the difference in habitat assessment results over time represents a change in habitat conditions or a change in methodology.

Since 2006, six of twelve assessments in the lower mainstem of Accotink Creek were below the Suboptimal threshold for overall habitat score. The Bank, Bank Vegetation, Embeddedness, Sediment, and Substrate metrics were Marginal in half or more of the assessments. Ten assessments of Bank Stability were Marginal, the other two were Poor. Poor scores were given for Channel Alteration, Embeddedness, Sediment, and Substrate. Overall, the lower Accotink Creek mainstem would appear to suffer from unstable and marginally-vegetated banks, contributing to sedimentation in both pools and riffles and suboptimal substrate.

DEQ performed two habitat assessments each in the upper Accotink Creek mainstem and Long Branch. The overall habitat scores were Suboptimal for one of the assessments in the upper mainstem and both of the assessments in Long Branch. A greater variety of metrics were Marginal in the Long Branch assessments, though Flow Alteration, Riparian Vegetation, and Sedimentation were Marginal in both assessments. Bank Stability had the only Poor score in either of the two Long Branch assessments. The assessment with the Suboptimal score in the upper mainstem also had a Poor Bank Stability score.

Table 3-17: Habitat Scores at DEQ Monitoring Locations in Accotink Creek Watershed

Watershed	Station ID	Date	Habitat Metric[1]										Total Habitat Score[2]
			ALTER	BANKS	BANKVEG	EMBED	FLOW	RIFFLES	RIPVEG	SEDIMENT	SUBSTRATE	VELOCITY	
Lower Accotink	1AACO002.50	6/1/2006	14	8	12	8	9	7	14	6	8	13	99
		11/21/2006	4	7	10	2	17	13	18	2	3	15	91
		4/30/2007	17	10	20	11	12	11	20	10	13	15	139
		11/1/2007	17	7	11	10	8	16	18	5	8	15	115
	1AACO006.10	11/4/1994	10	14	15	14	16	15	5	8	3	16	116
		5/18/1995	12	14	16	17	17	15	12	10	9	17	139
		11/29/1995	10	16	17	17	18	16	10	11	6	18	139
		5/30/1996	11	14	17	18	18	16	10	9	11	18	142
		11/18/1996	12	16	14	17	18	17	14	15	12	18	153
		6/1/2006	15	10	12	6	12	12	12	10	8	12	109
		11/21/2006	11	10	12	4	18	13	9	6	7	14	104
		4/30/2007	18	10	18	11	10	15	19	10	13	15	139
		11/1/2007	17	7	9	10	10	17	16	7	10	15	118
		5/30/2008	16	4	6	15	19	16	18	14	7	17	132
		10/31/2008	17	5	7	15	13	14	18	8	14	13	124
	1AACO009.14	5/30/2008	16	10	10	12	19	11	10	12	11	15	126
		10/31/2008	18	7	6	15	14	13	12	15	16	15	131
Upper Accotink	1AACO014.57	5/23/2007	18	9	11	16	13	17	11	16	17	16	144
		11/7/2007	17	4	8	12	8	9	12	7	12	15	104
Long Branch	1ALOE001.99	6/1/2006	15	12	12	8	10	14	9	7	11	7	105
		9/19/2006	12	4	14	14	6	17	10	7	8	13	105

[1]Yellow: Marginal; Red: Poor

[2]Orange: Suboptimal

3.2.2 FCDPWES Habitat Assessment and Infrastructure Inventory

FCDPWES contracted with CH2MHill (2005) to perform a stream physical assessment (SPA) on the streams in Fairfax County. Field work for the SPA was performed 2002-2005. The SPA had three components: (1) habitat assessment; (2) a stream survey to inventory infrastructure (crossings, pipes and ditches, buffers, etc.) and problems like erosion and head cuts; and (3) a geomorphic assessment which classifies stream reaches according to the Channel Evolution Model (CEM). The CEM assessment and the inventory of erosion and head cuts are discussed in **Section 3.3.2**; the remainder of the SPA is discussed in this section.

To facilitate the assessment, the streams in Fairfax County were divided into reaches. The Accotink Creek stream network was represented by 185 reaches, representing 91 miles of streams. The average length of a reach was about half a mile. Of the 185 reaches, 146 were assessed for both habitat and inventory, 36 were assessed for inventory only, and three were unassessed because of lack of access to the stream reach, lack of a defined channel, or lack of flow in the channel.

CH2MHill used two sets of metrics to assess habitat in Accotink Creek: one set for the Piedmont and one for the Coastal Plain. **Table 3-18** gives the metrics. The Piedmont metrics are similar to those used by DEQ in high gradient streams. All metrics except BANKS, BANKVEG, and RIPVEG were scored on a scale of 1-20, with higher scores representing better habitat conditions. Right and left banks were scored separately for BANKS, BANKVEG, and RIPVEG on a scale of 1-10. The range of total habitat scores were partitioned into five rating categories: Excellent, 142-168; Good, 114-141; Fair, 87-113; Poor, 59-86; and Very Poor, 32-58. The boundary between Good and Fair categories approximates the ProbMon sub-optimal threshold of 120 for total habitat score.

Table 3-18: Component Habitat Metrics in the Fairfax County Stream Physical Assessment

Metric	Description	Piedmont	Coastal Plain
COVER	Instream cover for aquatic organisms	X	X
SUBSTRATE	Epifaunal substrate/available cover	X	
EMBED	Embeddedness	X	
POOL	Pool substrate characterization		X
VARIABILITY	Pool variability		X
ALTER	Channel alteration	X	X
SEDIMENT	Sediment deposition	X	X
RIFFLES	Frequency of riffles	X	
SINUOSITY	Channel sinuosity		X
FLOW	Channel flow	X	X
BANKS	Bank stability	X	X
BANKVEG	Bank vegetative protection	X	X
RIPVEG	Riparian vegetation zone width	X	X

Table 3-19 summarizes the habitat assessment for steam reaches in the Piedmont. The average total habitat score, weighted by reach length, is Fair, except for the lower mainstem of Accotink Creek, which is rated Good. The median score of assessed reaches are Fair, even for the lower mainstem.

Following Barbour et al. (1999), metric scores 10 and below can be classified as Marginal (6-10) or Poor (1-5), with left and right BANKVEG, BANKS, and RIPVEG scores added together before classifying the overall score. Using this classification scheme, length-averaged FLOW is Marginal in the upper and lower mainstem of Accotink Creek, the mainstem of Long Branch, and all of their tributaries. Length-averaged BANKS and BANKVEG are also Marginal everywhere except for the lower mainstem of Accotink Creek. Length-averaged EMBED is Marginal everywhere except for the mainstem of Long Branch and the lower mainstem of Accotink Creek. In contrast, length-averaged COVER is Good (11-15) everywhere and length-averaged RIPVEG is Good everywhere except for the tributaries to upper Accotink Creek. All length-averaged metric scores in the upper mainstem of Accotink Creek are Marginal except for COVER and BANKVEG, and all length-averaged scores in its tributaries are Marginal except for COVER and RIFFLES.

Table 3-19: Summary of Fairfax County SPA Habitat Assessment in Piedmont Region of Accotink Creek Watershed

Watershed/ Waterbody	Statistic	COVER	SUBSTRATE	EMBED	ALTER	SEDIMENT	RIFFLES	FLOW	BANKVEG (left)	BANKVEG (right)	BANKS (left)	BANKS (right)	RIPVEG (left)	RIPVEG (right)	Total
Upper Mainstem	Count	21	21	21	21	21	21	21	21	21	21	21	21	21	21
	Min	1	0	0	2	3	0	5	1	1	2	1	3	3	50
	25th	4	5	5	6	7	6	8	2	2	3	3	3	4	65
	Median	7	6	9	8	10	8	10	2	3	4	4	6	6	82
	75th	13	9	11	11	11	10	11	4	4	5	5	9	9	100
	Max	17	14	15	15	12	14	17	7	8	8	8	10	10	128
	Average	8.52	6.95	7.57	8.33	8.52	7.76	9.52	2.81	3.05	4.19	4.24	6.62	6.43	84.52
	Length-Weighted Average	11.22	8.82	8.81	8.96	9.55	9.08	9.49	2.76	3.16	4.10	4.33	6.34	6.09	92.70
Upper Tributaries	Count	64	64	64	64	64	64	64	64	64	64	64	64	64	64
	Min	1	0	0	1	1	0	4	0	0	1	2	0	0	39
	25th	5	6	7	5	7	7	8	2	2	3	3	3	3	64.75
	Median	9.5	8	8	8	9	9	9	3	3	4	4	3	3.5	83
	75th	12.25	10.25	10	10	10	12	9	4	4	5	5	5	5	94.25
	Max	18	17	15	16	15	15	17	7	7	9	8	10	10	150
	Average	8.78	8.34	8.30	7.92	8.61	9.02	8.80	2.91	2.91	4.14	4.28	4.08	4.08	82.16
	Length-Weighted Average	10.39	9.35	8.83	8.17	8.80	10.24	9.01	3.05	3.04	3.95	4.14	4.01	4.25	87.24
Lower Mainstem	Count	27	27	27	27	27	27	27	27	27	27	27	27	27	27
	Min	6	5	7	5	8	6	7	3	3	4	4	3	1	71
	25th	9.5	7	9.5	11	10	9.5	8	5	5	5	5	4	5	99
	Median	12	11	10	12	11	11	9	6	5	6	6	5	5	108
	75th	13	12	11	13	11.5	12.5	9	6	6	6	6	6	6	117.5
	Max	17	15	15	16	16	14	15	8	7	8	7	9	10	155
	Average	11.44	10.00	10.30	11.52	11.00	10.67	8.89	5.48	5.44	5.81	5.59	5.30	5.56	107.00
	Length-Weighted Average	12.84	11.35	10.90	12.45	11.45	11.66	9.34	5.79	5.82	6.05	5.76	5.80	6.18	115.40
Lower Tributaries	Count	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Min	10	6	5	9	10	8	9	4	3	4	4	4	3	95

Watershed/ Waterbody	Statistic	COVER	SUBSTRATE	EMBED	ALTER	SEDIMENT	RIFFLES	FLOW	BANKVEG (left)	BANKVEG (right)	BANKS (left)	BANKS (right)	RIPVEG (left)	RIPVEG (right)	Total
	25th	11.5	7.5	7.25	10.5	10	8.75	9	4	3.75	4	4.75	4.75	4.5	95.75
	Median	12	9.5	8.5	11.5	10	10	9	4	4	4.5	5	5	5	97
	75th	12.25	11	9.75	12.25	10.25	11	9	4.25	4.25	5.25	5.25	5	6	99
	Max	13	11	12	13	11	11	9	5	5	6	6	5	9	102
	Average	11.75	9.00	8.50	11.25	10.25	9.75	9.00	4.25	4.00	4.75	5.00	4.75	5.50	97.75
	Length-Weighted Average	12.32	10.22	7.23	11.69	10.46	10.50	9.00	4.07	3.69	4.36	4.69	4.85	6.18	99.25
Long Branch Mainstem	Count	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Min	13	7	9	12	8	13	7	3	3	4	4	6	6	108
	25th	13.75	9.25	10.5	12	10.25	13.75	8.5	3.75	3	4.75	4.75	7.5	6.75	108.75
	Median	14	10.5	11	12.5	11	14	9.5	4	3.5	5	5	8	7	111
	75th	14	11	11	13	11.25	14.25	10	4.5	4.25	5.25	5	8	7	114.25
	Max	14	11	11	13	12	15	10	6	5	6	5	8	7	118
	Average	13.75	9.75	10.5	12.5	10.5	14	9	4.25	3.75	5	4.75	7.5	6.75	112
	Length-Weighted Average	13.99	10.81	10.69	12.69	10.84	14.15	9.82	3.48	3.32	4.47	4.46	7.98	6.99	113.69
Long Branch Tributary	Count	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Min	9	6	7	8	6	8	8	2	2	3	2	3	3	76
	25th	11.25	6	7	8.75	8.25	9	8.75	3	2.75	3.75	3.5	4.75	5	89.25
	Median	12	8.5	8.5	10	9.5	10.5	9	4	4	4	4.5	5.5	5.5	95.5
	75th	13.25	9.25	9.25	12.25	10.25	11.5	10	4.25	5	5	5	7.25	7	103
	Max	14	12	12	14	11	14	10	5	6	5	5	9	9	118
	Average	11.88	8.25	8.63	10.50	9.00	10.63	9.13	3.75	3.88	4.13	4.00	5.88	5.88	95.50
	Length-Weighted Average	11.16	8.57	9.05	10.03	9.12	10.14	9.10	3.38	3.39	3.84	3.45	5.30	5.08	91.61

Table 3-20 summarizes the habit assessment for stream reaches in the Coastal Plain. In contrast to the Piedmont, the length-averaged total habitat score for both the lower mainstem of Accotink Creek and its tributaries in the Coastal Plain are both Good. All of the length-average metric scores are above 10.

The SPA inventoried infrastructure and stream features that may cause problems for stream water quality or biological health. These include the following:

- Stream crossings by roads, railroads, or trails;
- Outfalls and ditches draining into the stream;
- Exposed sanitary sewer pipes or water, gas and cable lines in the vicinity of the stream;
- Trash dumps; and
- Stream obstructions caused by debris, dams, utility lines, beaver dams, etc.

Table 3-21 gives the number of each category of feature by waterbody. Stream crossings and pipe outfalls are generally the most numerous stream features inventoried.

The SPA inventory also assessed stream buffers by linear feet of stream reach; right and left banks were assessed separately. An adequate buffer was defined as a 100 ft wide forested buffer. A deficient buffer falls short of that standard, either in terms of width or type of cover. **Table 3-22** gives the linear feet of deficient buffers and the percent of stream length having deficient buffers for each watershed. In each watershed, the mainstem has more deficient buffers than the tributaries. Over 50% of the upper tributaries have deficient buffers. In contrast, only 15% of the lower mainstem of Accotink Creek and 10% of the mainstem of Long Branch have deficient buffers.

Table 3-20: Summary of Fairfax County SPA Habitat Assessment in Coastal Plain Region of Accotink Creek Watershed

Watershed/ Waterbody	Statistic	COVER	POOL	VARIABILITY	ALTER	SINUOSITY	SEDIMENT	FLOW	BANKVEG (Left)	BANKVEG (right)	BANKS (left)	BANKS (right)	RIPVEG (left)	RIPVEG (right)	Total
Lower Mainstem	Count	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Min	12	13	10	14	6	13	12	5	5	5	5	9	10	110
	25th	14.5	14.5	12.5	14.5	6	13	12	5	5	5.5	5	9.5	10	116.5
	Median	17	16	15	15	6	13	12	5	5	6	5	10	10	123
	75th	17	16.5	15.5	15	7.5	14.5	13	5.5	5.5	6	5.5	10	10	125
	Max	17	17	16	15	9	16	14	6	6	6	6	10	10	127
	Average	15.33	15.33	13.67	14.67	7.00	14.00	12.67	5.33	5.33	5.67	5.33	9.67	10.00	120.00
	Length-Weighted Average	16.26	16.23	15.12	14.15	11.38	13.95	13.03	5.00	5.85	5.15	5.82	9.82	10.00	127.81
Lower Tributaries	Count	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Min	5	6	3	8	2	7	9	3	4	3	3	2	2	70
	25th	11	6	6.5	11	9	10	11	4.5	5	5	4	5	5.5	92
	Median	15	11	10	14	12	12	11	5	5	5	5	9	9	111
	75th	17	15.5	14	15	14	13.5	13	5.5	6	6	6	10	10	119.5
	Max	18	17	16	17	15	16	15	8	9	9	9	10	10	145
	Average	13.93	11.53	10.27	13.07	10.93	11.73	11.93	5.20	5.47	5.53	5.47	7.13	7.73	108.20
	Length-Weighted Average	15.22	12.85	12.01	13.80	11.80	12.44	12.56	5.49	5.83	5.42	5.50	7.08	8.31	115.88

Table 3-21: SPA Inventory of Infrastructure and Potential Problem Areas in Accotink Creek Watershed

Watershed	Waterbody	Crossing	Ditch	Dump	Obstruction	Pipe	Utility
Upper Accotink	Mainstem	37	2	1	26	45	1
	Tributaries	226	22	8	73	182	19
Lower Accotink	Mainstem	30	3	0	4	56	5
	Tributaries	36	0	1	3	33	3
Long Branch	Mainstem	6	0	0	2	7	0
	Tributaries	10	0	1	3	12	1

Table 3-22: Deficient Riparian Buffers in Accotink Creek Watershed

Watershed	Waterbody	Deficient Buffer (ft)	Percent Deficient Buffer
Upper Accotink	Mainstem	50,220	35%
	Tributaries	236,150	51%
Lower Accotink	Mainstem	25,175	15%
	Tributaries	23,925	24%
Long Branch	Mainstem	5,375	10%
	Tributaries	9,500	26%

3.3 Geomorphic Assessment

Both DEQ and FCDPWES have performed assessments of stream geomorphology to determine stream stability and in-stream erosion. These are discussed in **Sections 3.3.1** and **3.3.2**, respectively, below. EPA performed pebble counts at the locations where they performed biological monitoring. These results are discussed in **Section 3.3.3**.

3.3.1 DEQ Geomorphic Assessment

The DEQ geomorphic assessment measures or calculates the following attributes of a steam reach: geometric mean substrate diameter, slope, percent of sands and fine particles, percent embeddedness (without fines or bedrock), and the Log_{10} Relative Bed Stability Index (LRBS). DEQ uses LRBS as a measure of excessive sediment transport. LRBS measures the relative stability of the bed substrate in a stream and how it is altered by anthropogenic impacts. Streams that have an excess supply of sediment from upland erosion tend to have more mobile beds with finer substrate like silts and clays. This finer substrate can bury the coarser substrate, which forms the habitat of pollutant-sensitive macroinvertebrates or the spawning ground of sensitive fish species, like trout. However, some bed mobility is part of the natural geomorphic processes in streams and is necessary to maintain variety in habitat and to clean coarser substrate of sediment (Kaufman et al., 1999). Streams are reworked during bankfull flow events. A stream can be too stable, however. Streams subject to persistent high flows, such as the tailwater below a dam, have beds dominated by coarser substrate, which cover the bed and prevent finer particles from scouring. This process is called armoring, and it represents the other extreme from excessively mobile beds dominated by fine sediment.

The LRBS postulates that under natural conditions, long term sediment supply is in equilibrium with the sediment transport capacity in a stream (Kaufman et al., 1999). The LRBS is the $\log_{10}$ of the ratio of the observed median diameter of the substrate in a stream (D_{50}) to the diameter of the largest substrate that is mobilized during bankfull flow (D_{cbf}). D_{50} can be approximated by the geometrical mean of observed substrate diameters. D_{cbf} can be calculated from the hydraulic radius under bankfull flows (R_{bf}) and the water surface slope, S (which can be approximated by the channel slope), using the following two equations:

$$\tau_{bf} = \rho_w * g * R_{bf} * S$$

where

τ_{bf} = average bottom shear stress at bankfull flow (kg-m/s^2)
ρ_w = density of water (kg/m^3)
g = gravitational acceleration (m/s^2)

$$\tau_c = \theta * (\rho_s - \rho_w) * g * D$$

where

θ = Shields parameter (0.044 for non-cohesive particles under turbulent flow)
τ_c = minimum shear stress required to move particle of size D (kg-m/s^2)
ρ_s = density of sediment (kg/m^3)
ρ_w = density of water (kg/m^3)
g = gravitational acceleration (m/s^2)
D = particle size (m)

By equating the critical shear stress, τ_c, to τ_{bf}, D_{cbf}, the largest substrate size mobilized by bankfull flow, can be determined. R_{bf} is corrected to take into account the roughness contributed by woody debris, riffles, and other channel structures.

If D_{cbf} equals D_{50}, LRBS is equal to zero. If D_{50} is less than D_{cbf}, LRBS is negative. This implies that flows less than bankfull flow can move more than half the substrate in the bed. The more negative the LRBS, the more unstable the bed. Conversely, large positive values of LRBS can indicate a bed that is armored.

Table 3-23 shows the LRBS scores from geomorphic assessments. **Figure 3-7** shows the locations where the assessments were made. The percentile ranking of the LRBS scores among statewide measurements from the ProbMon program is also shown. ProbMon (DEQ, 2012) classifies streams with LRBS scores less than -1.0 as Suboptimal and scores greater than -0.5 as Optimal. Large positive LRBS values tend to be associated with high slope streams that are dominated by larger particle sizes. According to the LRBS, streams in the Optimal category are carrying normal sediment loads while streams in Suboptimal category are carrying excess sediment. The LRBS scores for Accotink Creek assessments are all in the Optimal category and three of the four scores are positive; however, in urban watersheds, such as Accotink, positive LRBS values may be the result of the flashier storm flow which erodes the banks and removes fine-grain sediment from the reach, armoring the streambed (Hill, 2007).

Table 3-23 also shows the geometric mean substrate diameter, slope, percent of sands and fine particles, and percent embeddedness (without fines or bedrock) and the percentile of these scores among statewide ProbMon results.

Table 3-23: LRBS Scores and Geomorphic Characteristics at DEQ Monitoring Locations in Accotink Creek

Station ID	**1AACO004.84**	**1AACO006.10**	**1AACO006.10**	**1AACO009.14**
Date	6/25/2008	11/21/2006	6/26/2008	6/26/2008
LRBS	-0.246	0.517	0.374	0.459
LRBS Percentile[1]	75%	96%	94%	95%
Geometric Mean Substrate Diameter (mm)	14.6297583	38.2709204	21.25375351	27.38956708
Substrate Diameter Percentile[2]	67%	83%	77%	80%
Substrate Class	Fine Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel
Slope	0.521	0.220	0.173	0.223
Slope Percentile[2]	37%	14%	8%	15%
Percent Sands and Fines	19%	19%	25%	20%
Percent Sands and Fines Percentile[2]	24%	24%	30%	25%
Percent Embedded (without Fines or Bedrock)	53%	40%	48%	61%

[1] Based on ProbMon data, 2001-2012
[2] Based on ProbMon data, 2001-2010

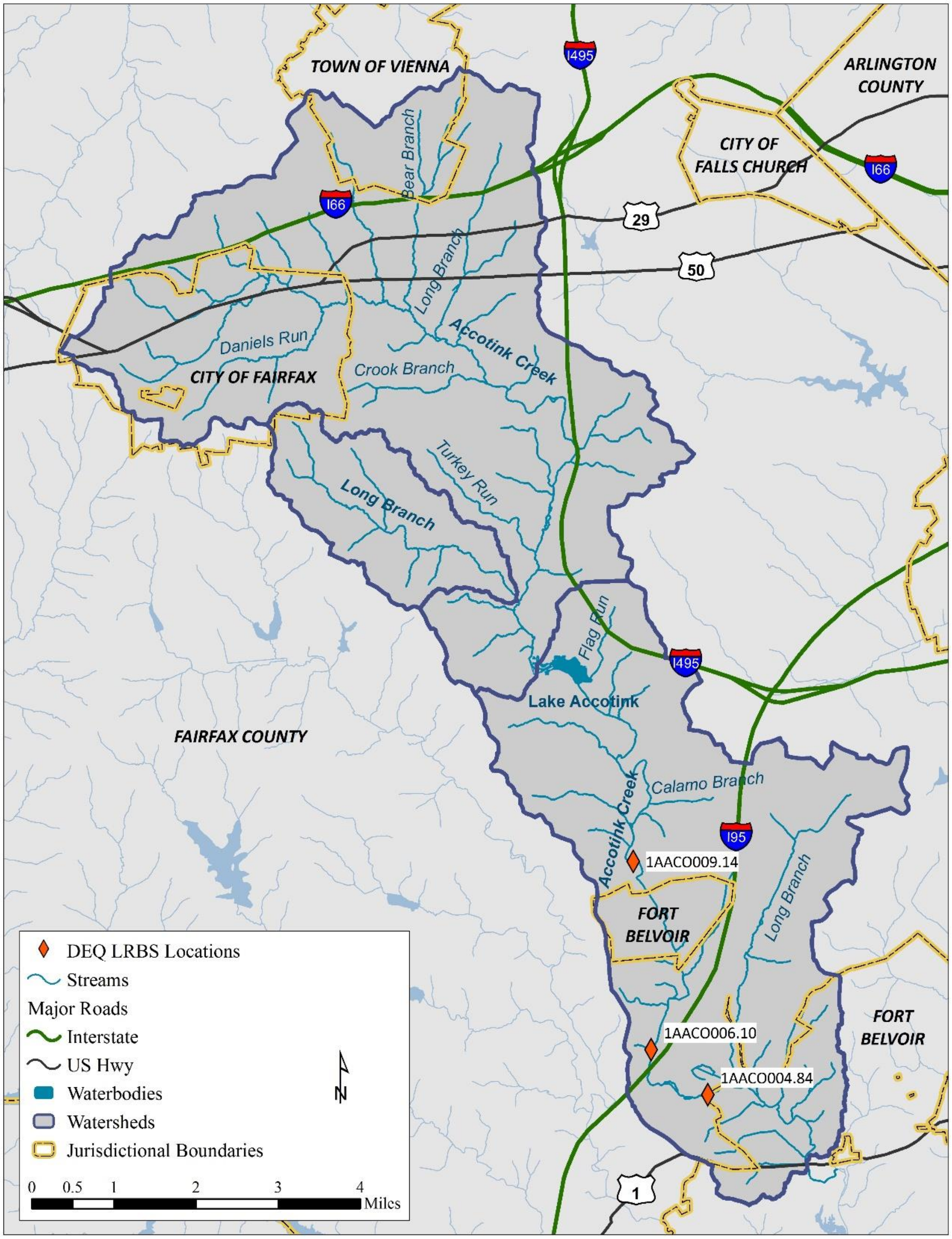


Figure 3-7: Location of DEQ LRBS Analyses in Accotink Creek

3.3.2 Fairfax County SPA Geomorphic Assessment

As part of the SPA, CH2MHill performed a geomorphic assessment of stream reaches in the Accotink Creek watershed using the CEM. CEM is a visual assessment which classifies reaches into one of five stages of channel transformation, shown in **Table 3-24**. Each stage is characterized by a type of channel. Type I represents a stable stream with a single terrace. Type II represents a stream which is actively eroding its bed and incising a new channel. In Type III, the incision of a new channel has stopped but the stream is actively widening its channel. Type IV represents the phase in which the new channel is stabilizing. Type V is a stream with a new stable configuration of channel and floodplain marked by a second terrace where the original floodplain had been. These stages are typical of streams whose watersheds are undergoing urbanization and need to readjust to the changes in flow brought about by development and the increase in impervious surface.

Table 3-24: Stages of Channel Evolution Model (CEM)

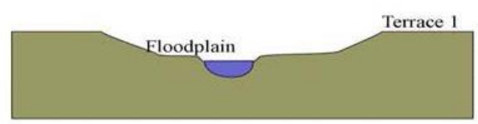
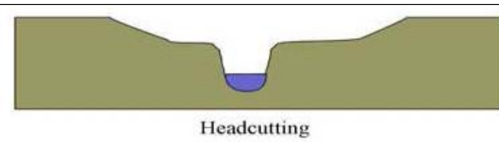
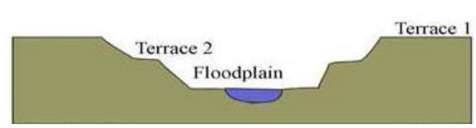
Type	Definition	Illustration
Type I Stable	Well-developed baseflow and bankfull channel; consistent floodplain features easily identified; one terrace apparent above active floodplain; predictable channel morphology; floodplain covered by diverse vegetation; streambanks ≤ 45°.	
Type II Incision	Head cuts; exposed cultural features (along channel bottom); sediment deposits absent or sparse; exposed bedrock (parts of reach); streambank slopes > 45°.	
Type III Widening	Streambank sloughing, sloughed material eroding; streambank slopes > 60° or vertical/undercut; erosion on inside of bends; accelerated bend migration; exposed cultural features (along channel banks); exposed bedrock (majority of reach).	
Type IV Stabilizing	Streambank aggrading; sloughed material not eroded; sloughed material colonized by vegetation; baseflow, bankfull and floodplain channel developing; predictable channel morphology developing; streambank slopes ≤ 45 °.	
Type V Stable	Well-developed baseflow and bankfull channel; consistent floodplain features easily identified; two terraces apparent above active floodplain; predictable channel morphology; streambanks ≤ 45°.	

Table 3-25 summarizes the CEM classification of Accotink Creek. Over 90% of the assessed stream reaches in the Accotink Creek watershed were classified as Type III. These are unstable channels that are actively widening by eroding their banks.

Table 3-25: Summary of Channel Evolution Model Assessment of Accotink Creek Watershed

Watershed	Waterbody	Type II (ft)	Type III (ft)	Type IV (ft)	Total Assessed (ft)
Upper Accotink	Mainstem	456	59,866	1,676	61,997
	Tributaries	12,745	153,291	0	166,036
Lower Accotink	Mainstem	0	46,798	8,190	54,988
	Tributaries	0	34,444	12,680	47,124
Long Branch	Mainstem	0	24,603	0	24,603
	Tributaries	0	15,752	0	15,752
Total		**13,200**	**334,754**	**22,546**	**370,500**

The SPA inventoried eroding stream banks and identified the linear feet of stream in reaches with moderate to severe erosion, defined as sites actively eroding more than two to three feet in height of banks. These are summarized in **Table 3-26**. Sites with moderate to severe erosion are not uncommon in the Accotink Creek watershed. Overall, 23% of the assessed reaches had actively eroding sites greater than 2-3 ft in height, including 31% of the reaches inventoried in the tributaries to upper Accotink Creek. The upper tributaries have the greatest amount of active erosion sites, as measured in linear feet or stream reach, but active erosion sites are not uncommon in both the upper and lower mainstem of Accotink Creek. Active sites of moderate to severe erosion do not, however, constitute a large percentage of stream length. Overall, sites with greater than two feet of erosion account for less than 1% of the assessed reach length.

Table 3-26: Summary of Moderate to Severe Bank Erosion (> 2-3 ft in height) in Accotink Creek Watershed

Watershed	Waterbody	Reaches Assessed	Reaches with Erosion	Percent Assessed Reaches with Erosion	Assessed Length (ft)	Active Erosion (ft)
Upper Accotink	Mainstem	21	3	14%	70,284	420
	Tributaries	89	28	31%	250,035	3,095
Lower Accotink	Mainstem	30	6	20%	67,205	450
	Tributaries	19	1	5%	45,929	250
Long Branch	Mainstem	4	0	0%	26,543	0
	Tributaries	8	1	13%	18,164	25
Total		**171**	**39**	**23%**	**478,160**	**4,240**

Head cuts are sites where the channel bottom is actively eroding. According to the SPA, there are eleven active head cuts in the upper Accotink Creek tributaries and one on a tributary to Long

Branch. The head cut on the Long Branch tributary was ten feet high, while the head cuts in the upper tributaries ranged one to three feet in height.

The SPA also included a classification of the dominant substrate in assessed reaches. Each reach was assigned a dominant substrate in one of the categories shown in **Table 3-27**. **Table 3-27** summarizes the classification of reaches by dominant substrate by summing the length of each reach where a substrate class is dominant. Gravel is the dominant substrate in half of the length of the reaches classified in the Accotink Creek watershed, but sand, silt, or mud were the dominant substrate in about a third of the length of the reaches classified in the upper tributaries, upper mainstem, and lower mainstem of Accotink Creek.

Table 3-27: Summary of SPA Classification of Dominant Substrate in Accotink Creek Watershed (in linear feet)

Watershed	Waterbody	Boulder	Clay	Cobble	Gravel	Mud with Leaves	Sand	Silt	Percent Sand or Finer
Upper Accotink	Mainstem	0	614	0	38,972	0	21,387	1,024	36%
	Tributaries	0	0	21,647	91,404	0	52,335	650	32%
Lower Accotink	Mainstem	5,112	0	26,766	5,773	686	13,388	3,262	32%
	Tributaries	470	0	21,148	17,978	0	5,851	1,677	16%
Long Branch	Mainstem	0	0	256	20,679	0	3,667	0	15%
	Tributaries	0	0	4,011	11,741	0	0	0	0%
Total		**5,582**	**614**	**73,829**	**186,548**	**686**	**96,628**	**6,613**	**28%**

3.3.3 EPA Particle Size Analysis

Selvakumar et al. (2008) performed a pebble count to determine the distribution of particle sizes at the EPA's biological sampling sites (**Figure 3-3**) on three dates: one before the stream restoration (11/03/2005), one during the restoration (03/01/2006), and one after the restoration was completed (10/03/2006). The particle size analysis was also performed upstream of the restoration site at Ranger Road during and after stream restoration. The percent of particles sand size or less (< 2 mm) tended to be similar before and after the restoration at all sites, but tended to be elevated during the restoration. Selvakumar et al. (2008) surmised that the increase in finer grain sizes may have been due to the restoration work disturbing the bank and channel; however, the percent of sand or finer material was also elevated at site A upstream of the restoration and at Ranger Road. At site A the fraction of sand or finer material ranged from about 15% to 25%; at Ranger Road it ranged from about 8% to 25%. These results may suggest that there is significant temporal variation in the amount of sand and fine-grained sediment at a given location.

3.4 Flow

There are two active USGS gages in Accotink Creek watershed: Accotink Creek near Annandale, VA (01654000), and Long Branch near Annandale, VA (01654500). Accotink Creek near Annandale, VA has been in operation since 1947; the gage on Long Branch recently began operation in 2013. A third gage, Accotink Creek near Ranger Road at Fairfax, VA (0165389205), began operating in 2011 and recently ceased operation in January 2015. **Figure 3-8** shows the location of these gages, and **Table 3-28** gives their period of record and drainage area. All three gages are in the upper portion of the watershed. The USGS operated a gage on the lower mainstem of Accotink Creek near Accotink Station, VA (01655000) between 1949 and 1956. The location of this gage is also shown in **Figure 3-8**.

Table 3-28: USGS Gages in Accotink Creek Watershed

Gage	Location	Area (mi^2)	Period of Record for Daily Flow
01654000	Accotink Creek near Annandale, VA	23.9	10/01/1947 - present
0165389205	Accotink Creek near Ranger Road at Fairfax, VA	3.99	10/18/2011 - 01/13/2015
01654500	Long Branch near Annandale, VA	3.72	02/18/2013 - present
01655000	Accotink Creek near Accotink Station, VA	37.1	10/01/1949 - 09/30/1956

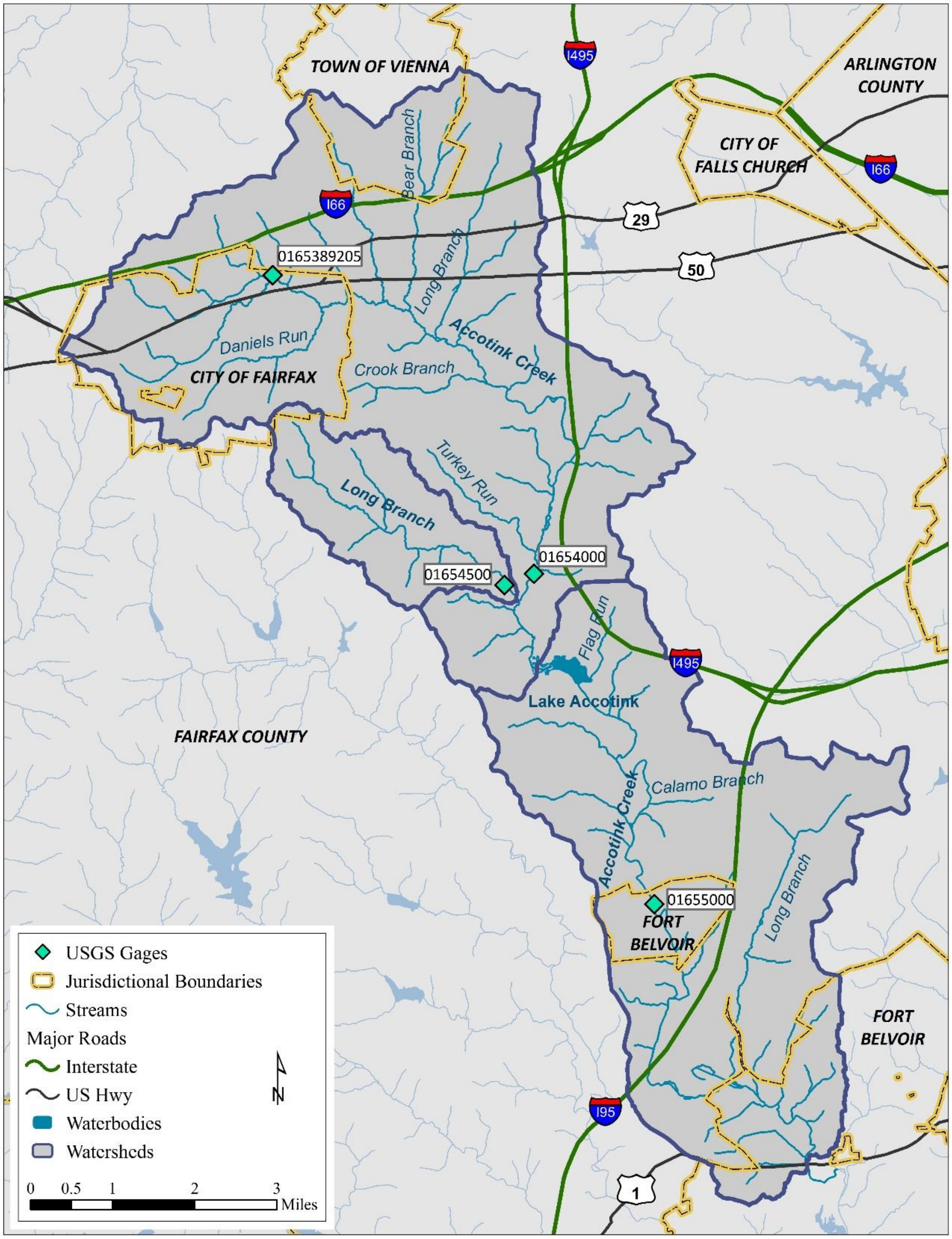


Figure 3-8: Location of USGS Gages in Accotink Watershed

Figure 3-9 shows the distribution of daily average flows at the gage on Accotink Creek near Annandale. The percentile flow of average daily flows from this gage was used to construct an index of daily hydrological conditions for the Accotink Creek watershed as a whole. Storm conditions generally occur at 90th or greater flow percentiles. The boundary between ambient and storm conditions is approximate, however, and small summer storms can have lower percentiles than ambient winter flows.

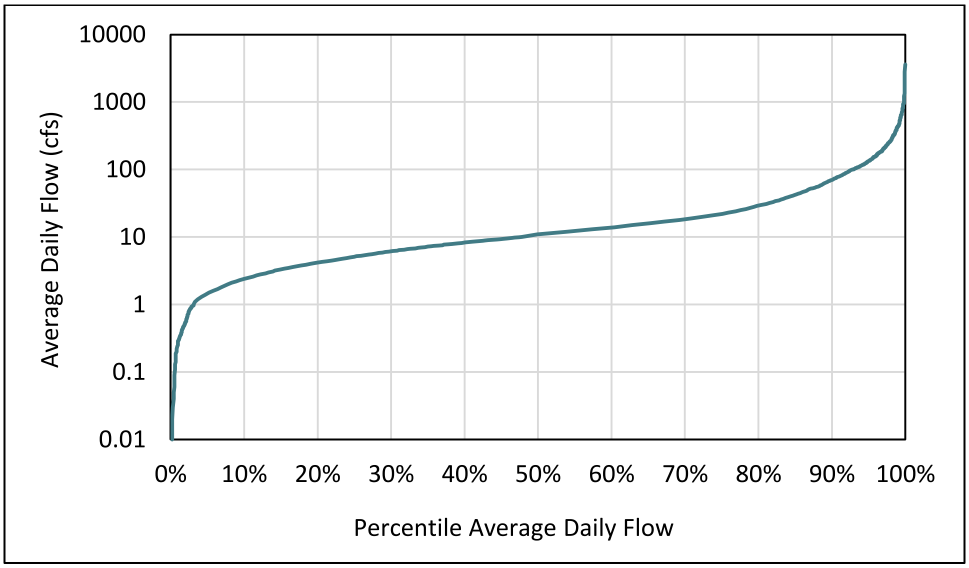


Figure 3-9: Average Daily Flow, Accotink Creek near Annandale, VA, 1990-2014

To test whether percentile flow at gage 01654000 is an appropriate index of hydrological conditions below Lake Accotink, the flows and flow percentiles from gages 01654000 and 0165500 were compared over their common period of record, 1949-1956. **Figure 3-10** compares flow and **Figure 3-11** compares flow percentiles for their common period of record. Flows are strongly correlated. The slope of a linear regression between the two gages has a slope of 1.51, close to the ratio of watershed areas (1.55). The coefficient of determination (R^2) between the two gages is 0.89. Flow percentiles are not as tightly correlated, but generally, the flow at one gage is above the 90th percentile if and only if the flow at the other gage is above the 90th percentile. This indicates that storm flow and baseflow conditions tend to occur on the same day above and below Lake Accotink, and therefore the flow percentiles from the gage on Accotink Creek near Annandale on the upper mainstem can be used as an index of hydrological conditions for the lower mainstem. This information will be used in the analysis of water quality monitoring data in **Section 3.5**.

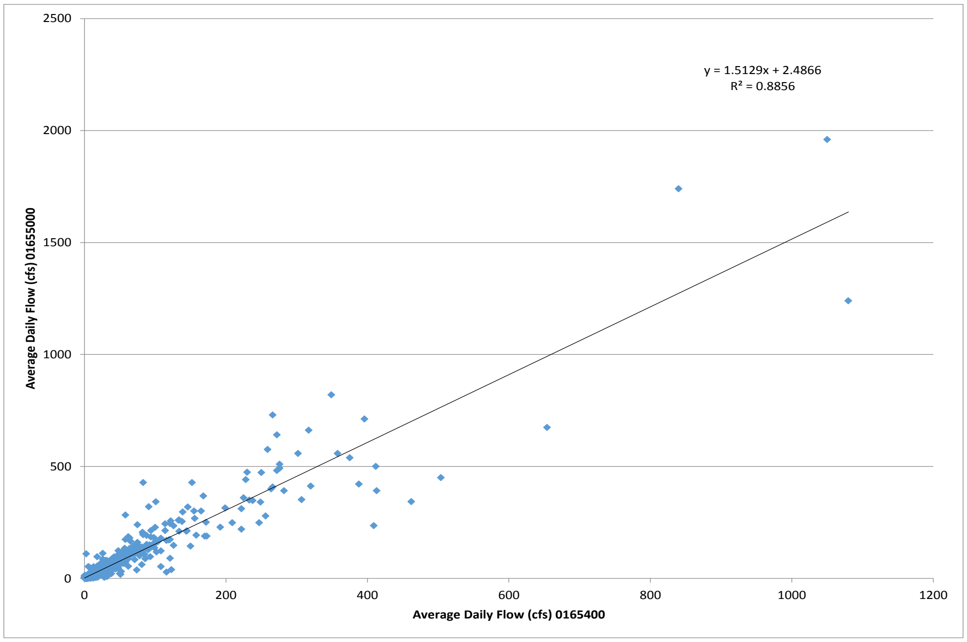


Figure 3-10: Average Daily Flow, Accotink Creek, at Annandale (01654000) and Accotink Station (0165500), 1949-1956

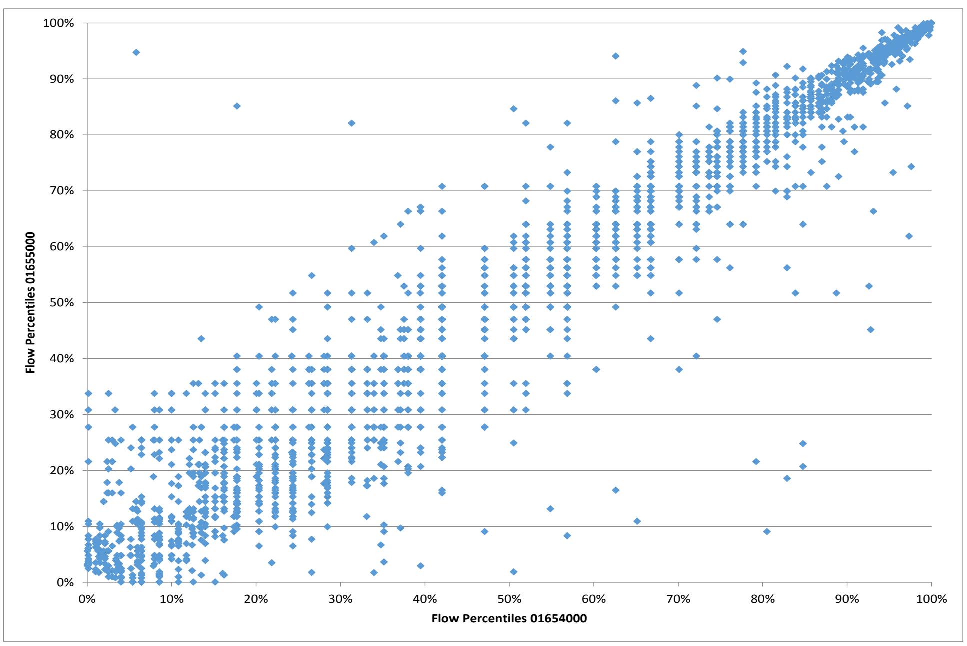


Figure 3-11: Percentiles of Average Daily Flow, Accotink Creek, at Annandale (01654000) and Accotink Station (0165500), 1949-1956

3.5 Analysis of Conventional Water Quality Monitoring Data

This section analyzes conventional water quality monitoring data for constituents that can adversely impact biological communities. Constituents analyzed in this section include temperature; pH; dissolved oxygen (DO); specific conductance (SC); total dissolved solids (TDS); chloride (CL); turbidity, measured in either Formazin Nephelometric Units (FNU) or Nephelometric Turbidity Units (NTU); total suspended solids (TSS) or suspended sediment (SS); ammonia nitrogen (NH_3); nitrate nitrogen (NO_3); total Kjeldahl nitrogen (TKN); total nitrogen (TN); total orthophosphate (PO_4); and total phosphorus (TP). Metals and organic toxic pollutants are discussed in **Section 3.6.**

DEQ, USGS, EPA, and FCDPWES all monitored at least some of these constituents in the Accotink Creek watershed. DEQ conducted water quality monitoring at twelve locations. These are shown in **Figure 3-12**. The USGS monitored water quality constituents at three gage locations: Accotink Creek near Annandale, VA (01654000), Accotink Creek at Ranger Road (0165389205), and Long Branch near Annandale, VA (01654500). These locations are shown in **Figure 3-8**. The USGS collected water quality monitoring data under several programs and projects, including (1) storm sampling performed at gage 01654000, (2) storm and ambient monitoring conducted in Long Branch in conjunction with FCDPWES as part of a county-wide monitoring program, and (3) sampling performed at gage 01654000 under the National Water Quality Assessment (NAWQA) program. The USGS also participated in an EPA monitoring study of the effects of stream restoration described below.

DEQ and USGS monitoring data will be analyzed together in **Sections 3.5.1** through **3.5.14**, devoted to individual constituents, and **Section 3.5.15**, which summarizes the analysis. Although the available data stretched back into the 1990's, for most constituents, except specific conductance and chloride, only monitoring data collected between January, 2004 and October, 2014 was used in the SI analysis. The analysis also focused on the mainstem sections of upper Accotink Creek, lower Accotink Creek, and Long Branch. To take into account all data collected by DEQ, however, monitoring data from DEQ station, 1ALOA000.17, on Long Branch South, is included in the analysis of data from lower mainstem Accotink Creek.

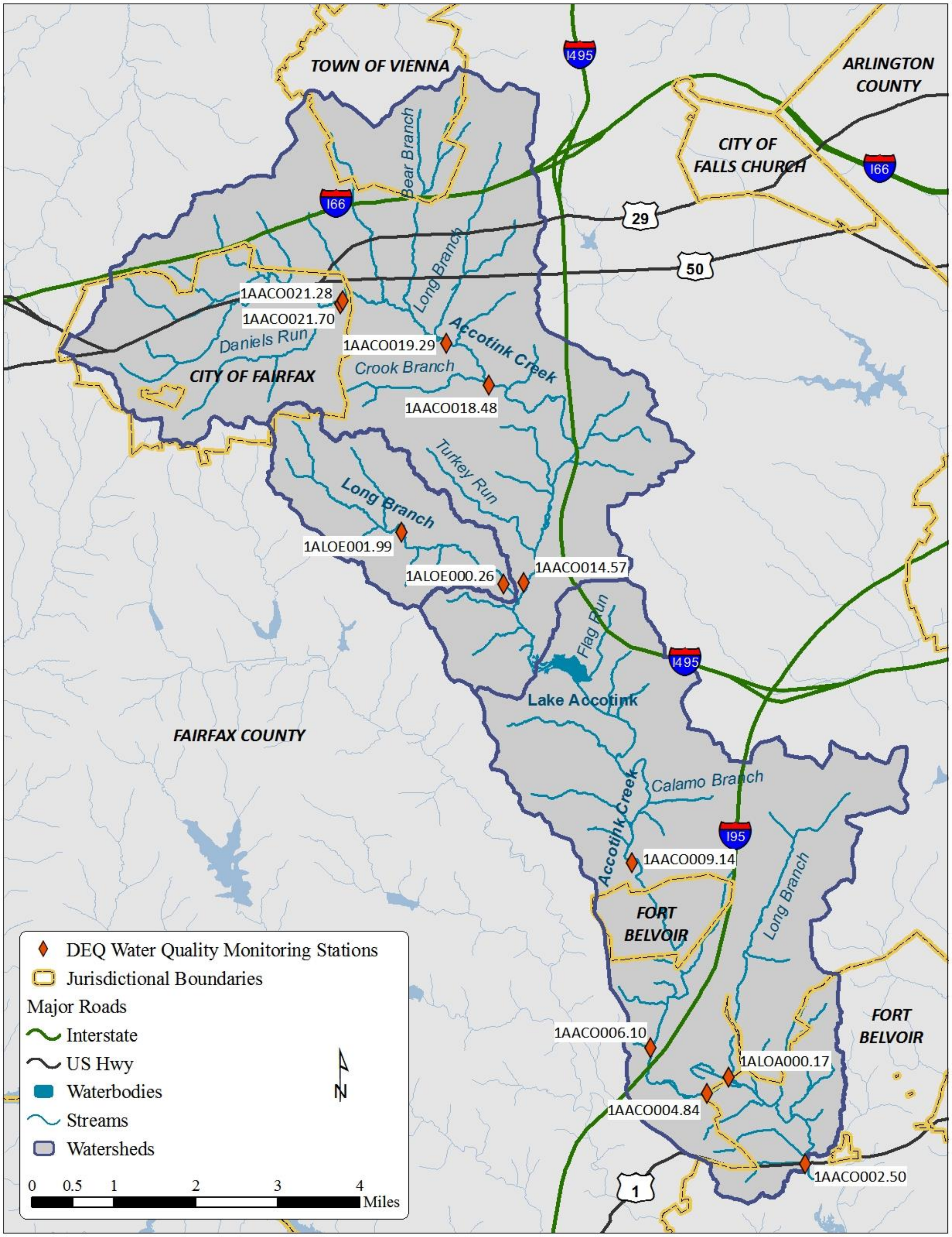


Figure 3-12: DEQ Water Quality Monitoring Stations

The original SI analysis was released for public comment in the summer of 2015. As will be discussed in detail in Section 4.3.1, the SI analysis determined that chloride is a stressor of the biota in the Accotink Creek watershed. To verify that conclusion, DEQ collected additional monitoring data in the winter of 2015 and 2016 and analyzed it for chloride and specific conductance, as well as other constituents. Observations of chloride and conductance made by DEQ in 2015 and 2016 were used to revise the analysis of these constituents in this report. Observations of other constituents made by DEQ in 2015 and 2016 did not contribute any additional information to the existing analysis, so the analyses of those other constituents were not updated to include these observations.

FCDPWES conducted water quality monitoring in conjunction with their biological sampling described in **Section 3.1.3,** and the sampling locations are shown in **Figures 3-4 and 3-5**. FCDPWES monitoring data, which was primarily collected on smaller order streams, is analyzed separately in **Section 3.5.16**.

The EPA conducted water quality monitoring at four locations above, within, and downstream of the stream restoration which was the focus of their study, described in **Section 3.1.2**. The complete record of EPA water quality monitoring data was not available electronically, and therefore could not be included quantitatively in the analysis. Results reported by Selvakumar et al. (2008) are discussed in **Section 3.5.17**.

Table 3-29 shows the number of individual water quality monitoring samples collected by waterbody, agency and constituent. DEQ and USGS also performed continuous monitoring of temperature, pH, DO, SC, and other constituents in the Accotink Creek watershed. Only continuous monitoring data from the period 2004 through 2014 was used in the original analysis. Subsequent to the completion of the original analysis, the USGS moved the location of its continuous monitoring station from Ranger Road to its gage near Annandale (01654000). The revised analysis incorporated specific conductance data from this gage, the USGS gage at Long Branch (01654500), and from continuous monitoring performed by DEQ at Station 1AACO004.84 at Telegraph Road. For other constituents, continuous monitoring data collected subsequent to the original analysis had no impact on the conclusions and were not included in the revised analysis. **Table 3-30** shows what constituents were monitored and the period over which the monitoring occurred for each agency. The EPA, in conjunction with the USGS, also performed continuous monitoring in Accotink Creek as part of their study of the effects of stream restoration; results are discussed in **Section 3.5.17**.

Table 3-29: Discrete Water Quality Observations in Accotink Creek Watershed, 2004-2014[1]

Watershed	Constituent	DEQ	USGS	FCDPW	EPA
Upper Accotink	Temperature	122	174	20	0
	pH	122	174	20	0
	DO	107	172	20	0
	SC	135	174	20	0
	CL	25	146	0	0
	NTU	22	0	0	0
	FNU	0	34	0	0
	TDS	13	41	0	0
	TSS	39	24	0	12
	SS	10	166	0	0
	NH_3	126	0	0	26
	NO_3	125	137	0	0
	TKN	94	40	0	29
	TN	116	120	0	0
	PO_4	20	0	0	28
	TP	117	170	0	0
Lower Accotink	Temperature	111	0	21	0
	pH	105	0	21	0
	DO	96	0	21	0
	SC	116	0	21	0
	CL	34	0	0	0
	NTU	41	0	0	0
	FNU	0	0	0	0
	TDS	29	0	0	0
	TSS	38	0	0	0
	SS	0	0	0	0
	NH_3	41	0	0	0
	NO_3	41	0	0	0
	TKN	29	0	0	0
	TN	44	0	0	0
	PO_4	29	0	0	0
	TP	64	0	0	0
Long Branch	Temperature	2	24	5	0
	pH	2	24	5	0
	DO	2	24	5	0
	SC	9	24	5	0
	CL	8	0	0	0
	NTU	1	0	0	0
	FNU	0	22	0	0
	TDS	1	0	0	0
	Turbidity	1	0	0	0
	TSS	1	0	0	0
	SS	0	91	0	0
	NH_3	2	0	0	0
	NO_3	2	75	0	0
	TKN	1	74	0	0
	TN	1	74	0	0
	PO_4	2	74	0	0
	TP	2	74	0	0

[1]Includes CL and SC observations collected by DEQ in 2015 and 2016.

Table 3-30: Continuous Water Quality Monitoring in Accotink Creek Watershed (with percent measurement of constituents in Period of Analysis)

Station ID	0165389205	1AACO006.10	01654500	01654000	1AACO004.84
Agency	USGS	DEQ	USGS	DEQ	DEQ
Watershed	Upper Accotink	Lower Accotink	Long Branch	Upper Accotink	Lower Accotink
Period of Record	11/19/2011 - 01/08/2015	08/03/2006 - 08/08/2006	02/08/2013 - present	01/15/2015 - present	01/11/2016 - 02/29/2016
Period of Analysis	11/19/2011- 10/10/2014	08/03/2006 - 08/08/2006	02/08/2013- 10/10/14	Not analyzed (except for SC)	01/11/2016 - 02/29/2016
Temperature	96%	100%	98%	not analyzed	not analyzed
pH	95%	100%	96%	not analyzed	not monitored
DO	95%	100%	92%	not analyzed	not monitored
SC[1]	90%	100%	97%	100%	100%
Turbidity	80%	not monitored	88%	not analyzed	not analyzed

[1]Percent measure based on observations through April 16, 2016

Virginia water quality standards contained in 9VAC25-260 et seq. (State Water Control Board, 2011) provide the most basic criteria for analyzing water quality data. Among the constituents examined in this section, numerical criteria exist for temperature, pH, DO, CL, and NH_3. Numerical criteria for these constituents in non-tidal waters in the Piedmont and Coastal Plain (Class III waters) are given in **Table 3-31**. In accordance with EPA guidance (1997), a water quality standard for a conventional pollutant is met unless more than 10.5% of the observations exceed the criteria in an assessment period (DEQ, 2014).

Table 3-31: Virginia Water Quality Standards for Conventional Pollutants

Constituent	Criteria (for Aquatic Life Use, Non-tidal Waters in Coastal and Piedmont Zones)
Temperature	Maximum: 32°C; maximum hourly change in temperature: ± 2°C; No more than 3°C rise above natural conditions
pH	Minimum: 6.0; Maximum: 9.0.
Dissolved Oxygen	Minimum: 4.0 mg/l; Daily Average 5.0 mg/l
Chloride	Acute[1]: 860 mg/l; Chronic[2]: 230 mg/l
Ammonia	Acute and chronic criteria function of pH and temperature

[1]One hour average concentration not to be exceeded more than once every three years.
[2]Four-day average concentration not to be exceeded more than once every three years.

Continuous monitoring data is generally assessed on a daily basis. A water quality criterion expressed as a minimum or maximum is exceeded only if 10.5% of the observations within a 24-hour period exceed the criterion. A criterion expressed as a daily average is exceeded if the mean of all observations (including grab samples) exceeds the criterion within a 24-hour period. Overall, a water quality standard is met by continuous monitoring data if no more than 10.5% of the days with continuous monitoring exceed the criterion, with the exception that the criterion for the maximum hourly temperature change is exceeded if more than 10.5% of the total number of hourly observations exceeds the criterion.

In the absence of numerical criteria in Virginia's standards, results from the DEQ's ProbMon program were used to help analyze the data. ProbMon is a probabilistic monitoring program designed to survey Virginia's streams and assess their biology and water quality. Sample sites for the ProbMon program are chosen at random, so that the collection of sample sites provides an unbiased view of Virginia's streams. ProbMon stations are typically sampled once in the spring and once in the fall, and are not usually sampled during or right after major weather events (e.g. rain or snow). A biological assessment and habitat assessment is performed at each sample site. Not only are conventional pollutants monitored, but metals and organic chemicals are monitored as well, both in the sediments and in the water column.

The ProbMon program has adopted condition thresholds for six potential biological stressors that do not have water quality criteria: (1) total nitrogen (TN), (2) total phosphorus (TP), (3) total dissolved solids (TDS), (4) the cumulative impact of dissolved metals [using the Cumulative Criterion Unit (CCU) Metals Index], (5) habitat degradation, and (6) sedimentation (using the LRBS). These thresholds are used in evaluating the data collected in the ProbMon program and are included in the Freshwater Probabilistic Monitoring chapter in Virginia's Integrated Water Quality Reports (DEQ, 2010, 2012, and 2014a). The thresholds are also shown in **Table 3-32**. For each of the six thresholds, ProbMon data were used to estimate the relative risk of a site receiving a failing VSCI score when the stressor has a suboptimal value at that site. **Table 3-32** also shows the relative risk for each stressor. The relative risk calculated by ProbMon is based on a state-wide data, without regard to ecoregion or the land use in the catchment upstream the monitoring sites.

Table 3-32: ProbMon Thresholds for Stressor Indicators with Relative Risk for Suboptimal Scores

Parameter	Optimal	Suboptimal	Relative Risk
TN	< 1 (mg/l)	> 2 (mg/l)	3.4
TP	< 0.02 (mg/l)	> 0.05 (mg/l)	3.9
TDS	< 100 (mg/l)	> 350 (mg/l)	5.1
CCU Metals Index	< 1 (unitless)	> 2 (unitless)	4.3
Habitat	> 150 (of 200)	< 120 (of 200)	4.1
LRBS	> - 0.5 (unitless)	< -1.0 (unitless)	2.8

In this analysis, the 90th percentile of the ProbMon monitoring data collected 2001-2012 are also used as a guide to evaluate the monitoring data in Accotink Creek. Since ProbMon data represent a random sample of Virginia's streams, any observed concentration in excess of the 90th percentile concentration of ProbMon samples is, therefore, high relative to concentrations found in the rest of the state and an indicator that a water quality constituent may be contributing to abnormal and possibly adverse conditions for stream biota.

Since ProbMon sampling usually does not take place during or right after storm events, only samples collected under ambient or baseflow conditions were compared to the ProbMon suboptimal thresholds or the 90th percentile ProbMon concentrations. Ambient or baseflow conditions are defined as occurring whenever the average daily flow at the USGS gage near Annandale (01654000) is less than the 90th percentile of the flow observed 1990-2014. **Section 3.4** describes how the daily average flow at this gage serves as an index of hydrological conditions throughout the Accotink Creek watershed. In the sections that follow, time series plots will represent observations taken under all hydrological conditions. Box-and-whisker plots will be restricted to observations under ambient conditions, to facilitate comparison with the ProbMon suboptimal thresholds or the 90th percentile concentrations. **Figure 3-13** illustrates a box plot. The edges of the box represent the 75th and 25th percentile of the data. The heavy line within the box is the median value. The upper horizontal whisker line represents the observation no greater than 1.5 times the interquartile range (75th percentile – 25th percentile) beyond the 75th percentile, while the lower whisker line represents the observation no less than 1.5 times the interquartile range smaller than the 25th percentile. Observations above the upper whisker or below the lower whisker are shown individually. In **Figure 3-13**, since there are no observations below the lower whisker, the lower whisker represents the minimum value.

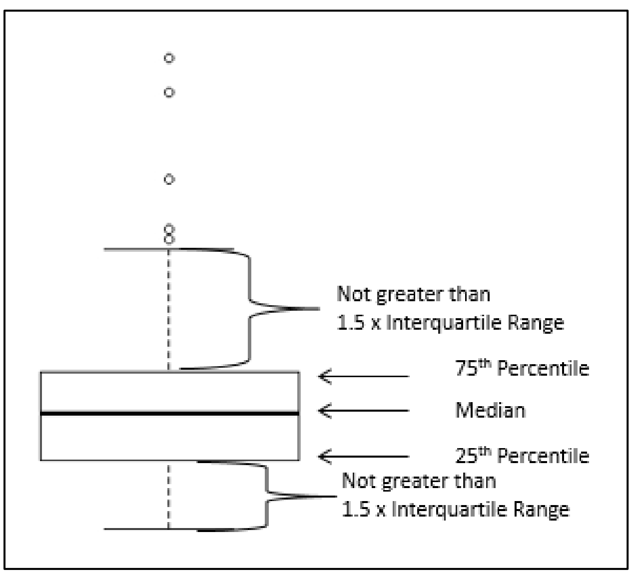


Figure 3-13: Illustration of a Box and Whisker Plot

3.5.1 Temperature

Water temperature measurements are made in the field when water quality samples are collected. **Figures 3-14, 3-15,** and **3-16** show the temperature measurements of the samples from upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Virginia water quality standards for Class III waters specify that water temperature should not be greater than 32°C (9VAC-25-260-50). No discrete sample in Accotink Creek exceeded this criterion.

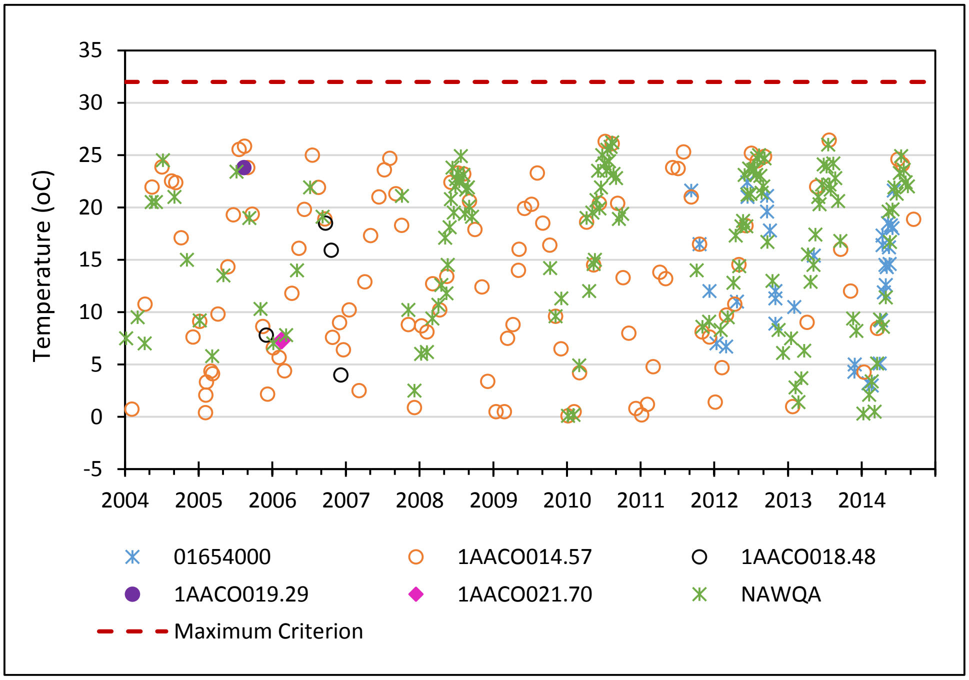


Figure 3-14: Observed Temperature (°C) in Upper Accotink Creek

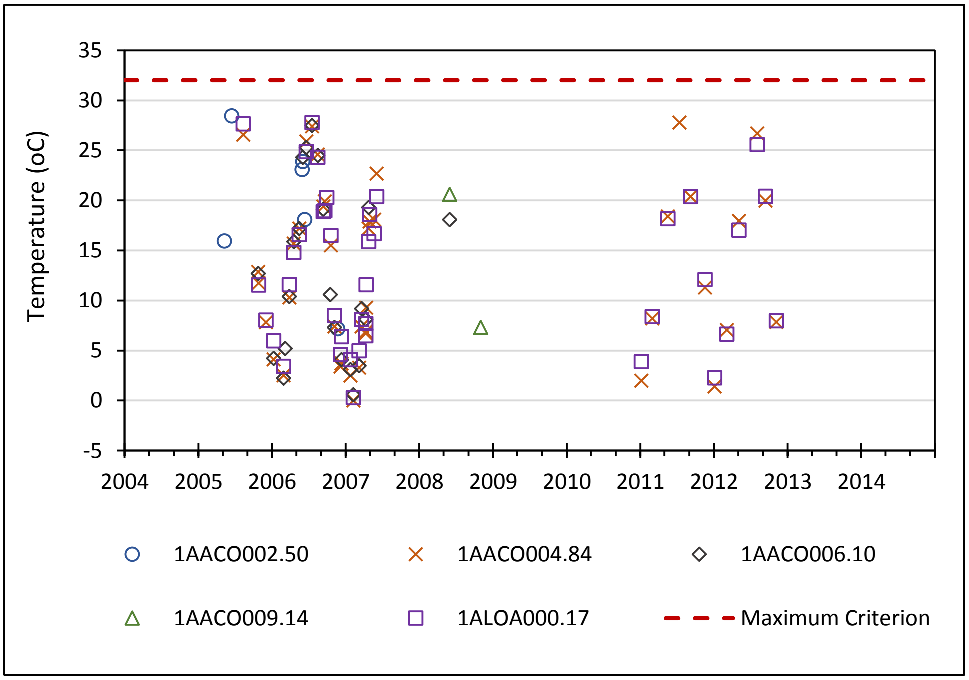


Figure 3-15: Observed Temperature (°C) in Lower Accotink Creek

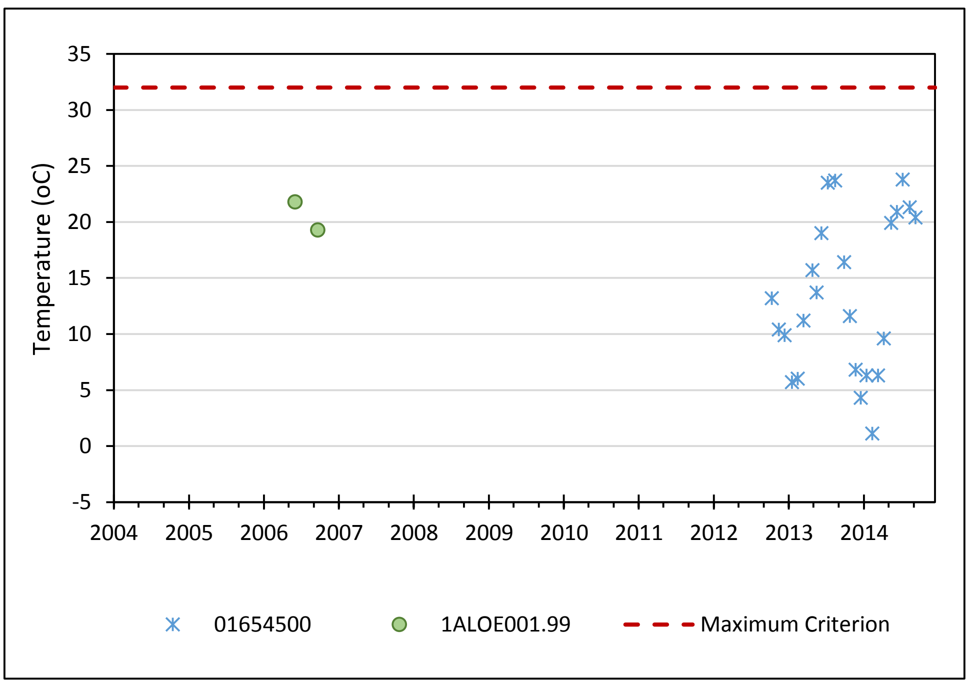


Figure 3-16: Observed Temperature (°C) in Long Branch

Temperature was also measured during continuous monitoring in Accotink Creek. **Figures 3-17, 3-18** and **3-19** show temperature values for, Accotink Creek near Ranger Road, Accotink Creek at Alban Road, and Long Branch near Annandale, respectively. There are no exceedances of the maximum temperature criterion.

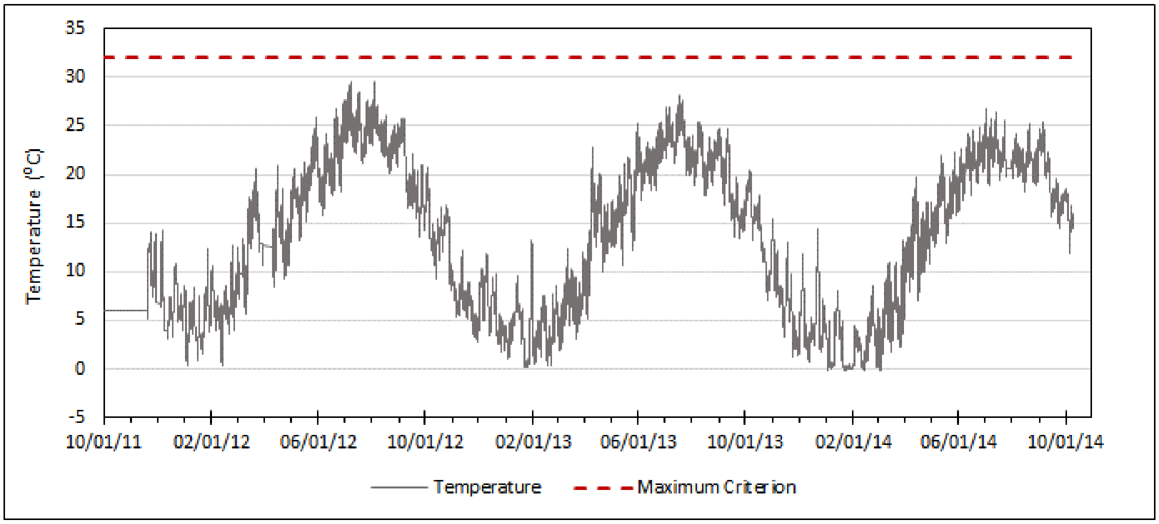


Figure 3-17: Observed Temperature (°C), Continuous Monitoring, Accotink Creek near Ranger Road

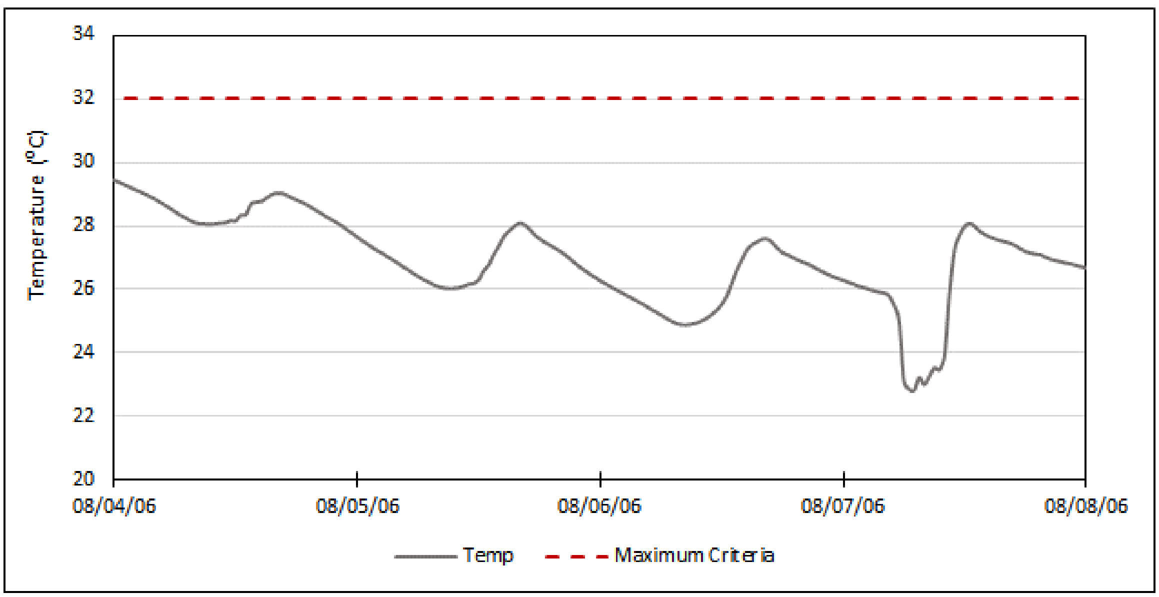


Figure 3-18: Observed Temperature (°C), Continuous Monitoring, Accotink Creek at Alban Road

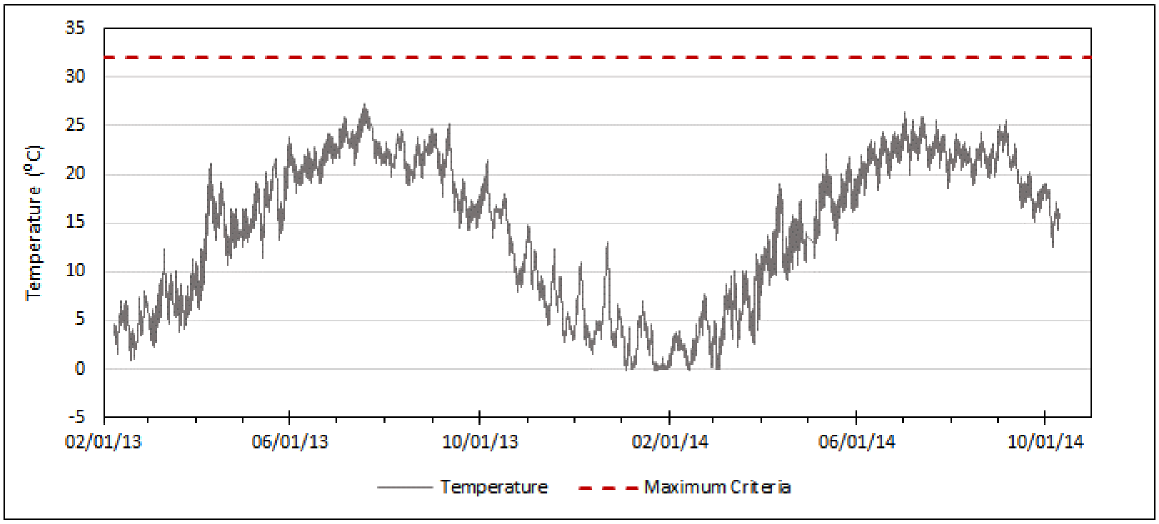


Figure 3-19: Observed Temperature (°C), Continuous Monitoring, Long Branch near Annandale

Virginia water quality standards also specify that the maximum hourly temperature change should not exceed 2°C (9VAC25-260-70). Only nine hourly temperature changes recorded during continuous monitoring in Accotink Creek exceeds the maximum hourly change criterion. These are shown in **Table 3-33**. In Accotink Creek near Ranger Road and Long Branch, where turbidity was also measured, all temperature exceedances are associated with a sharp rise in turbidity, indicating that they are brought about by storm events. See **Section 3.5.7** for a discussion of turbidity and flow. In urban areas stormwater discharge can lead to a rise in temperature if impervious surfaces are hotter than air temperature, especially in summer months. Since most of the recorded large changes in water temperature in the Accotink Creek watershed are negative, heat transfer from impervious surfaces does not seem to be the dominant effect in large changes in water temperature. Large changes in temperature are probably a function of the temperature of precipitation and the rapid conveyance of precipitation to streams by the storm sewer system. DEQ's continuous monitoring at Alban Road captured a storm event on 08/07/2006. As shown in **Figure 3-18**, temperature first rapidly decreased, then increased. The rise in temperature is possibly an effect of flow from Lake Accotink arriving at Alban Road after the start of the storm, but it is not possible to determine if this is the case with the limited data available.

Table 3-33: Hourly Temperature Change Criterion Exceedances in Accotink Creek Watershed

Station	Agency	Date and Time	Final Temperature (°C)	Change in Temperature (°C)
1AACO006.10	DEQ	08/07/2006 06:00	23.1	-2.42
1AACO006.10	DEQ	08/07/2006 11:00	27.26	3.37
0165389205	USGS	07/10/2012 21:15	23.9	-2.1
0165389205	USGS	07/20/2012 00:15	24.5	-2.3
0165389205	USGS	09/08/2012 16:15	22.7	-2.9
0165389205	USGS	01/30/2013 20:15	12.7	3.0
01654500	USGS	05/28/2013 19:00	20.7	2.3
0165389205	USGS	05/28/2013 19:15	20.5	2.3
0165389205	USGS	05/16/2014 06:15	15.9	-2.7

Virginia water quality standards also specify that any rise above natural temperature shall not exceed 3°C (9VAC25-260-60). Presumably this criterion is directed at the discharge of cooling water or other discharges from treatment plants or industrial processes, but it could possibly be applied to storm sewer system discharges. It is difficult to determine in a watershed as developed as Accotink Creek what the natural temperature should be, but **Figures 3-17, 3-18**, and **3-19** do show that temperature can rise rapidly in Accotink Creek and Long Branch. To determine the likelihood that stormwater inflows are responsible for the rise in temperature, an analysis of daily temperature changes was performed on the continuous monitoring data in Accotink Creek near Ranger Road. **Figure 3-20** shows the distribution of daily temperature changes in Accotink Creek near Ranger Road. On 28% of the dates in which monitoring occurred, the change in temperature was 3°C or greater. **Figure 3-21** classifies whether the daily temperature changes occurred under storm flow or ambient conditions, as indexed by the percentile flow at USGS gage 01654000 (see **Section 3.4**). Large temperature changes are more likely to occur under ambient conditions than storm conditions, indicating that storm sewer discharges are not likely to be responsible for daily fluctuations in temperature greater than 3°C.

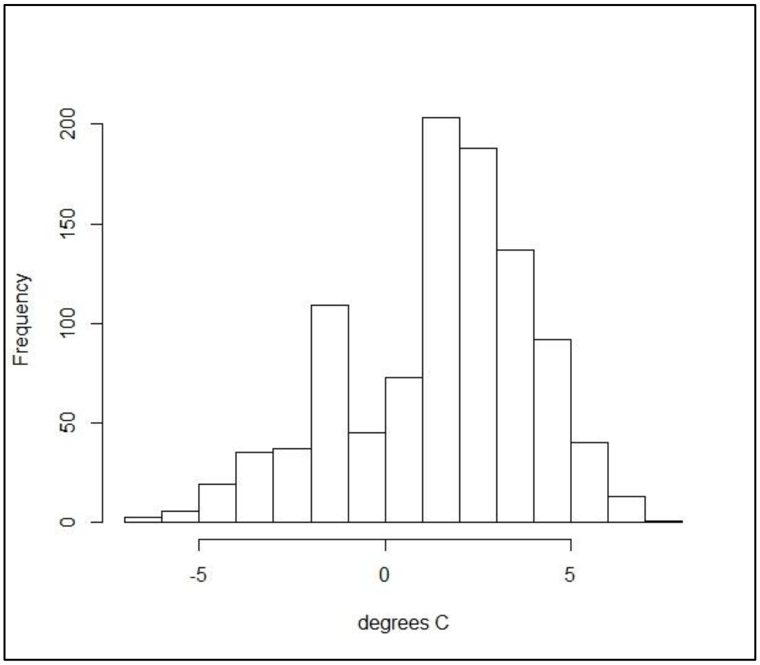


Figure 3-20: Absolute Difference Between Daily Maximum and Minimum Temperature, Accotink Creek near Ranger Road

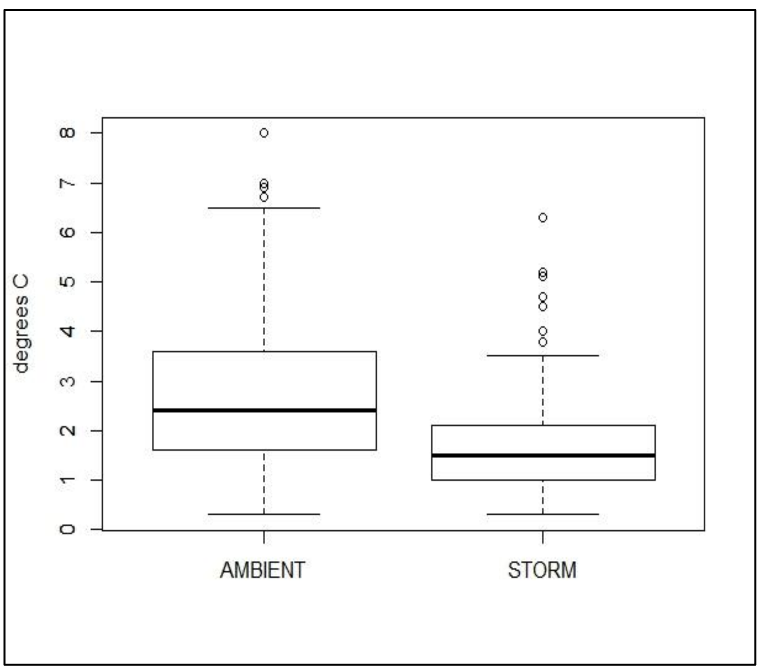


Figure 3-21: Comparison of Absolute Difference between Daily Maximum and Minimum Temperature during Storm Flow and Ambient Flow, Accotink Creek near Ranger Road

3.5.2 pH

pH measurements are made in the field when water quality samples are collected. **Figures 3-22, 3-23,** and **3-24** show the pH measurements of the samples from upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Virginia water quality standards specify that for Class III waters, pH should not be less than 6.0 or greater than 9.0 (9VAC-25-260-50). All samples from the lower mainstem Accotink Creek and Long Branch have pH values between the minimum and maximum criteria. One field sample out of 239 in the upper mainstem of Accotink Creek was below the minimum criterion; none were above the maximum criterion.

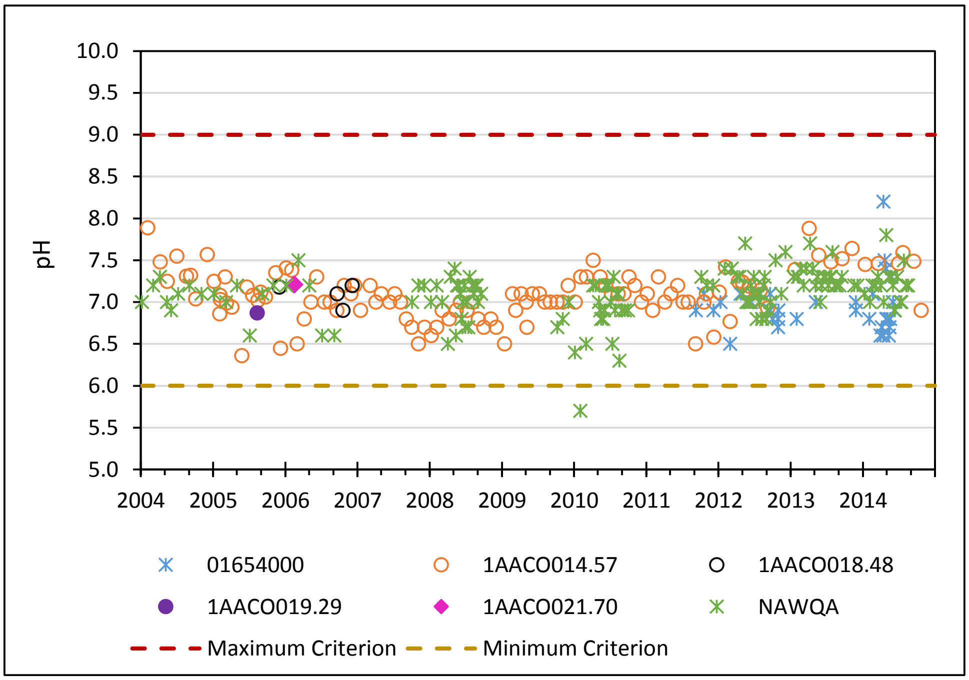


Figure 3-22: Observed pH in Upper Accotink Creek

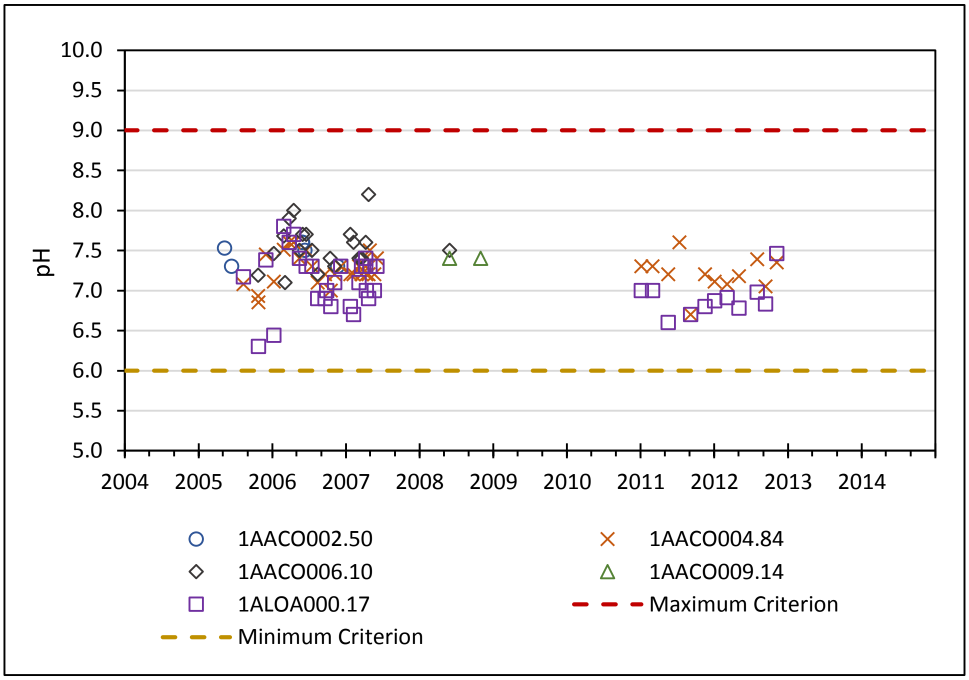


Figure 3-23: Observed pH in Lower Accotink Creek

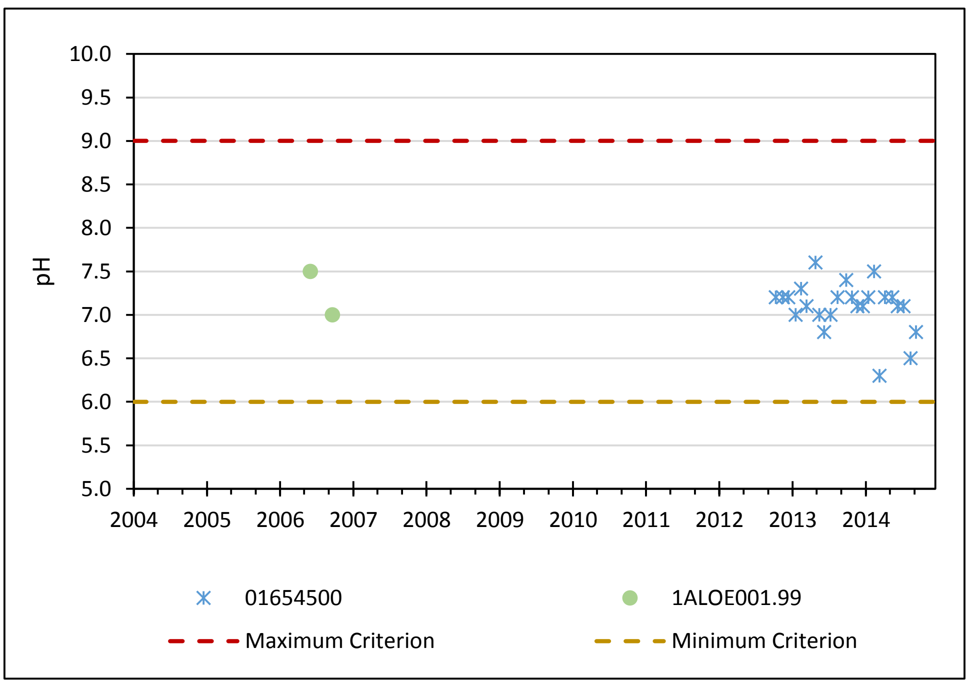


Figure 3-24: Observed pH in Long Branch

pH was also measured during continuous monitoring in Accotink Creek. **Figures 3-25, 3-26** and **3-27** show pH values for, Accotink Creek near Ranger Road, Accotink Creek at Alban Road, and

Long Branch near Annandale, respectively. All observed pH values in Long Branch and in Accotink at Alban Road are between the minimum and maximum criteria. In Accotink Creek near Ranger Road, the maximum criterion is exceeded on 04/17/2012 and on four consecutive days in July 2014: 07/21/2014 - 07/24/2014. All exceedances occurred under ambient conditions late in the afternoon. The April 2012 exceedance was accompanied by a rise in DO concentrations to 14 mg/l, about 150% of DO saturation. This suggests that excessive primary production was responsible for the rise in pH. During the July 2014 exceedances, the range of DO saturation was approximately 120% to 130%, which may indicate that primary production contributed to the exceedance.

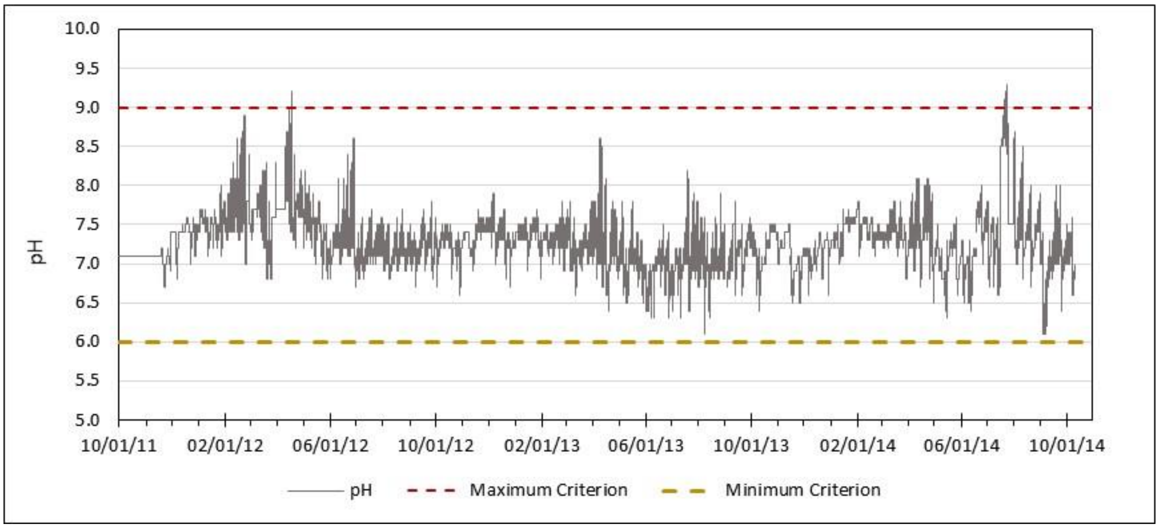


Figure 3-25: Observed pH, Continuous Monitoring, Accotink Creek near Ranger Road

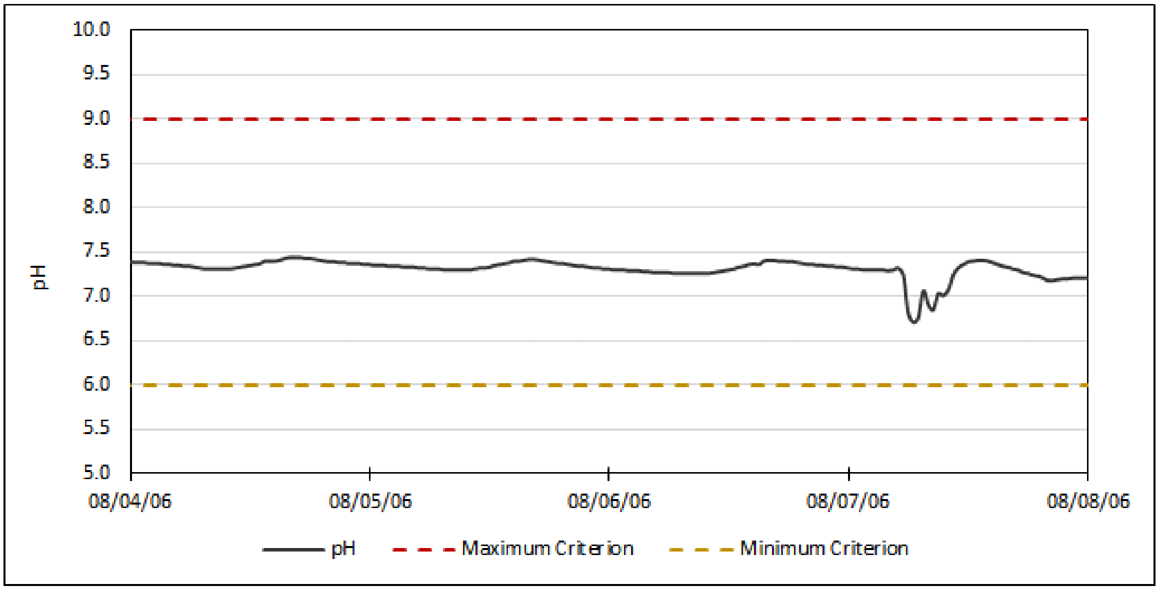


Figure 3-26: Observed pH, Continuous Monitoring, Accotink Creek at Alban Road

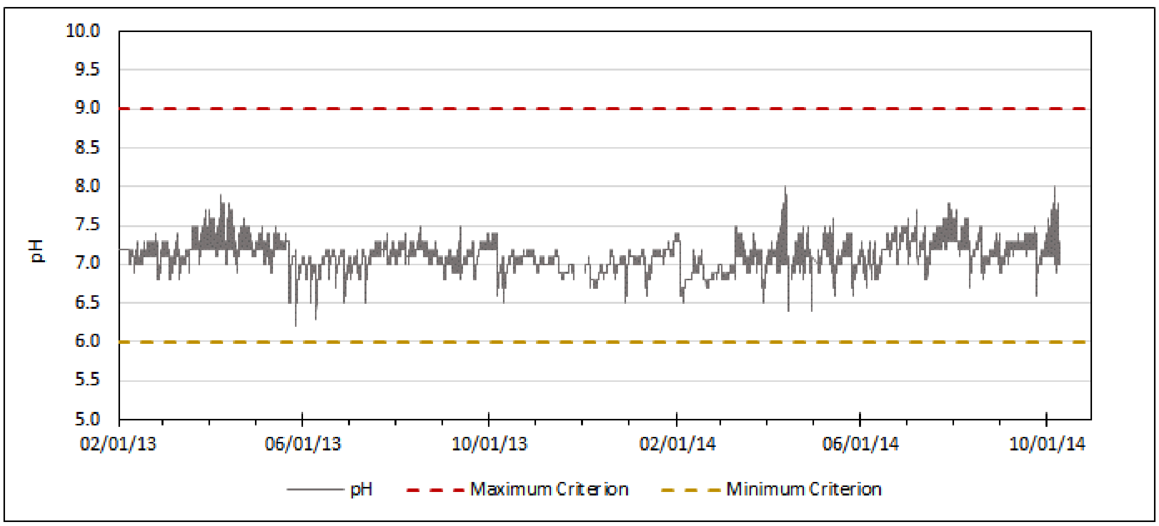


Figure 3-27: Observed pH, Continuous Monitoring, Long Branch near Annandale

3.5.3 Dissolved Oxygen

Dissolved oxygen measurements are also made in the field when water quality samples are collected. **Figures 3-28, 3-29,** and **3-30** show the DO measurements of the samples from upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Virginia water quality standards specify that for Class III waters the minimum instantaneous DO concentration should not be less than 4.0 mg/l (9VAC-25-260-50). None of the field samples taken in the Accotink Creek watershed have DO concentrations less than the minimum instantaneous criterion.

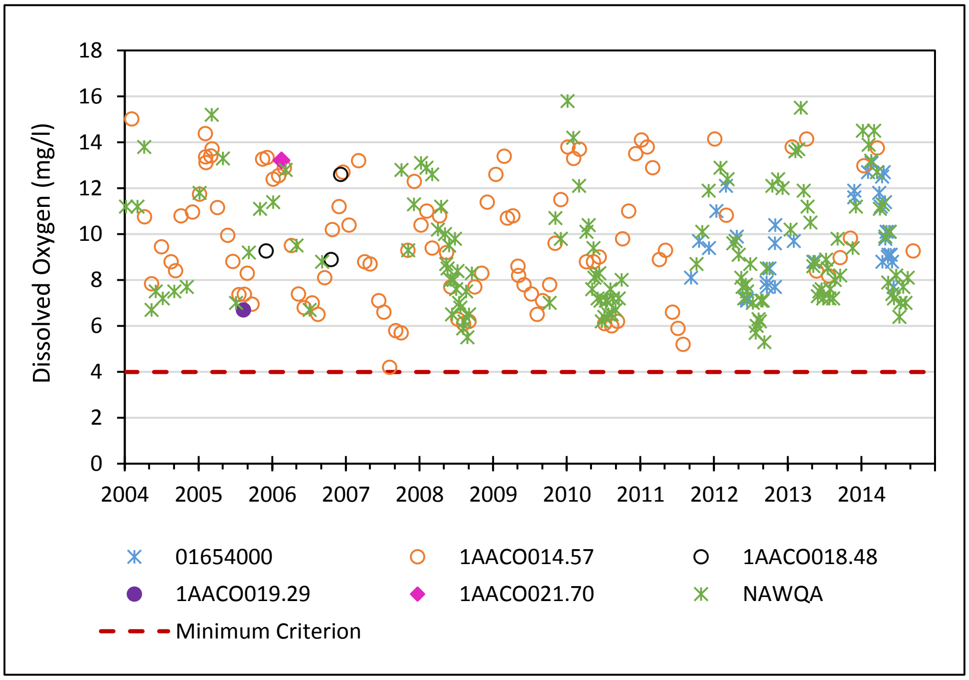


Figure 3-28: Observed Dissolved Oxygen (mg/l) in Upper Accotink Creek

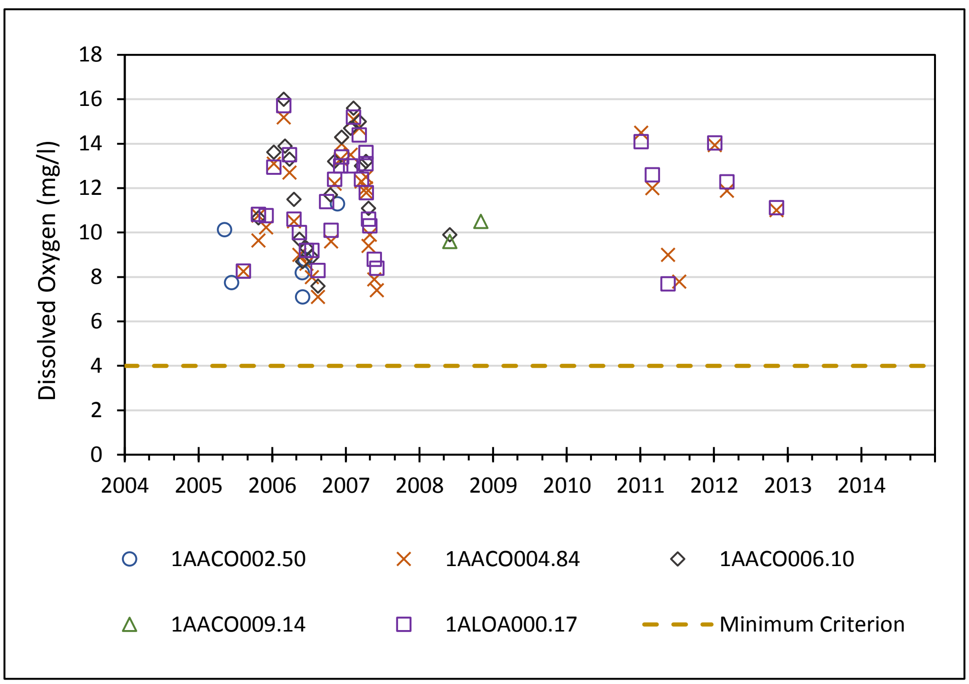


Figure 3-29: Observed Dissolved Oxygen (mg/l) in Lower Accotink Creek

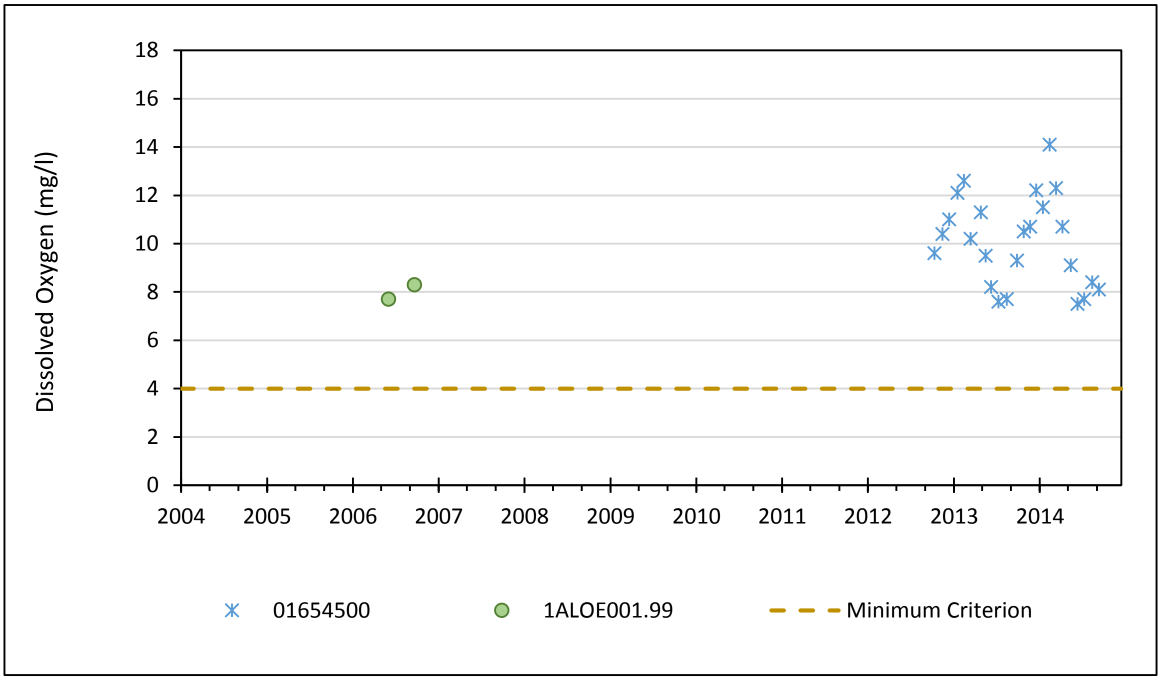


Figure 3-30: Observed Dissolved Oxygen (mg/l) in Long Branch

DO was also measured during continuous monitoring in Accotink Creek. **Figures 3-31, 3-32** and **3-33** show DO concentrations for Accotink Creek near Ranger Road, Accotink Creek at Alban Road, and Long Branch near Annandale, respectively. Virginia's standards require Class III waters to have a daily average DO concentration no less than 5.0 mg/l (9VAC-25-260-50). The minimum DO concentrations at Alban Road and Long Branch are 5.8 and 5.4 mg/l, respectively, so both the instantaneous DO criterion and the daily average criterion are met. There are observations of DO below 4.0 mg/l in Accotink Creek near Ranger Road, however, as is shown in **Figure 3-31**. Only about 1.2% of the dates where continuous monitoring was performed have observations of DO below 4.0 mg/l; these dates are concentrated in May and July, where 4.4% and 8.0%, respectively, of the dates where continuous monitoring was performed have observations of DO below 4.0 mg/l. The daily average DO concentration is less than 5 mg/l only on five dates. All but one of them occur in the month of July.

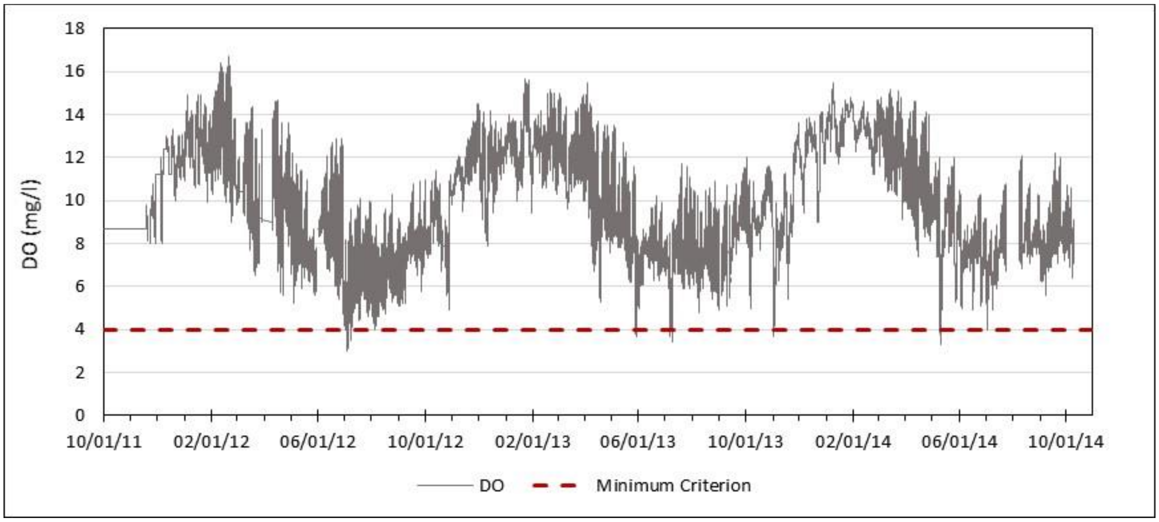


Figure 3-31: Observed Dissolved Oxygen (mg/l), Continuous Monitoring, Accotink Creek near Ranger Road

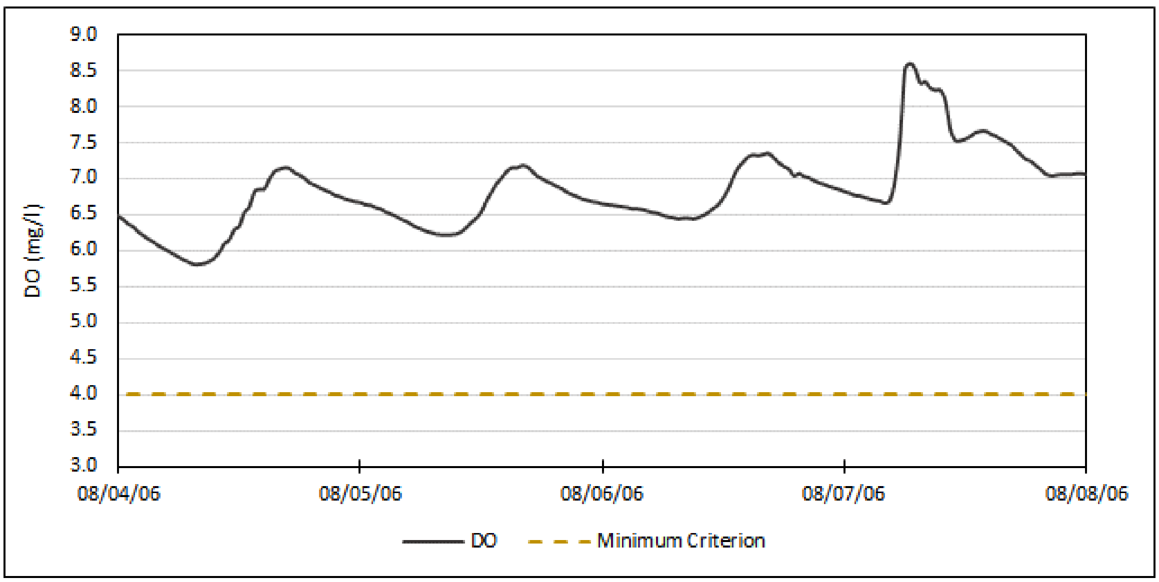


Figure 3-32: Observed Dissolved Oxygen (mg/l), Continuous Monitoring, Accotink Creek at Alban Road

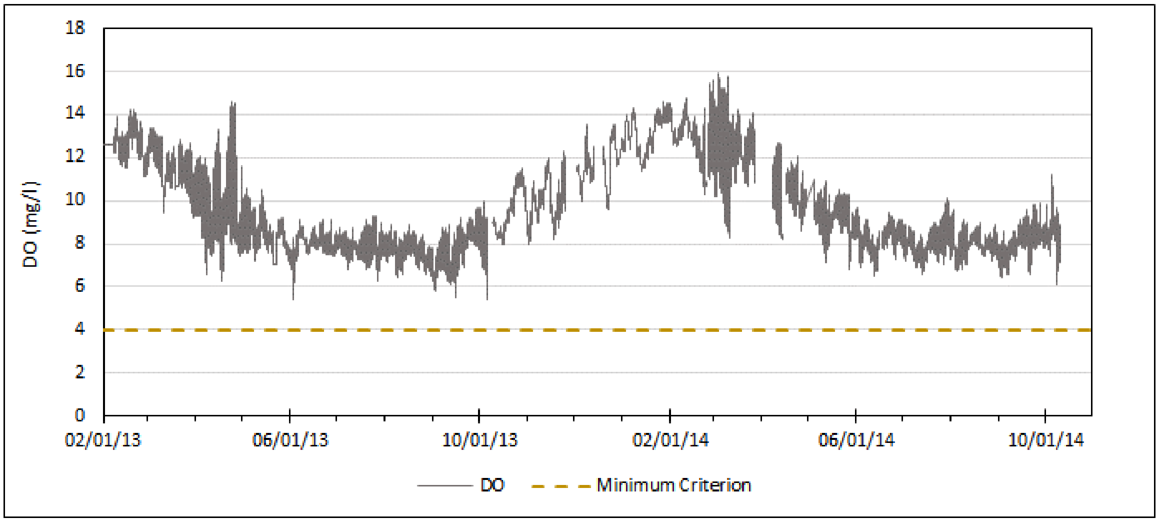


Figure 3-33: Observed Dissolved Oxygen (mg/l), Continuous Monitoring, Long Branch near Annandale

Percent DO saturation, corrected for temperature but not salinity, was calculated from continuous monitoring data from Accotink Creek near Ranger Road using a formula from Chapra (1997). **Figure 3-34** shows the percent DO saturation monitored in Accotink Creek near Ranger Road. There are large swings in DO saturation. Percent saturation is outside the 75% to 125% range about over 15% of the time and outside the 60% to 140% range about 3% of time. In contrast, percent DO saturation in Long Branch is outside the 75% to 125% range less than 3% of time and outside the 60% to 140% range less than 0.01% of the time. On a monthly basis, April has the most number of days where DO saturation is above 140% in Accotink Creek near Ranger Road. April also has the largest average daily percent DO saturation difference. The average daily change in percent DO saturation in April is 49%.

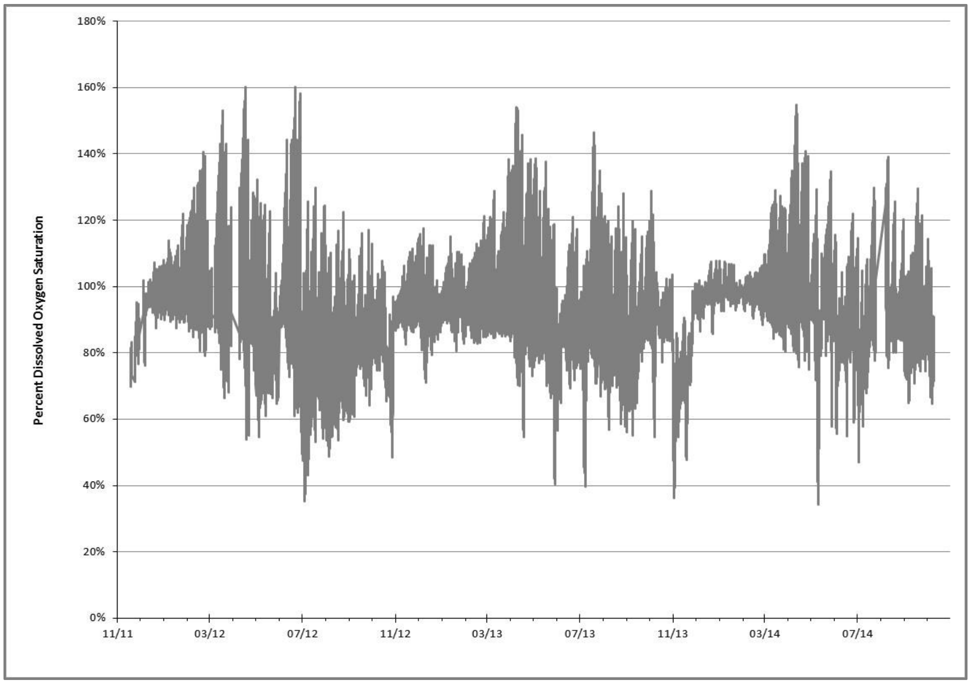


Figure 3-34: Percent Dissolved Oxygen Saturation, Accotink Creek Near Ranger Road

3.5.4 Specific Conductance

Specific conductance (SC) is measured in the field concurrently with water quality sampling and also in the laboratory. There are no criteria in Virginia for specific conductance. **Figures 3-35, 3-36,** and **3-37** show the SC observed in individual samples from upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. The figures show laboratory measurements or field measurements where laboratory measurements were not available. The 90th percentile concentration of state-wide ProbMon samples is 374 μS/cm. **Figure 3-38** shows the distribution of SC observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch compared to the 90th percentile concentration of the ProbMon data. Twenty-eight percent, 30%, and 23% of the measurements made in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively, under ambient conditions are higher than the 90th percentile of the ProbMon data. **Figure 3-39** shows the average monthly SC. There is a seasonal trend: SC measurements are higher in the winter months and decline through spring, summer, and fall.

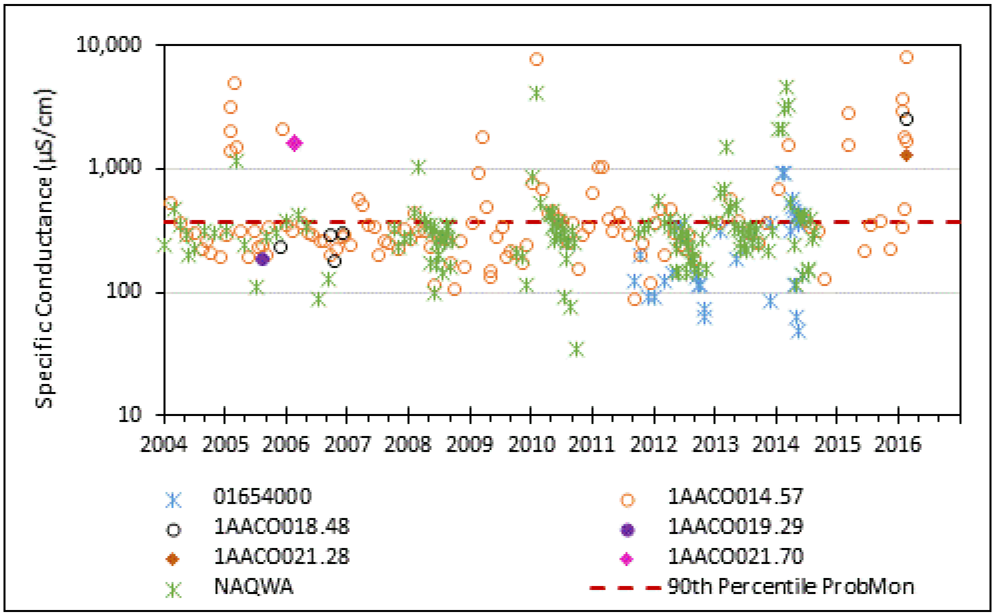


Figure 3-35: Observed Specific Conductance (µS/cm) in Upper Accotink Creek

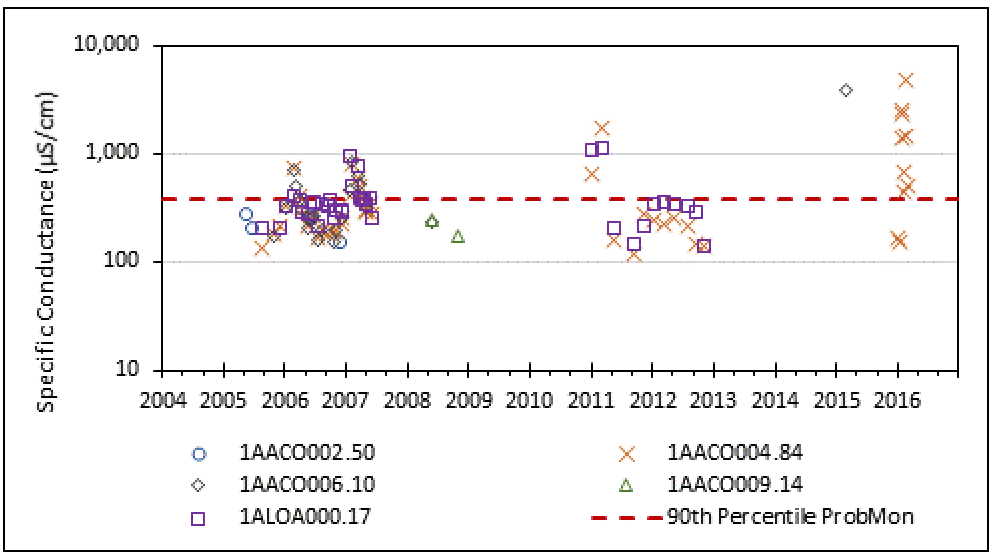


Figure 3-36: Observed Specific Conductance (µS/cm) in Lower Accotink Creek

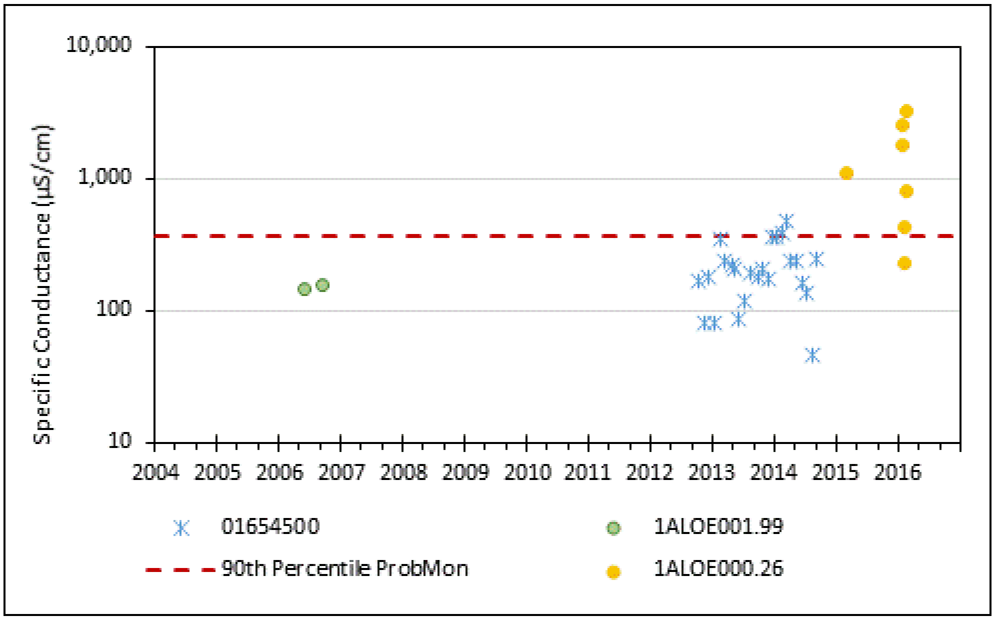


Figure 3-37: Observed Specific Conductance (µS/cm) in Long Branch

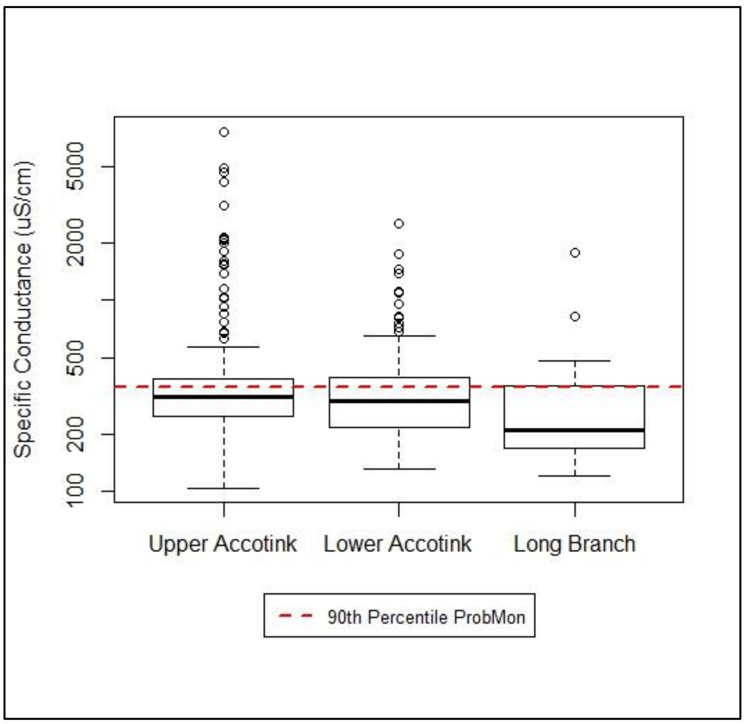


Figure 3-38: Ambient Specific Conductance (µS/cm) in Accotink Creek Watershed

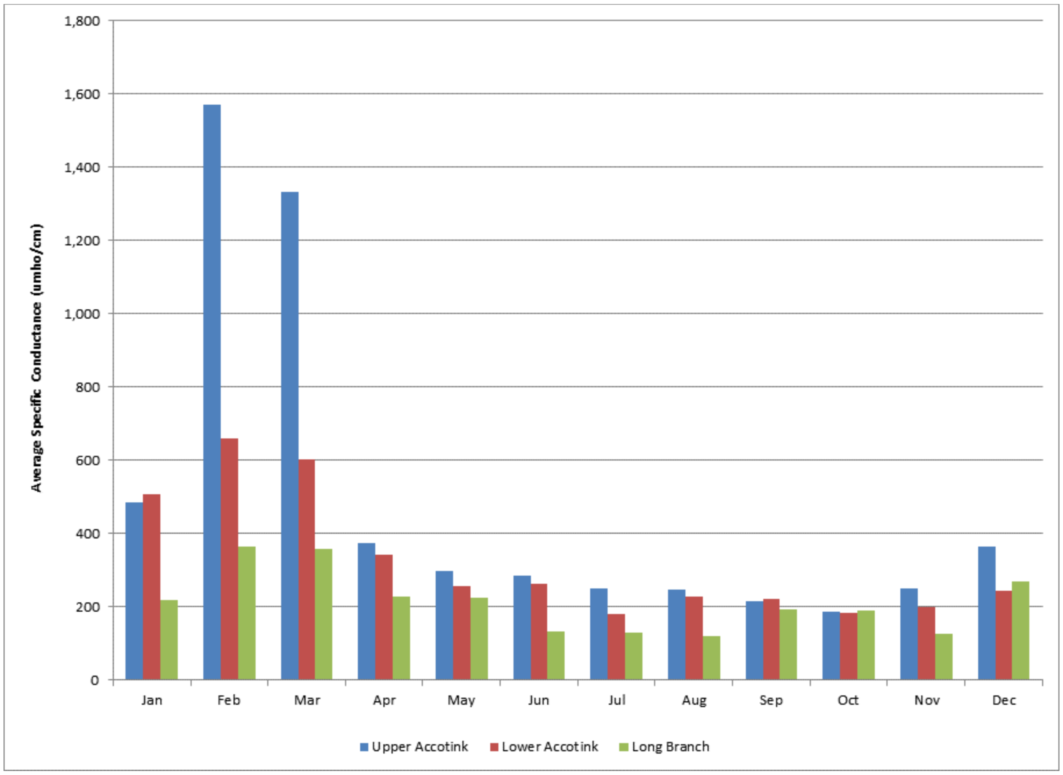


Figure 3-39: Average Monthly Specific Conductance (μS/cm) in Accotink Creek

SC was also measured during continuous monitoring in Accotink Creek. **Figures 3-40, 3-41, 3-42, 3-43, and 3-44** show SC measurements for Accotink Creek near Ranger Road, Accotink Creek at Alban Road, Long Branch near Annandale, Accotink Creek near Annandale, and Accotink Creek at Telegraph Road, respectively. Outside of the winter months (December through March), SC measurements tend to decrease during storm events, as illustrated by the 08/07/06 storm event captured by DEQ monitoring at Alban Road, shown in **Figure 3-41**. The continuous monitoring data are characterized by large increases in SC during the winter months and sharp decreases the rest of the year. The sharp decreases are due to storm events outside of the winter months. The large increases in winter are most likely due not to storm events per se but to snow melt. SC measurements increase by over an order of magnitude in upper Accotink Creek during the winter, reaching 10,000 μS/cm. The average level of SC in Long Branch is generally below the 90th percentile of the ProbMon data, but the average level in upper Accotink Creek is generally above the 90th percentile of the ProbMon data except during storm events outside of winter.

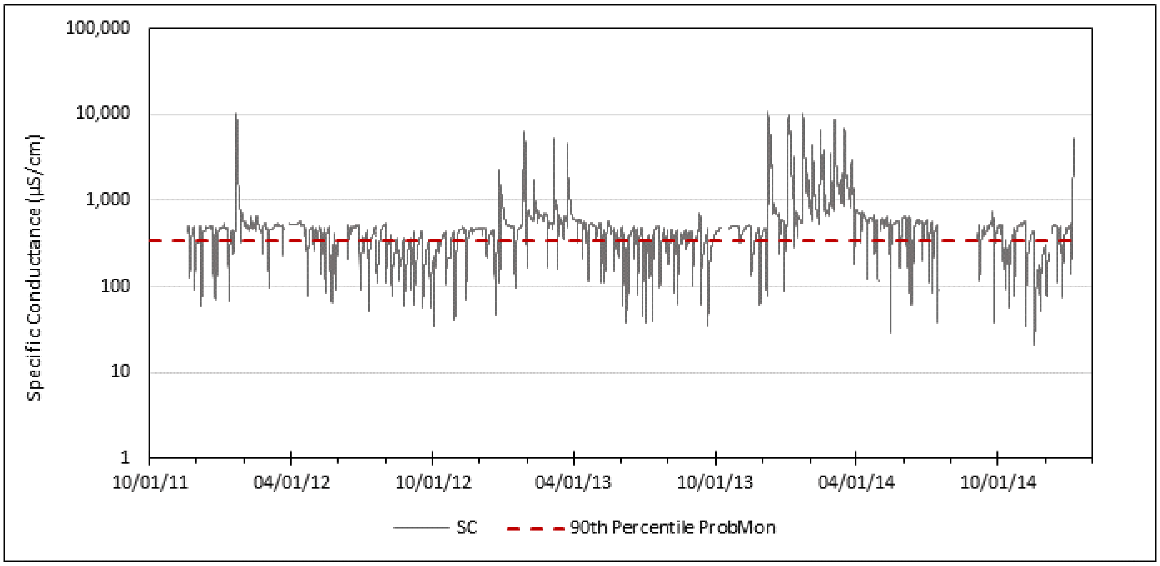


Figure 3-40: Observed Specific Conductance (µS/cm), Continuous Monitoring, Accotink Creek near Ranger Road

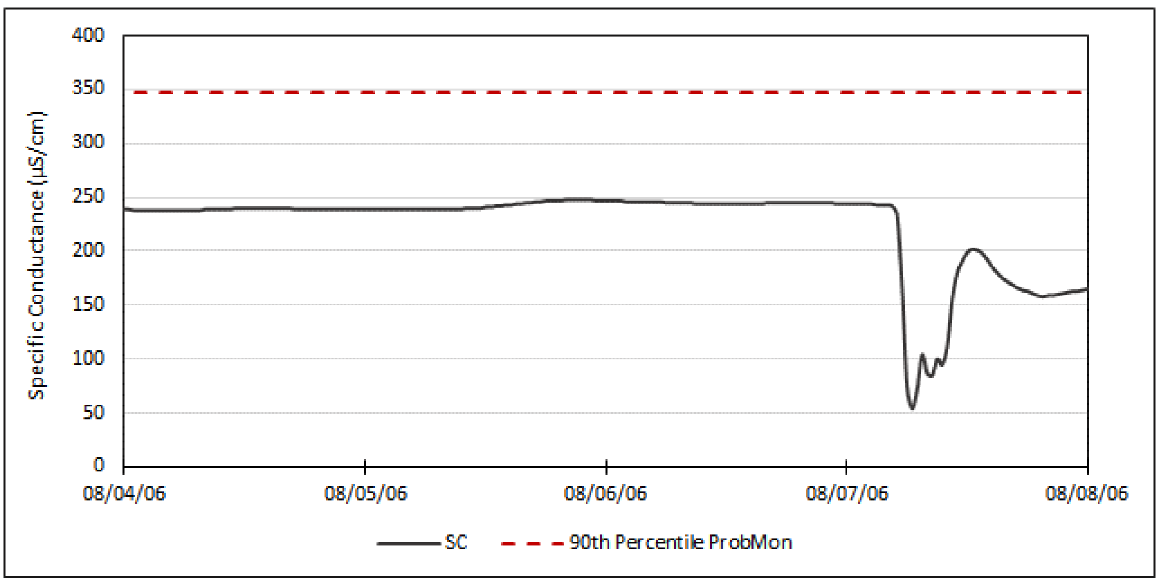


Figure 3-41: Observed Specific Conductance (µS/cm), Continuous Monitoring, Accotink Creek at Alban Road

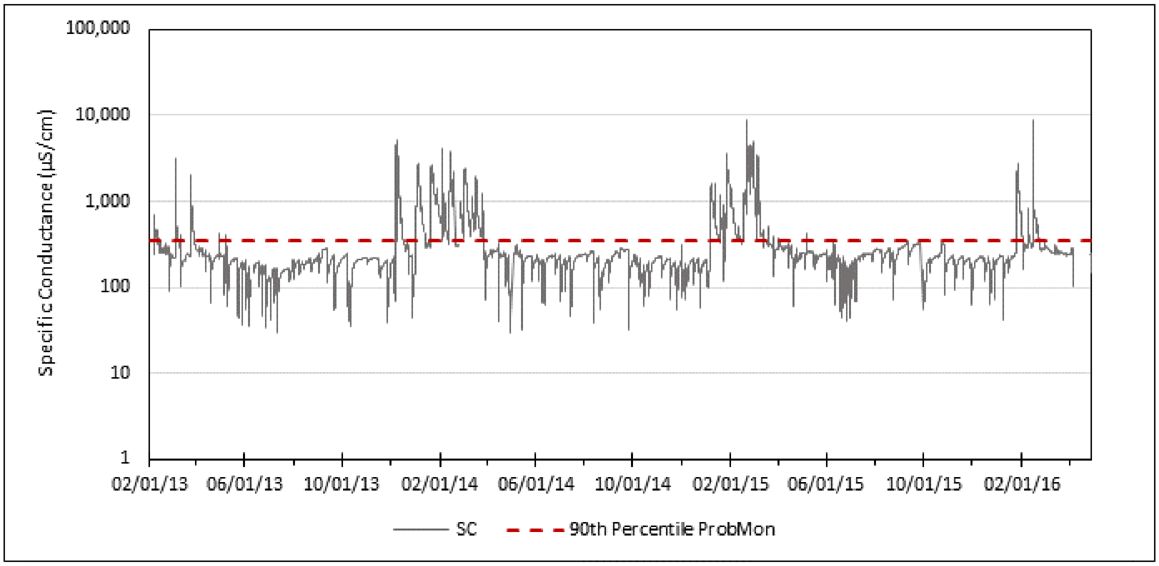


Figure 3-42: Observed Specific Conductance (µS/cm), Continuous Monitoring, Long Branch near Annandale

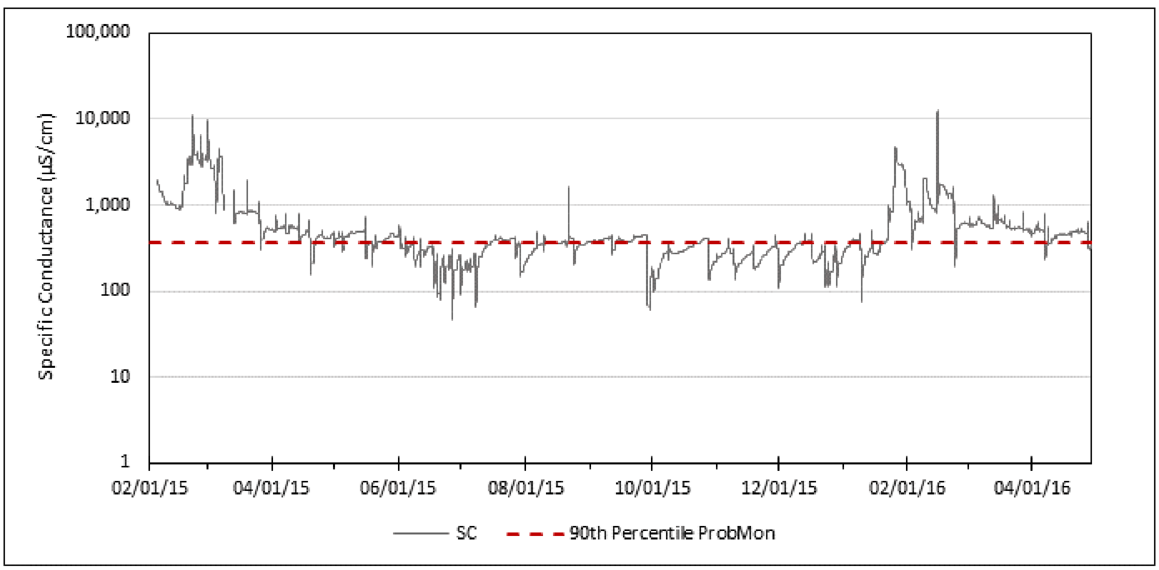


Figure 3-43: Observed Specific Conductance (µS/cm), Continuous Monitoring, Accotink Creek near Annandale

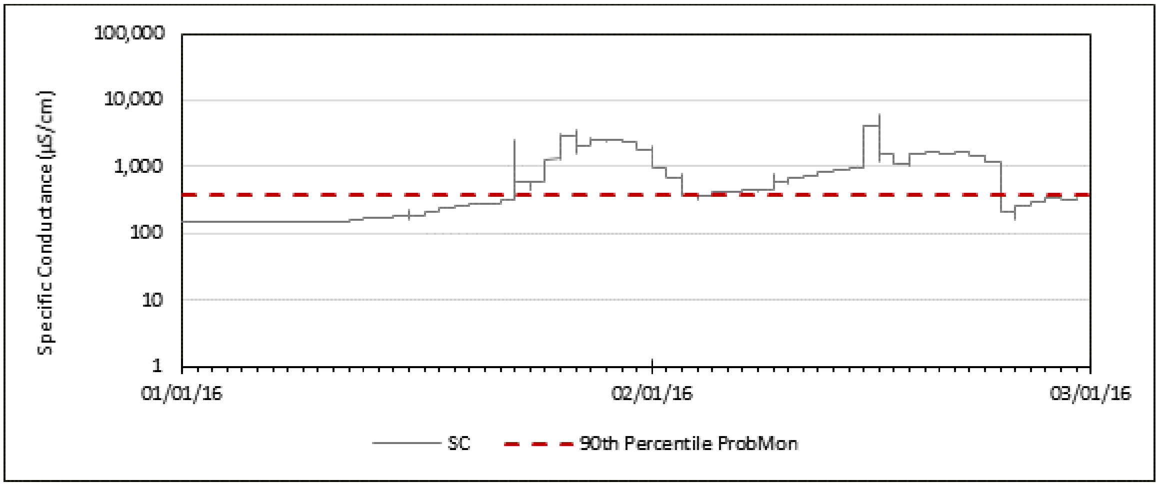


Figure 3-44: Observed Specific Conductance (µS/cm), Continuous Monitoring, Accotink Creek near Telegraph Road

3.5.5 Total Dissolved Solids

Figures 3-45 and 3-46 show the concentrations of total dissolved solids (TDS) observed in water quality samples from upper Accotink Creek and lower Accotink Creek, respectively. The laboratory analyses necessary to calculate TDS were not performed in Long Branch except in one sample. Virginia's water quality standards include a criterion of a maximum concentration of 500 mg/l for drinking water intakes, which is not relevant for the Accotink Creek watershed, since it is not used as a drinking water supply. **Figure 3-47** shows the distribution of TDS concentrations observed under ambient conditions in upper Accotink Creek and lower Accotink Creek compared to the ProbMon suboptimal threshold and 90th percentile concentration of the ProbMon data. About 20% of the concentrations observed in upper Accotink Creek and 19% in lower Accotink Creek under ambient conditions are above the ProbMon condition threshold of 350 mg/l for suboptimal conditions. Sixty-eight percent of the samples in upper Accotink Creek and 78% of the samples in lower Accotink Creek are above the 90th percentile ProbMon concentration of 176 mg/l.

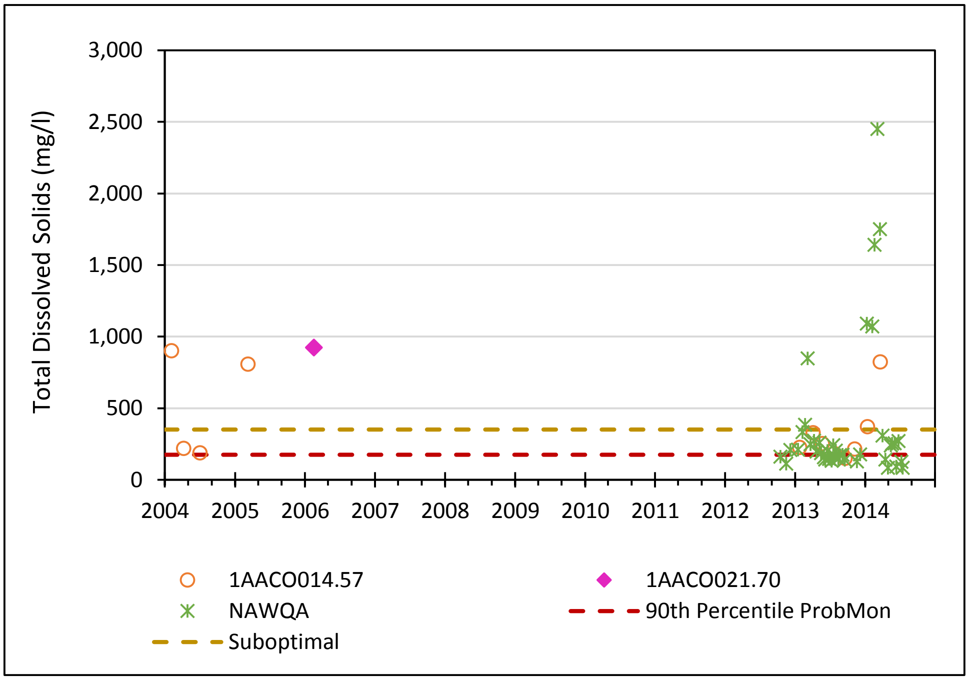


Figure 3-45: Observed Total Dissolved Solids (mg/l) in Upper Accotink Creek

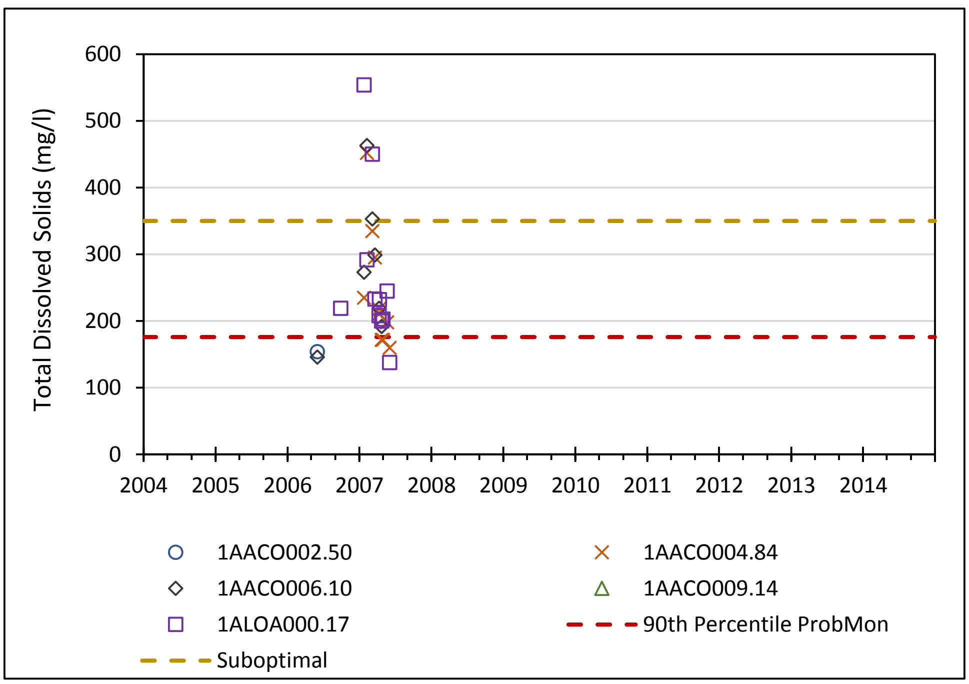


Figure 3-46: Observed Total Dissolved Solids (mg/l) in Lower Accotink Creek

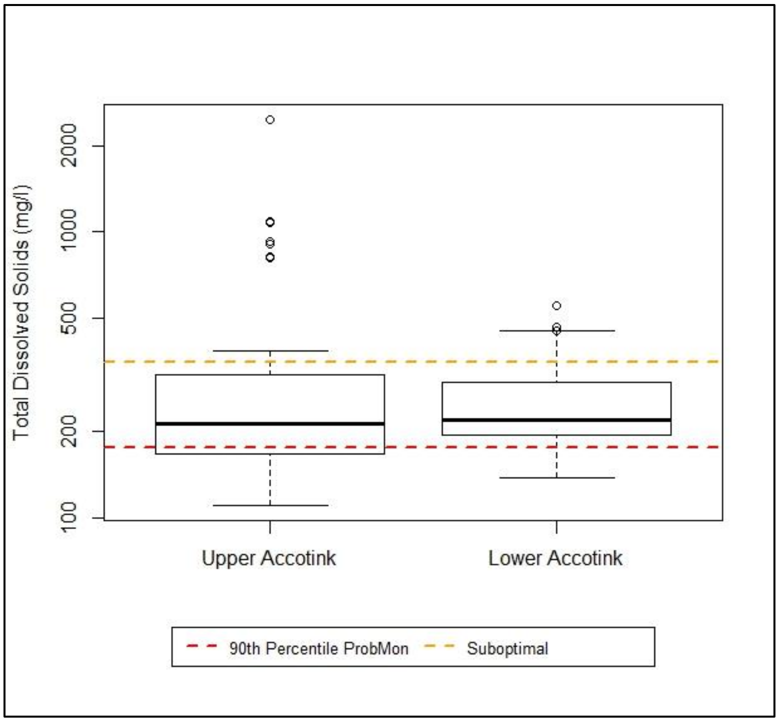


Figure 3-47: Ambient Total Dissolved Solids (mg/l) in Accotink Creek Watershed

The anions and cations that induce conductance are also major components of TDS, so it would not be surprising if SC and TDS are highly correlated. **Figures 3-48** and **3-49** show the correlation between SC and TDS in upper and lower Accotink Creek, respectively. The coefficient of determination (R^2) between TDS and SC is 0.97 in upper Accotink Creek and 0.99 in lower Accotink Creek, demonstrating the strength of the correlation.

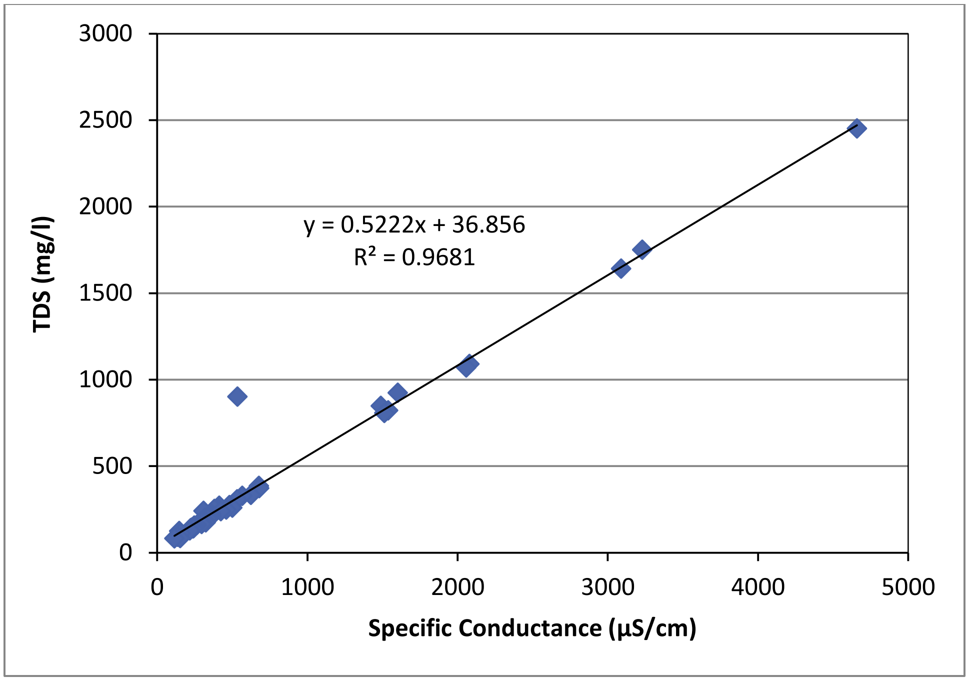


Figure 3-48: Correlation between Total Dissolved Solids and Specific Conductance, Upper Accotink Creek

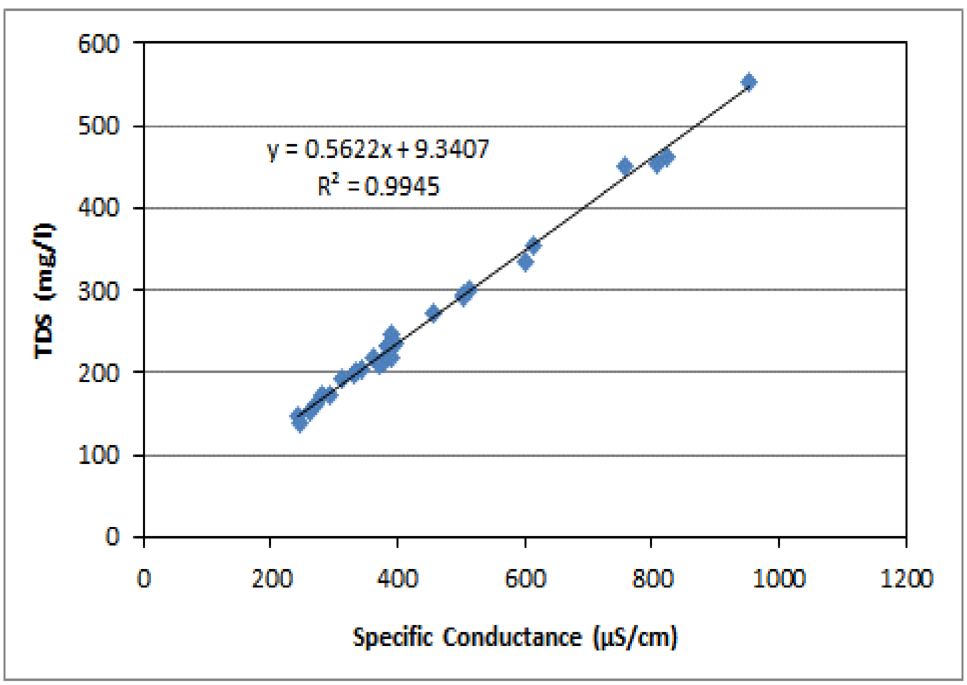


Figure 3-49: Correlation between Total Dissolved Solids and Specific Conductance, Lower Accotink Creek

3.5.6 Chloride

Figures 3-50, 3-51, and 3-52 show the concentrations of chloride (CL) observed in water quality samples from upper Accotink Creek, lower Accotink Creek, and Long Branch respectively. Virginia water quality standards include an acute maximum CL concentration criterion of 860 mg/l and a chronic maximum concentration criterion of 230 mg/l to protect aquatic life. The acute criterion is for a one-hour average not to be exceeded more than once every three years; the chronic criterion applies to a four-day average, which is also not to be exceeded more than once every three years (9VAC25-260-140). The 90th percentile concentration of ProbMon data for chloride (not shown in **Figures 3-52, 3-53** and **3-54**) is 15 mg/l, and it is exceeded by all observations taken in the Accotink Creek watershed except for two observations in upper Accotink Creek.

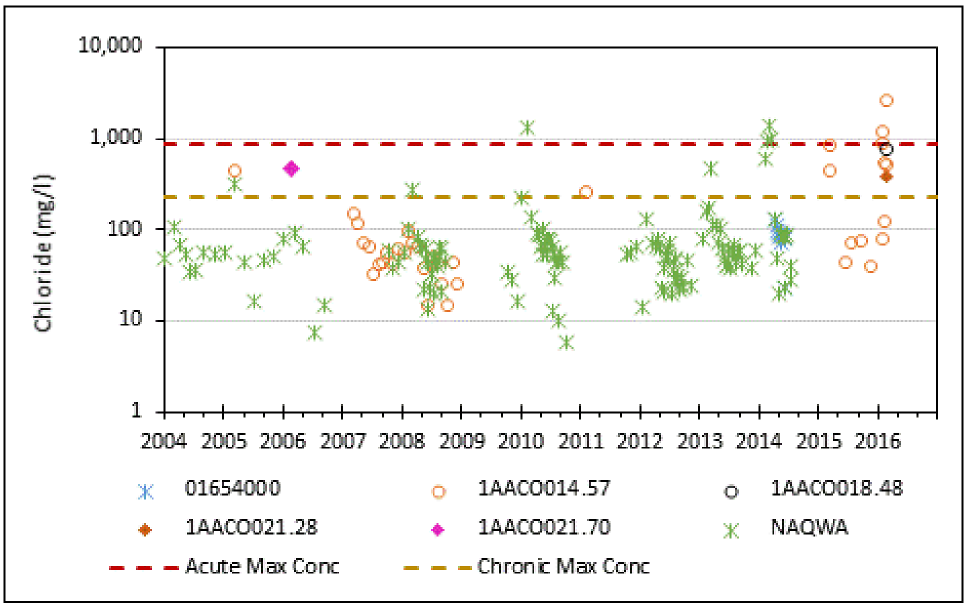


Figure 3-50: Observed Chloride (mg/l) in Upper Accotink Creek

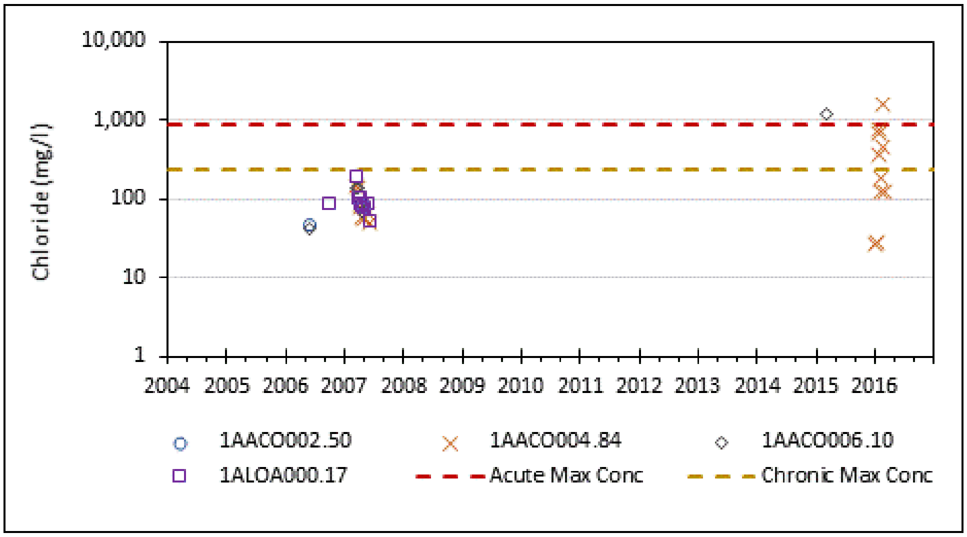


Figure 3-51: Observed Chloride (mg/l) in Lower Accotink Creek

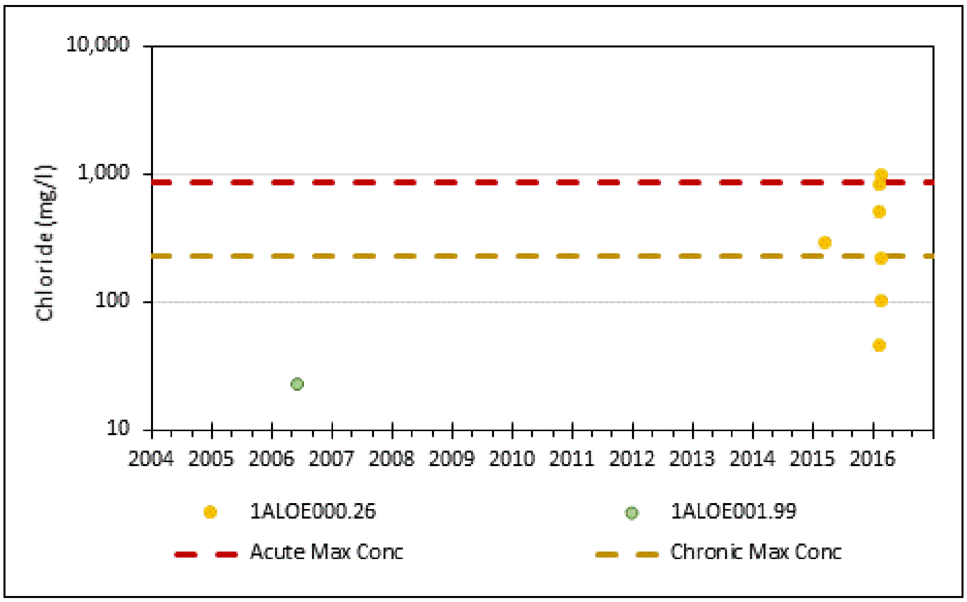


Figure 3-52: Observed Chloride (mg/l) in Long Branch

Seven observed chloride concentrations in upper Accotink Creek, two concentrations in lower Accotink Creek, and one concentration in Long Branch exceed the 860 mg/l acute criterion. These are shown in **Table 3-34**. **Table 3-35** shows the individual observed chloride concentrations which exceeded the 230 mg/l chronic criterion. The chronic criterion applies to a four-day average concentration, and can be evaluated if two or more samples are collected on different days in a four-day period. Using that rule-of-thumb, the snowmelt in late January, 2016, and the combined snow and rain event in February, 2016, exceeded the 4-day chronic criterion in upper Accotink Creek, lower Accotink Creek, and Long Branch.

Table 3-34: Observed Chloride Concentrations Exceeding the Acute Chloride Criterion

Watershed	Agency	Station	Date	Chloride (mg/l)
Upper Accotink Creek	USGS	01654000	2/02/2010	1,320
	USGS	01654000	2/19/2014	925
	USGS	01654000	3/05/2014	1,410
	USGS	01654000	3/19/2014	977
	DEQ	1AACO014.57	1/27/2016	1,210*
	DEQ	1AACO014.57	1/28/2016	888*
	DEQ	1AACO014.57	2/16/2016	2,570
Lower Accotink Creek	DEQ	1AACO004.84	3/04/2015	1,160
	DEQ	1AACO004.84	2/16/2016	1,580*
Long Branch	DEQ	1ALOE000.26	2/16/2016	1,010*

[1]The acute criterion is a one-hour average of 860 mg/l, not to be exceeded more than once every three years.
*These values were also used in the calculation of chronic criterion violations.

Table 3-35: Observed Chloride Concentrations Exceeding the Chronic Chloride Criterion

Watershed	Agency	Station	Date	Chloride (mg/l)
Upper Accotink Creek	USGS	01654000	2/02/2010	1,320
	USGS	01654000	2/19/2014	925
	USGS	01654000	3/05/2014	1,410
	USGS	01654000	3/19/2014	977
	DEQ	1AACO014.57	1/27/2016	1,210*
	DEQ	1AACO014.57	1/28/2016	888*
	DEQ	1AACO014.57	2/16/2016	2,570*
	DEQ	1AACO014.57	2/18/2016	504*
Lower Accotink Creek	DEQ	1AACO004.84	3/04/2015	1,160
	DEQ	1AACO004.84	1/26/2016	367*
	DEQ	1AACO004.84	1/27/2016	681*
	DEQ	1AACO004.84	1/28/2016	767*
	DEQ	1AACO004.84	2/16/2016	1,580*
	DEQ	1AACO004.84	2/18/2016	448*
Long Branch	DEQ	1ALOE000.26	1/27/2016	847*
	DEQ	1ALOE000.26	1/28/2016	526*
	DEQ	1ALOE000.26	2/16/2016	1,010*
	DEQ	1ALOE000.26	2/18/2016	504*

[1]The chronic criterion is a four day average of 230 mg/l, not to be exceeded more than once every three years.
*These values were used to calculate chronic criterion violations for the associated 4-day window.

Chloride is a major anion contributing to SC so it can be expected that SC and CL are strongly correlated. **Figures 3-53**, **3-54, and 3-55** demonstrate the strength of the correlation in upper

Accotink Creek, lower Accotink Creek, and Long Branch, respectively. The coefficient of determination (R^2) between CL and SC is greater than 0.99 for all three watersheds.

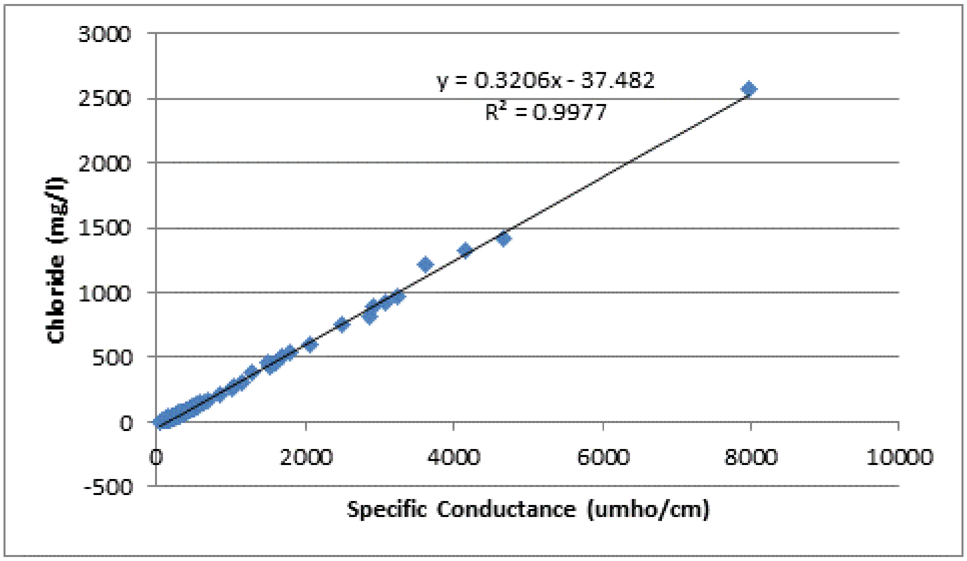


Figure 3-53: Correlation between Chloride and Specific Conductance, Upper Accotink Creek

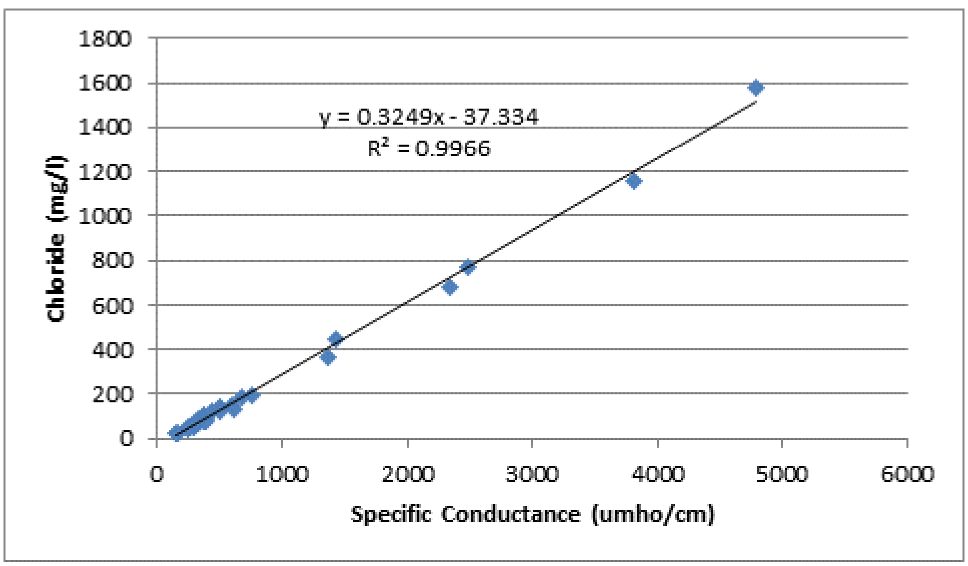


Figure 3-54: Correlation between Chloride and Specific Conductance, Lower Accotink Creek

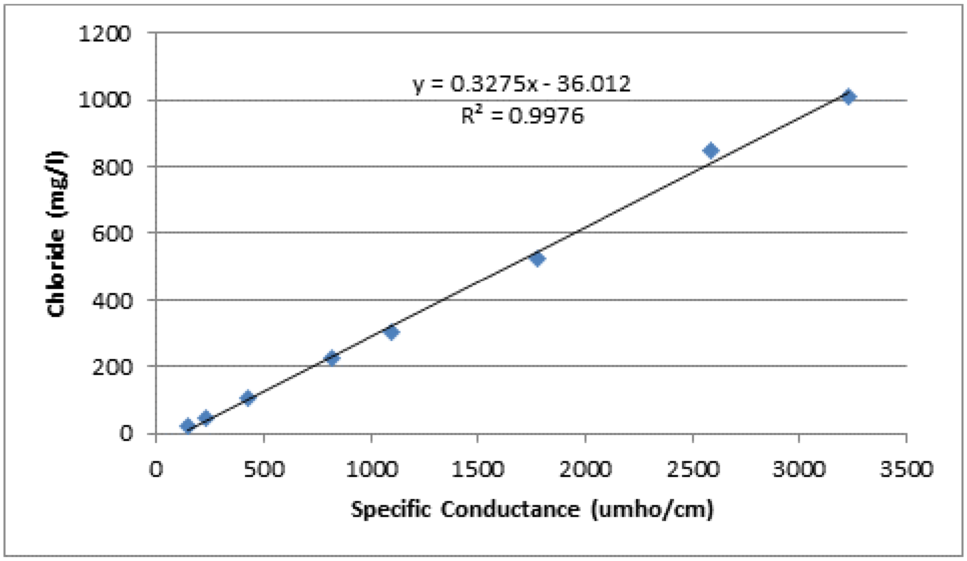


Figure 3-55: Correlation between Chloride and Specific Conductance, Long Branch

Sanford et al. (2011) performed a synoptic survey of CL and SC in the neighboring watershed of Difficult Run during a winter runoff event. They found that the ratio of CL to SC was 0.33 when SC is greater than 1,000 µS/cm. This ratio is close in value to the slope of the regression lines, 0.32, 0.32, and 0.33, shown in **Figures 3-53, 3-54**, and **3-55,** respectively, for the relation between CL and SC. At a ratio of CL:SC of 0.33, the acute CL criterion would be exceeded at SC measurements of 2,580 µS/cm. SC measurements of this magnitude or greater are not uncommon in upper Accotink Creek, lower Accotink Creek, or Long Branch, as shown in **Figures 3-40**, **3-42**, **3-43,** or **3-44**.

Deicing salt, applied to roads, sidewalks, driveways, etc., is likely to be a major source of CL in developed areas like Accotink Creek. **Figure 3-56** shows the average monthly CL concentrations in upper and lower Accotink Creek. Monthly CL concentrations generally follow a pattern similar to the seasonal SC measurements, shown in **Figure 3-39**, with higher concentrations in the winter months.

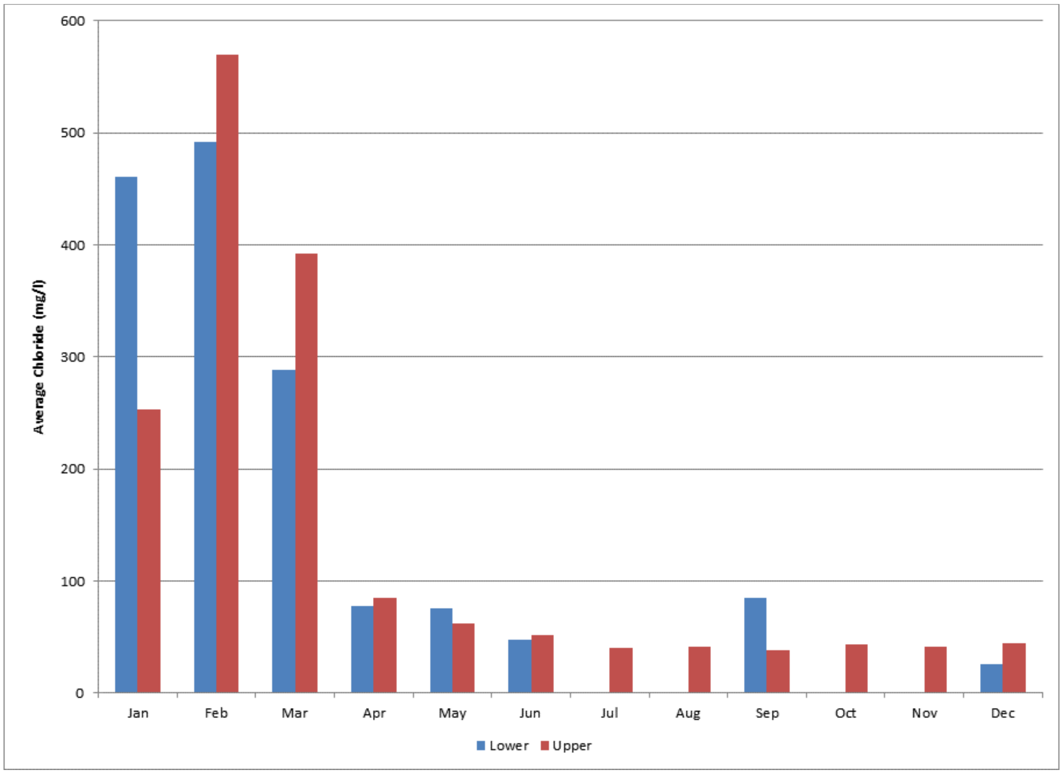


Figure 3-56: Average Monthly Chloride (mg/l) in Accotink Creek

3.5.7 Turbidity

Turbidity is a measure of water clarity. It represents the ability of water to scatter light. Turbidity is caused by suspended particles or soluble organic molecules which give water color.

Both DEQ and USGS measured turbidity in Accotink Creek but they used different methods that are reported in different units. DEQ turbidity measurements are reported in Nephelometric Turbidity Units (NTUs), while the USGS measurements are reported in Formazin Nephelometric Units (FNUs). Both methods measure the light scattered at a 90° angle from the source, but FNUs measure light scattered from the infrared range (780 to 900 nm), whereas NTUs measure light scattered in the visible range (460 to 680 nm) (http://or.water.usgs.gov/grapher/fnu.html).

Figures 3-57 and **3-58** show turbidity measured by DEQ in water quality samples from upper Accotink Creek and lower Accotink Creek, respectively. Virginia does not have water quality criteria for turbidity. The 90th percentile turbidity measurement recording in the ProbMon dataset is 14 NTU. **Figure 3-59** compares the distribution of turbidity measurements made by DEQ under ambient conditions with the 90th percentile measurement from the ProbMon data. Twenty-seven percent of samples from upper Accotink Creek and 29% of samples from lower Accotink Creek have turbidity measurements greater than the 90th percentile ProbMon measurement. DEQ made only one turbidity measurement in Long Branch, and its value was below the 90th percentile ProbMon measurement.

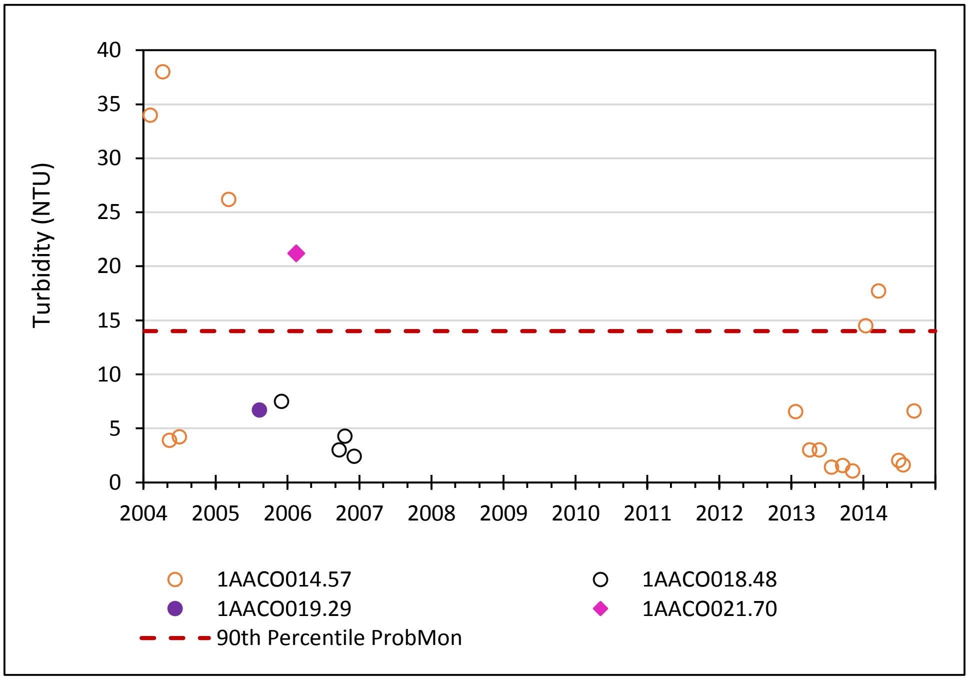


Figure 3-57: DEQ Observed Turbidity (NTU) in Upper Accotink Creek

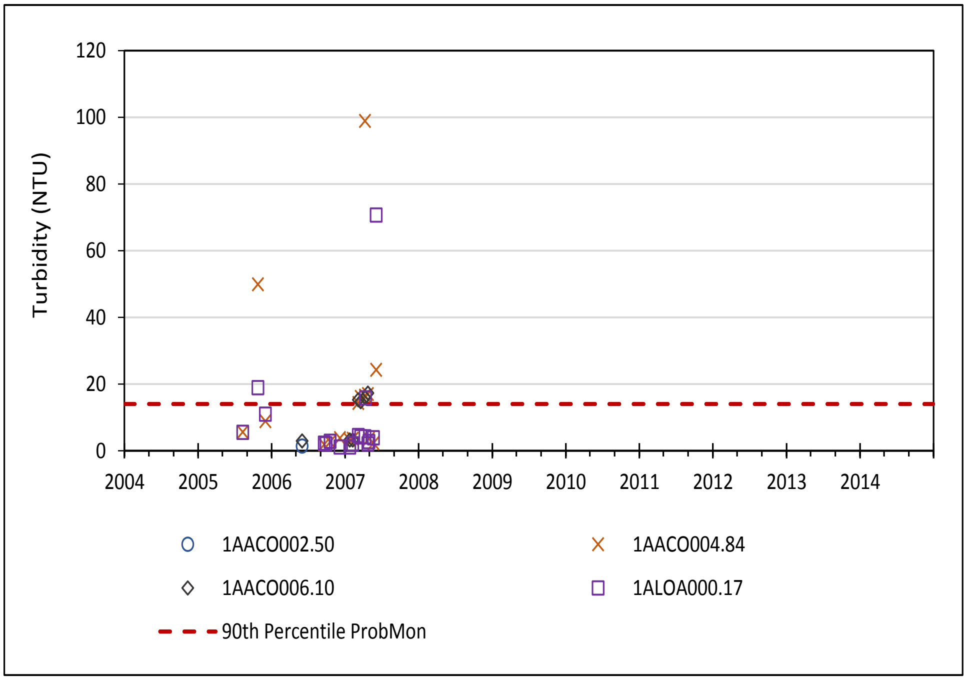


Figure 3-58: DEQ Observed Turbidity (NTU) in Lower Accotink Creek

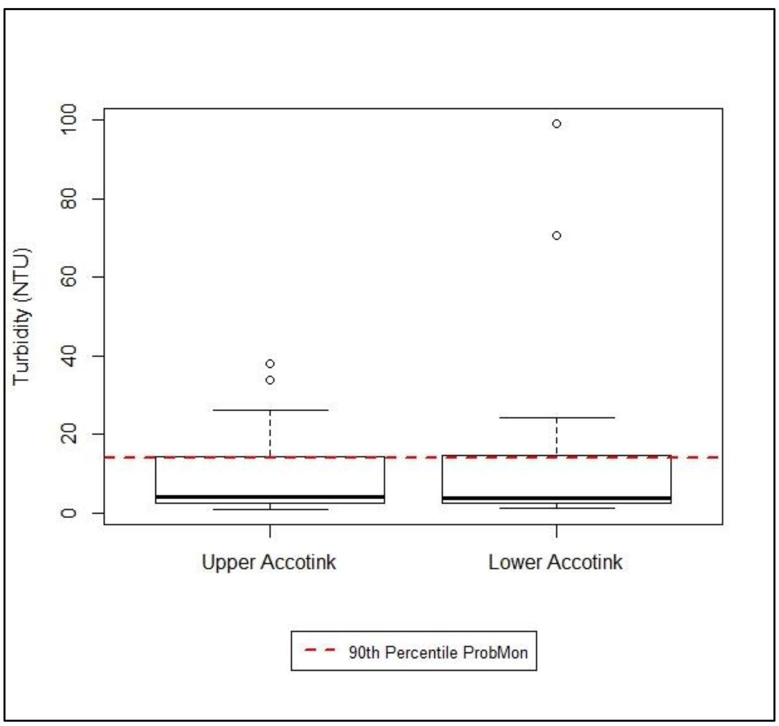


Figure 3-59: DEQ Ambient Turbidity in Accotink Creek Watershed

The USGS measured turbidity in grab samples taken in Accotink Creek near Annandale and Long Branch, as well as in continuous monitoring in Accotink Creek near Ranger Road and Long Branch. **Figures 3-60** and **3-61**shows turbidity from grab samples in upper Accotink Creek and Long Branch, respectively, while **Figures 3-62** and **3-63** show turbidity measured in continuous monitoring in Accotink Creek near Ranger Road and Long Branch, respectively. Because the measurements are in FNUs, they cannot be compared to the turbidity measured in the ProbMon program, which is in NTUs.

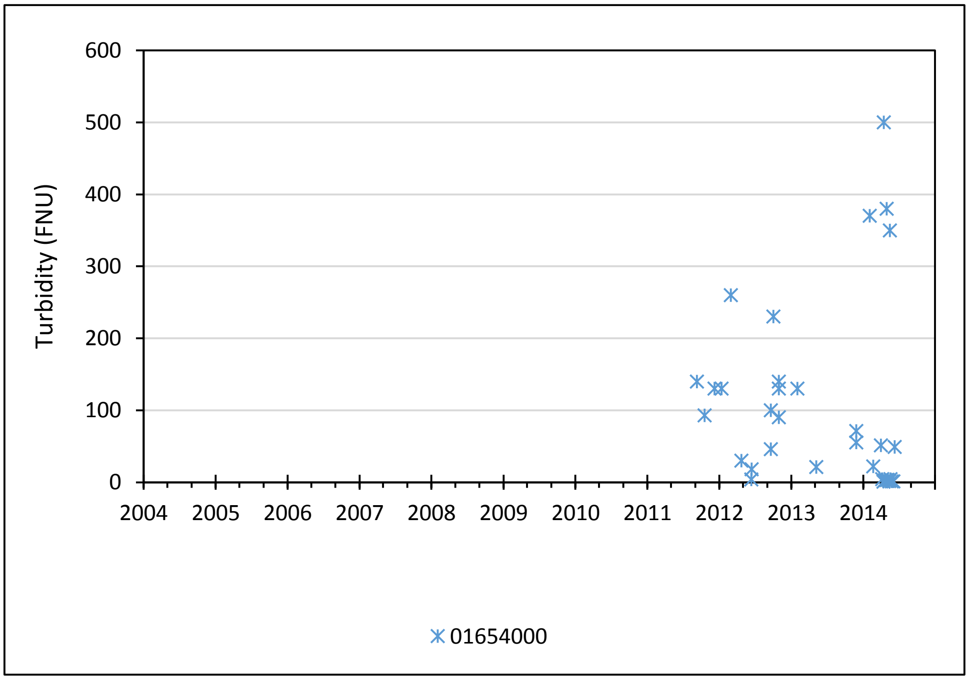


Figure 3-60: USGS Observed Turbidity (FNU) in Upper Accotink Creek

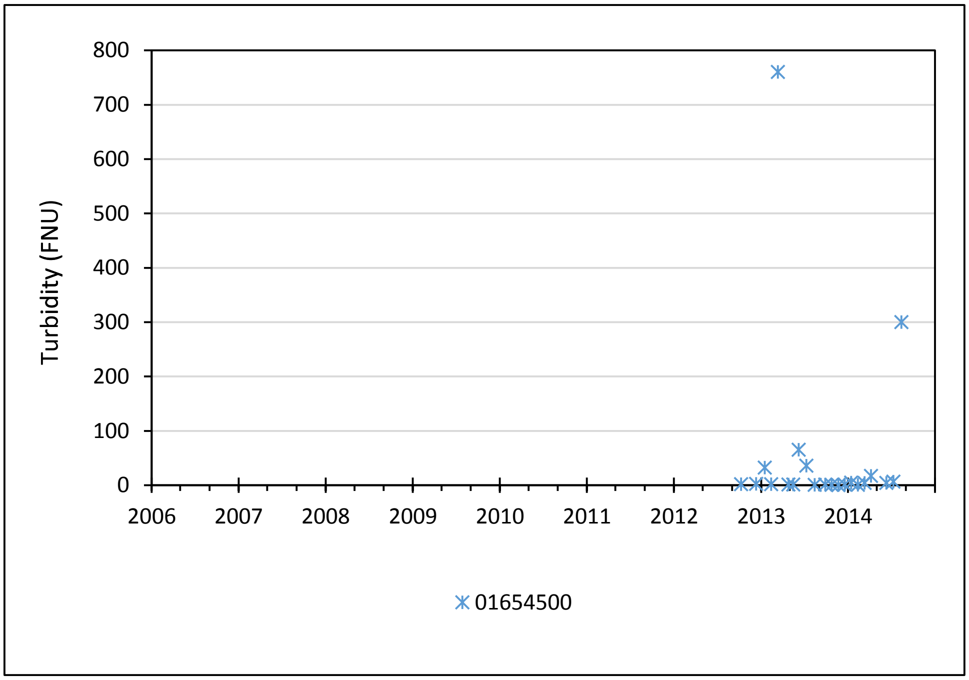


Figure 3-61: USGS Observed Turbidity (FNU) in Long Branch

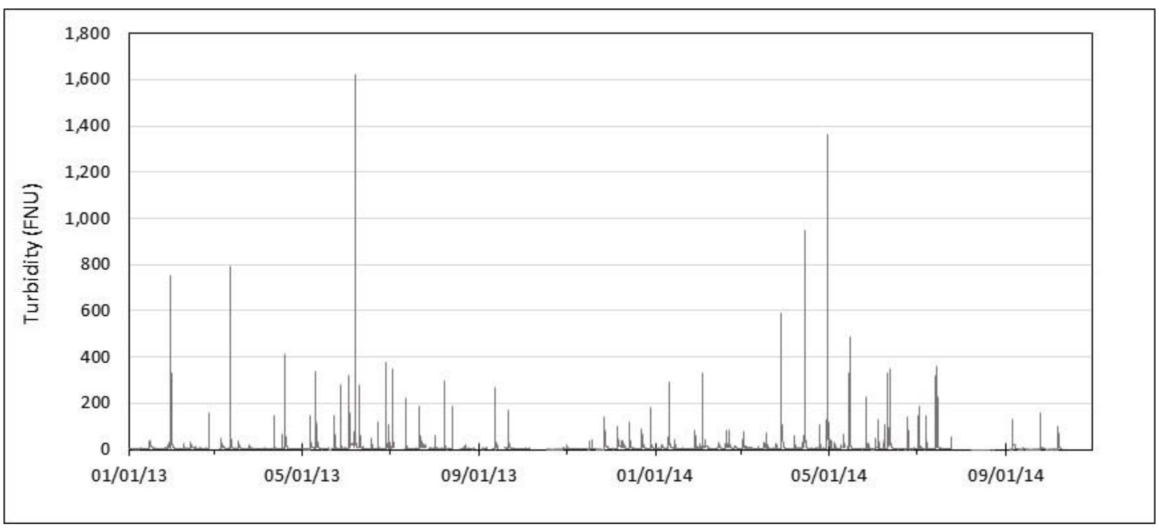


Figure 3-62 Observed Turbidity (FNU), Continuous Monitoring, Upper Accotink Creek

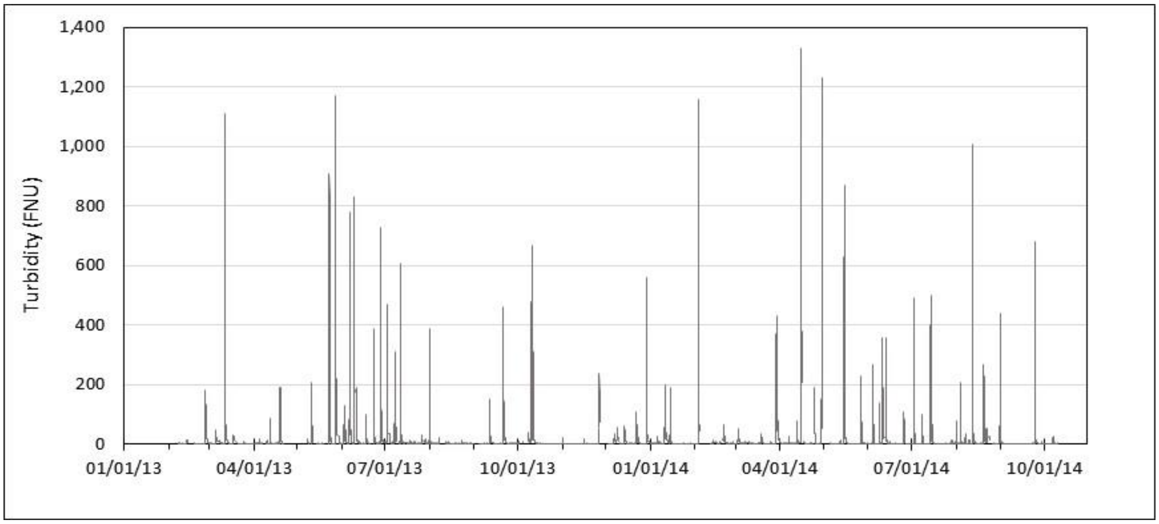


Figure 3-63: Observed Turbidity (FNU), Continuous Monitoring, Long Branch

Peaks in the turbidity generally correspond to storm events. **Figures 3-64** and **3-65** show the positive correlation between USGS turbidity measurements in grab samples and daily average flow at the USGS gages in Accotink Creek near Annandale and Long Branch, respectively.

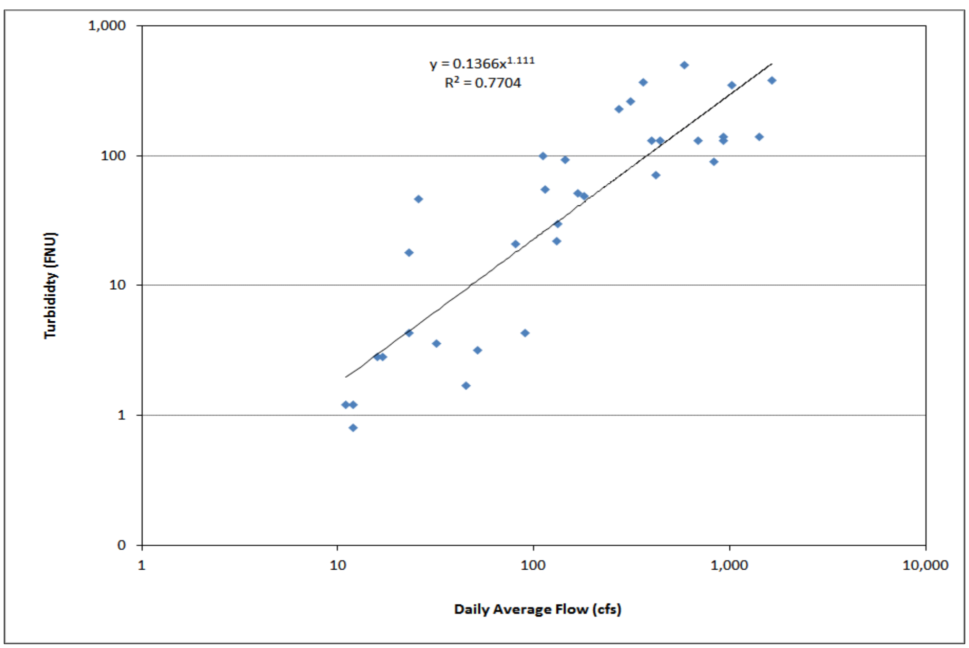


Figure 3-64: Correlation between Turbidity and Daily Average Flow, Accotink Creek near Annandale

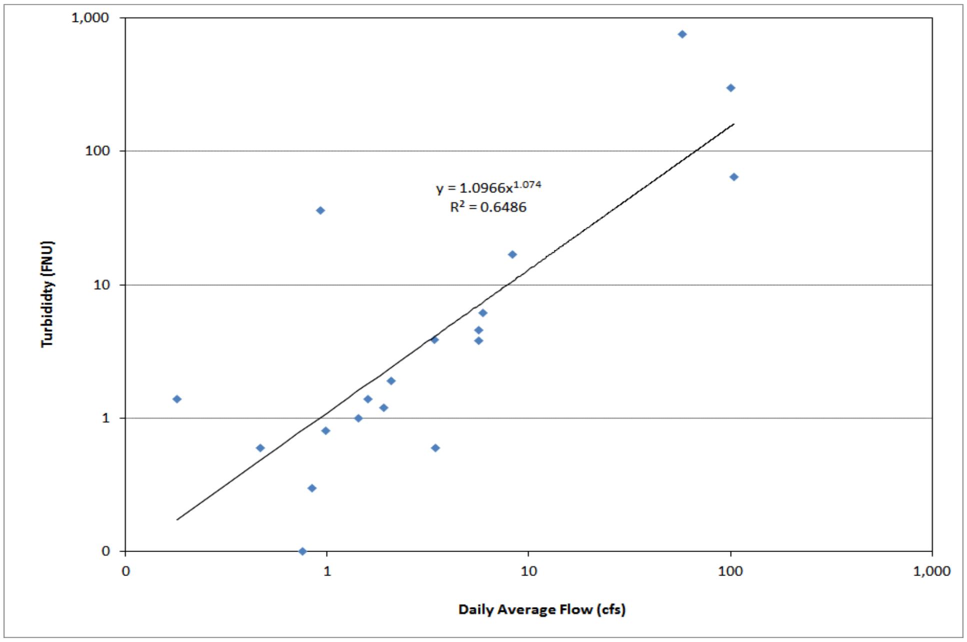


Figure 3-65: Correlation between Turbidity and Daily Average Flow, Long Branch

3.5.8 Total Suspended Solids and Suspended Sediment

Two different methods are used to measure sediment suspended in the water column in the Accotink Creek watershed. The USGS uses a new method (STORET number 80154), which is called Suspended Sediment (SS). SS is intended to more accurately capture sand-size particles in suspended sediment. DEQ uses the new method as well as an older technique, which measures what is called Total Suspended Solids (TSS) (STORET number 00530). **Figures 3-66** and **3-67** show the TSS concentrations observed by DEQ in water quality samples in upper and lower Accotink Creek, respectively. There are no water quality criteria for TSS in Virginia. High TSS concentrations generally occur during storm events. The 90^{th} percentile TSS concentration in the ProbMon data is 32 mg/l. **Figure 3-68** compares the distribution of TSS concentrations observed by DEQ under ambient conditions with the 90^{th} percentile measurement from the ProbMon data. Eight percent of the samples under ambient conditions in upper Accotink Creek and three percent of the samples in lower Accotink Creek have concentrations above the 90^{th} percentile ProbMon concentration. The only sample analyzed by DEQ for TSS in Long Branch has a concentration of 3 mg/l.

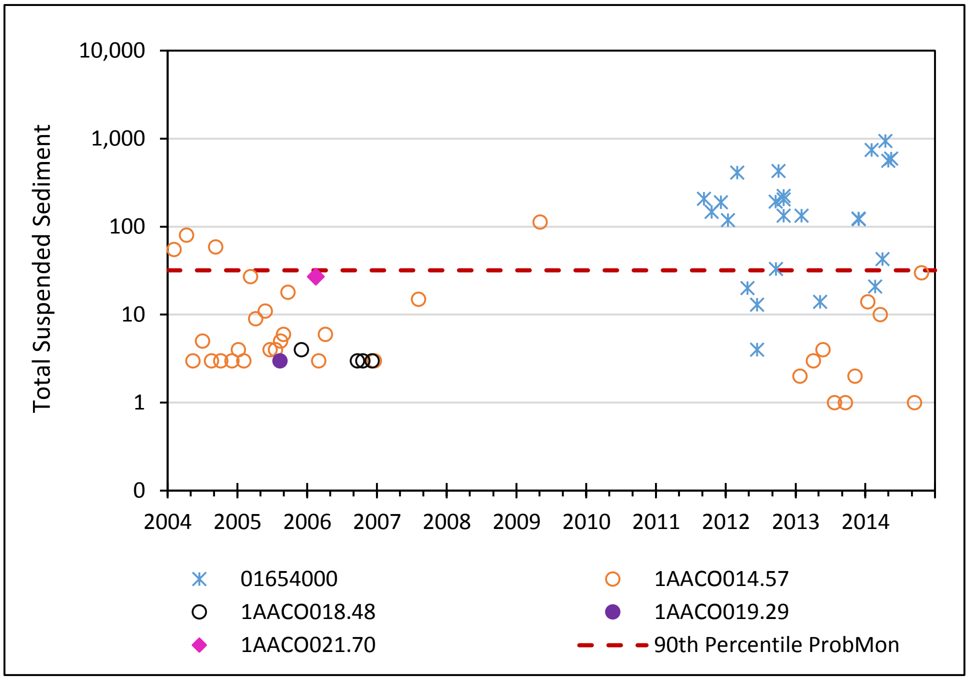


Figure 3-66: Observed Total Suspended Sediment (mg/l) in Upper Accotink Creek

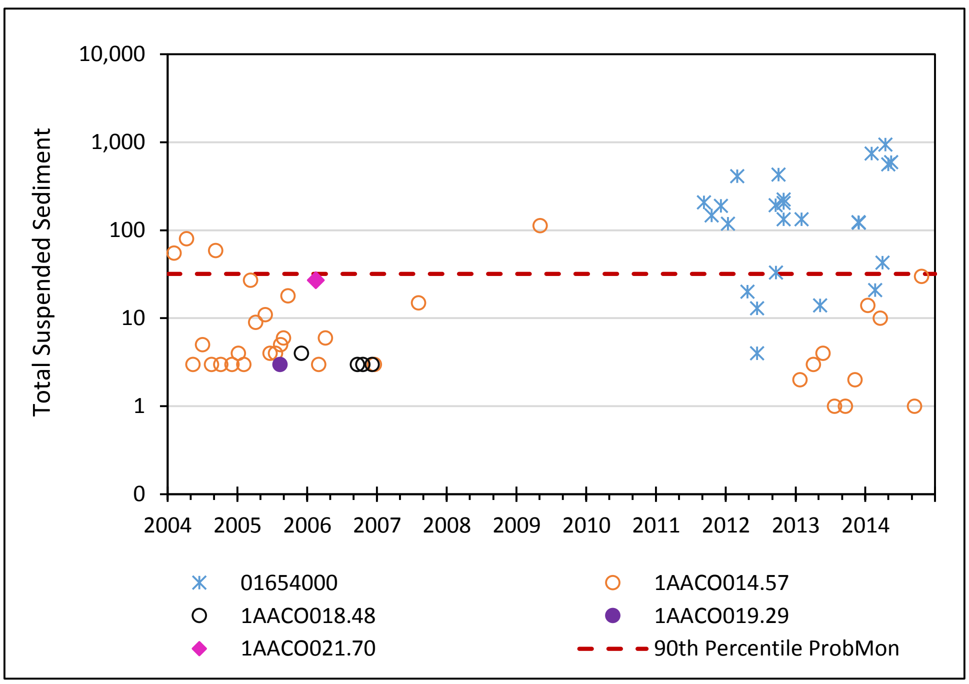


Figure 3-67: Observed Total Suspended Sediment (mg/l) in Lower Accotink Creek

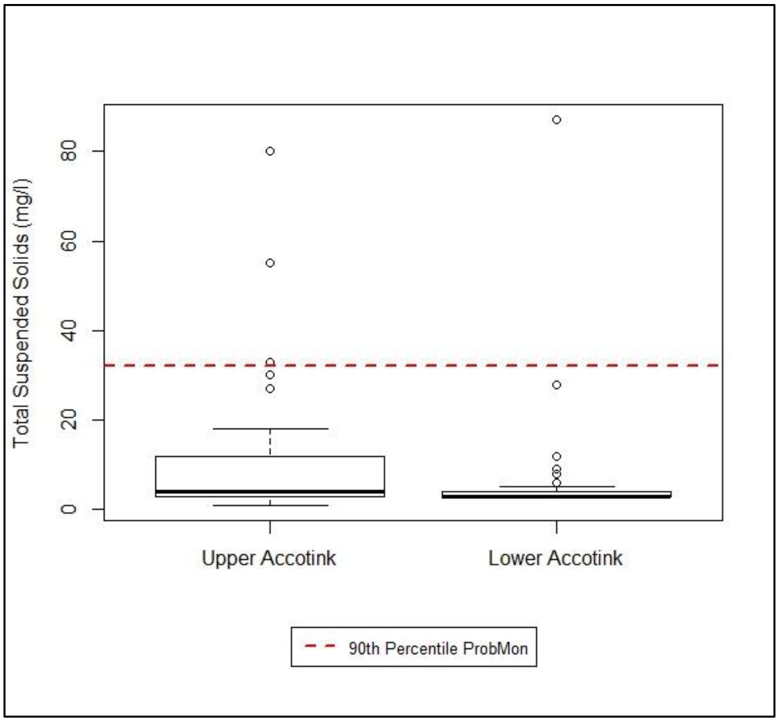


Figure 3-68: Ambient Total Suspended Sediment (mg/l) in Accotink Creek Watershed

Figures 3-69 and **3-70** shows the SS concentrations observed in water quality samples in upper Accotink Creek and Long Branch, respectively. SS measurements cannot be compared to the 90th percentile of ProbMon data, which are measured as TSS.

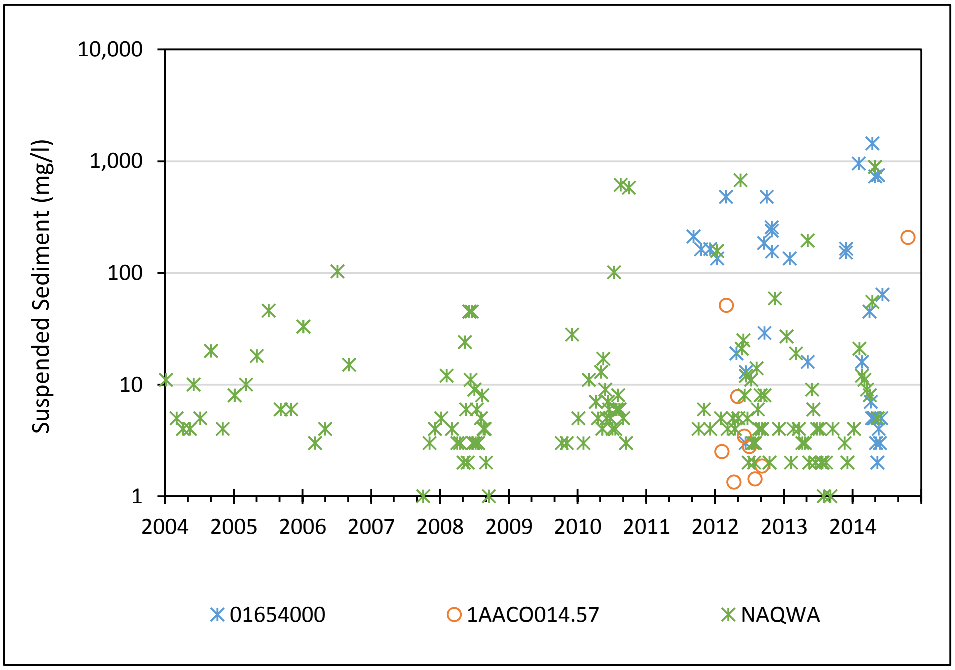


Figure 3-69: Observed Suspended Sediment (mg/l) in Upper Accotink Creek

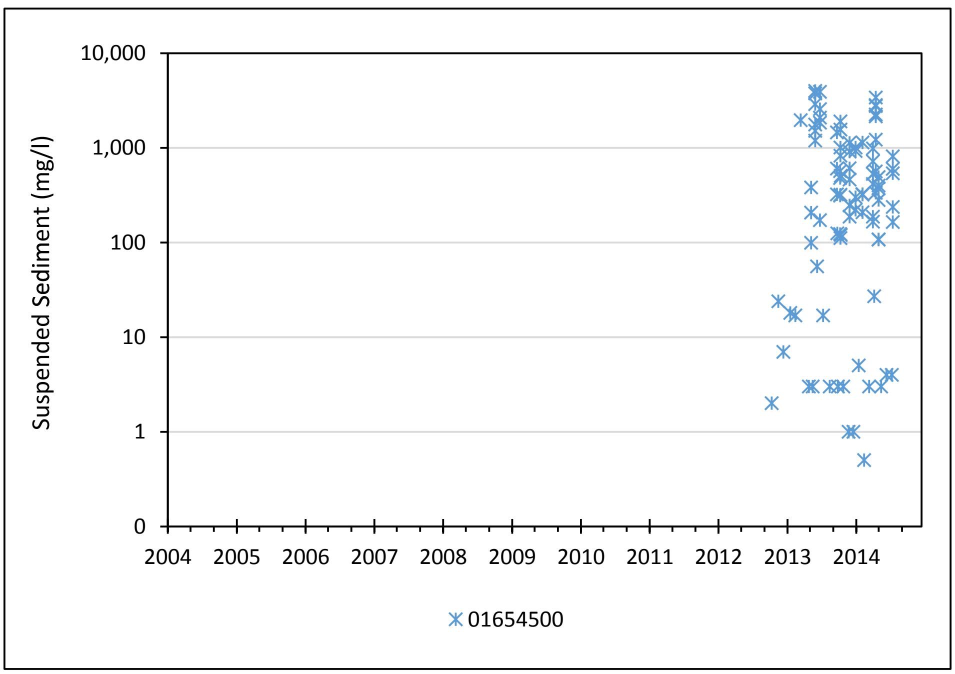


Figure 3-70: Observed Suspended Sediment (mg/l) in Long Branch

SS is highly correlated with flow and turbidity. **Figures 3-71** and **3-72** show the log-log relation between SS and daily average flow in Accotink Creek near Annandale and in Long Branch, respectively. The coefficient of determination (R^2) between SS and flow is 0.77 in upper Accotink Creek and 0.65 in Long Branch. **Figures 3-73** and **3-74** show the relation between SS and turbidity in Accotink Creek near Annandale and in Long Branch, respectively. The coefficient of determination (R^2) between SS and turbidity is 0.94 in upper Accotink Creek and 0.81 in Long Branch. A log-log relation between SS and turbidity is used in Long Branch because of the presence of a single observation that is an order of magnitude larger than the others with respect to both flow and turbidity. The relation between turbidity and SS can be used to estimate sediment loads from continuous turbidity measurements.

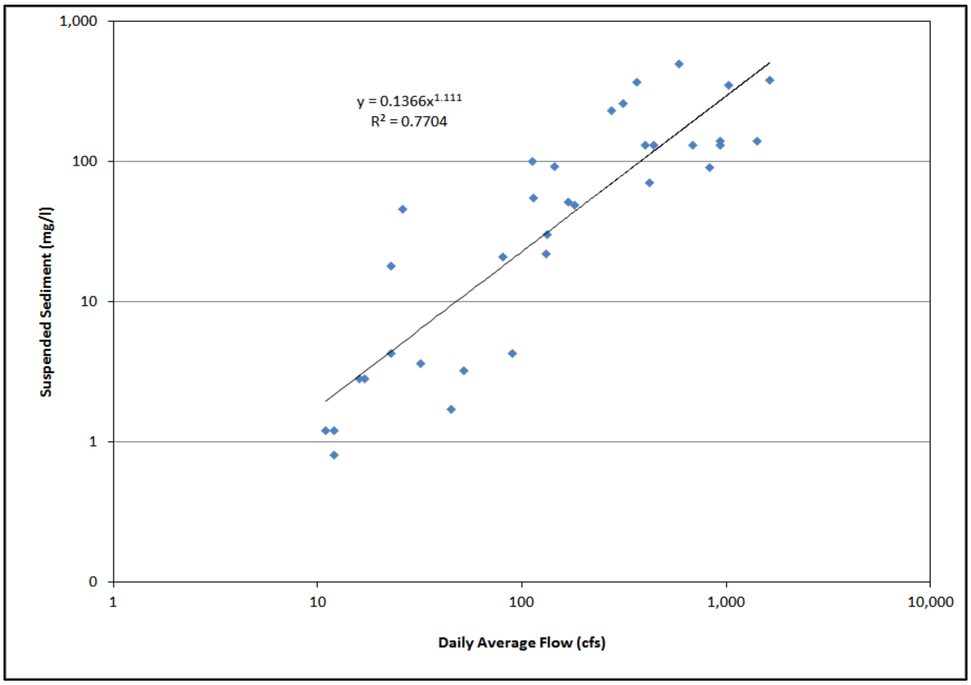


Figure 3-71: Correlation between Suspended Sediment and Daily Average Flow, Upper Accotink Creek

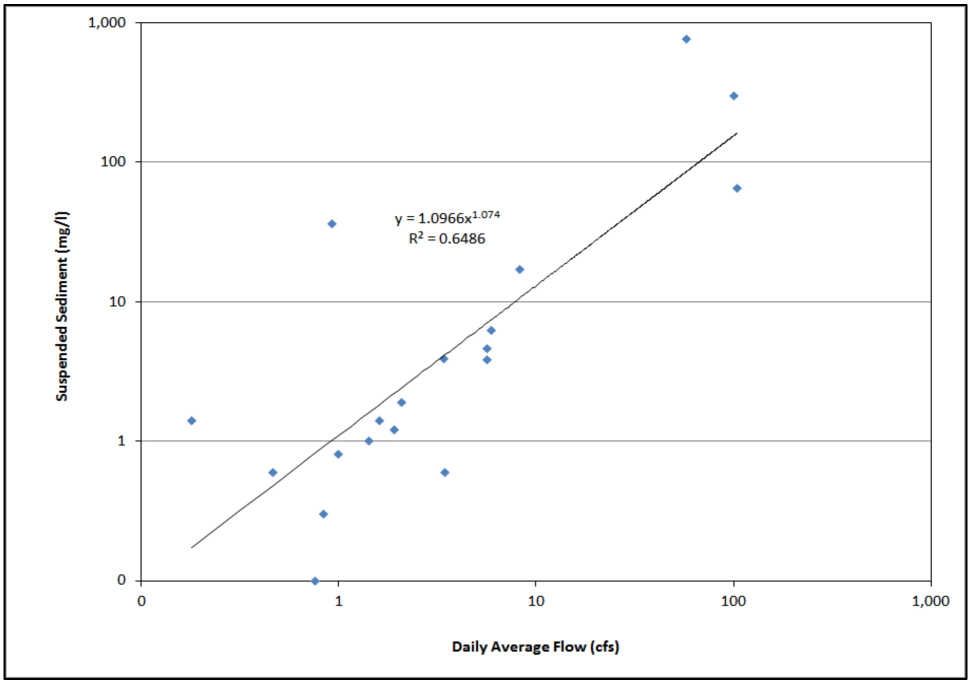


Figure 3-72: Correlation between Suspended Sediment and Daily Average Flow, Long Branch

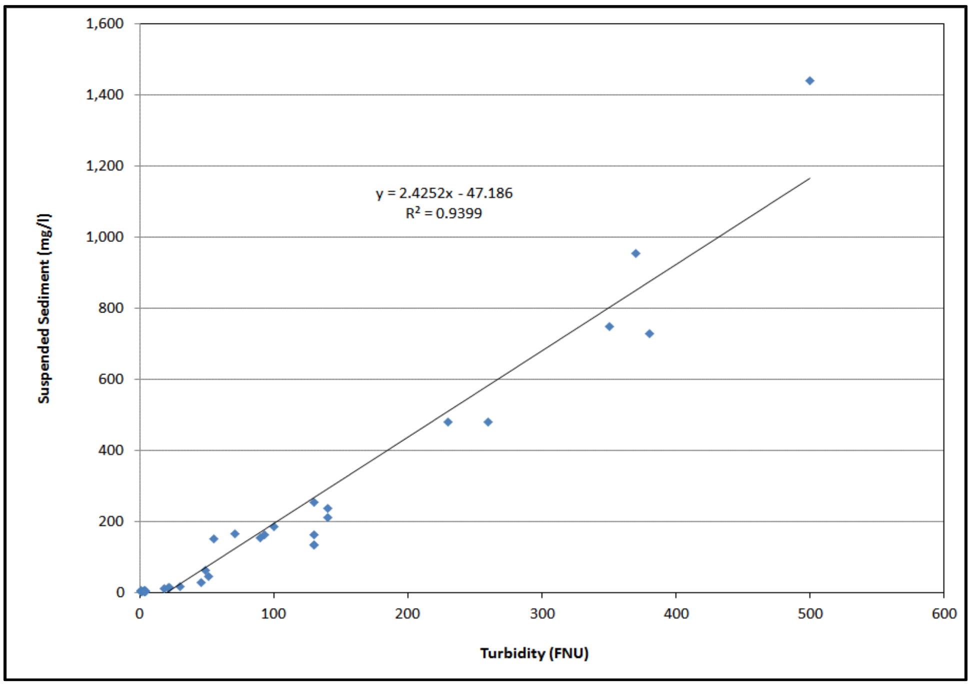


Figure 3-73: Correlation between Suspended Sediment and Turbidity, Upper Accotink Creek

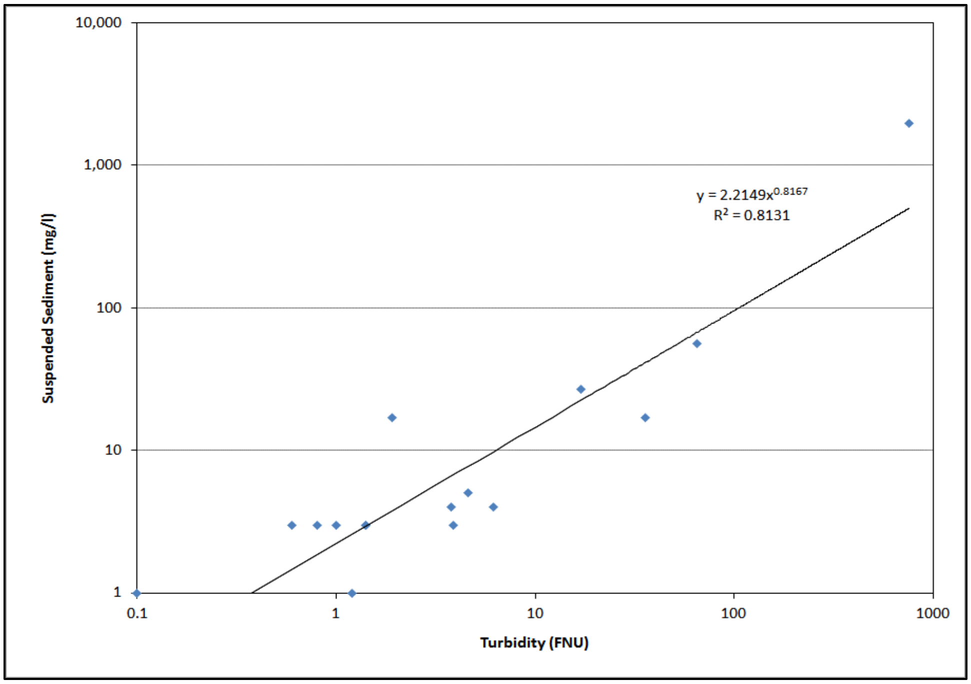


Figure 3-74: Correlation between Suspended Sediment and Turbidity, Long Branch

3.5.9 Ammonia

Figures 3-75 and **3-76** show the total ammonia (NH_3) concentrations (in nitrogen) observed in water quality samples in upper Accotink Creek and lower Accotink Creek, respectively. The USGS measured only dissolved ammonia nitrogen which is not comparable to total ammonia and therefore not included in the figures. Fifty-seven percent of the samples in upper Accotink Creek and 61% of the samples in lower Accotink Creek were reported as below the detection limits. Samples below detection limits are represented at their detection limits in the figures. Only two samples taken in Long Branch were analyzed for NH_3 and one was below the detection limit.

Virginia has acute and chronic criteria for ammonia to protect aquatic life. The acute criteria are a function of pH, while the chronic criteria are a function of pH and temperature (9VAC25-260-140). There are no exceedances of the acute criteria in the Accotink Creek watershed and the observed concentrations are all below the range of the chronic criteria. The 90th percentile ammonia concentration in the ProbMon data is 0.05 mg/l. Sixteen percent of the concentrations observed under ambient conditions in upper Accotink Creek and 14% of the concentrations observed in lower Accotink Creek are greater than the 90th percentile of the ProbMon data. No figures are shown comparing the distribution of observed concentrations to the 90th percentile of the ProbMon data because of the high percentage of observations below the detection limit. The two observations of NH_3 in Long Branch are below the 90th percentile of the ProbMon data.

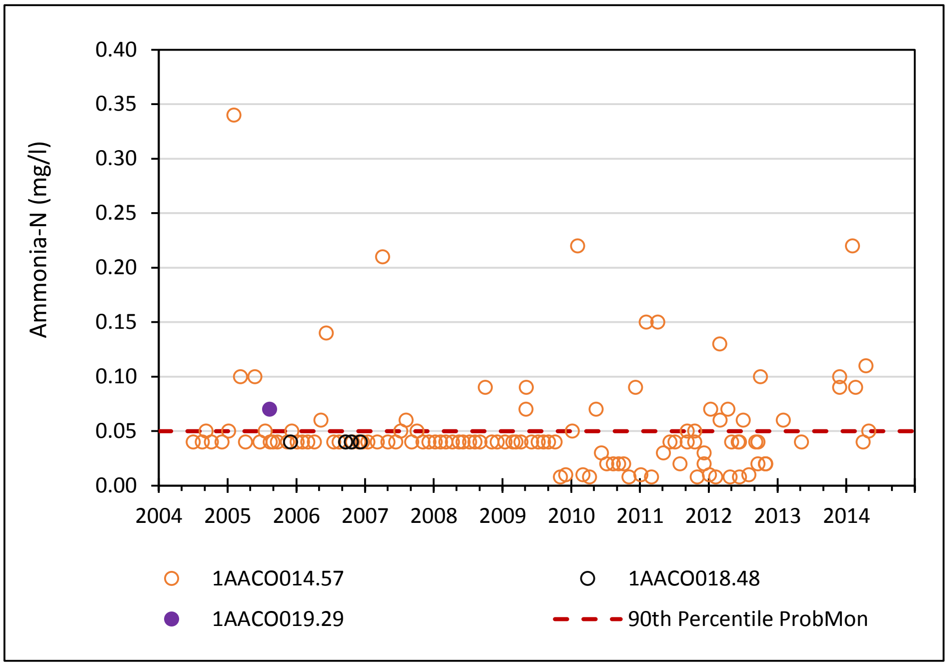


Figure 3-75: Observed Ammonia (mg/l) in Upper Accotink Creek

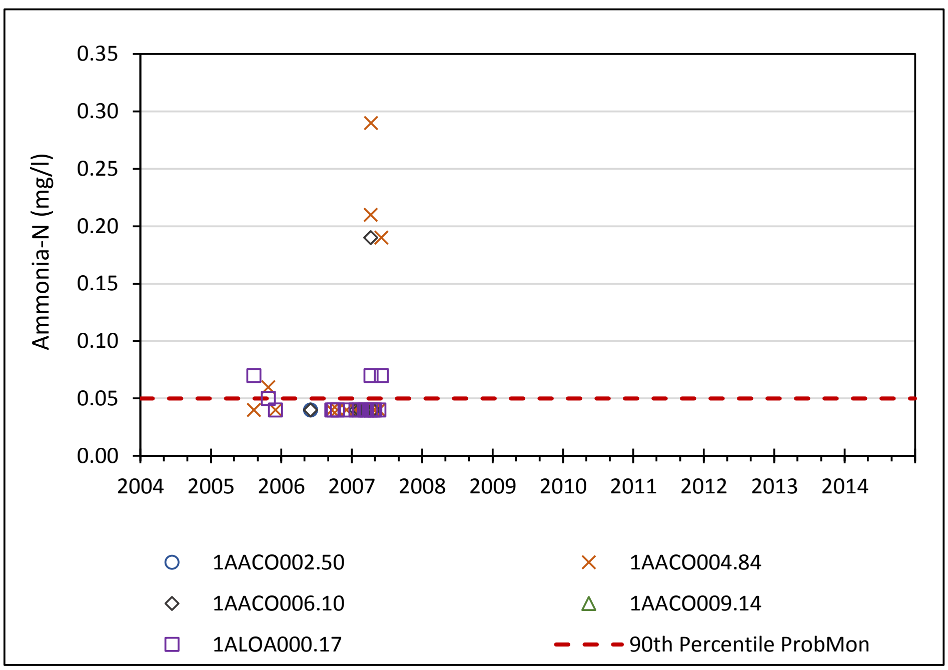


Figure 3-76: Observed Ammonia (mg/l) in Lower Accotink Creek

3.5.10 Nitrate

Figures 3-77, 3-78, and 3-79 show the nitrate (NO_3) concentrations (in nitrogen) observed in water quality samples in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Observations of nitrite-nitrate were included in the analysis of nitrate. Both total and dissolved forms were used.

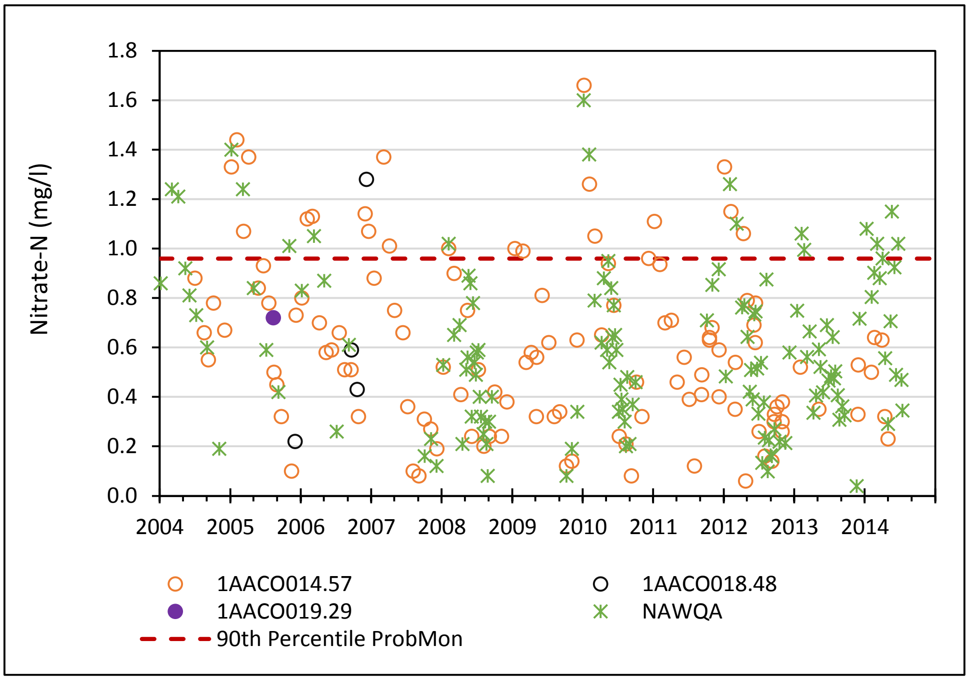


Figure 3-77: Observed Nitrate (mg/l) in Upper Accotink Creek

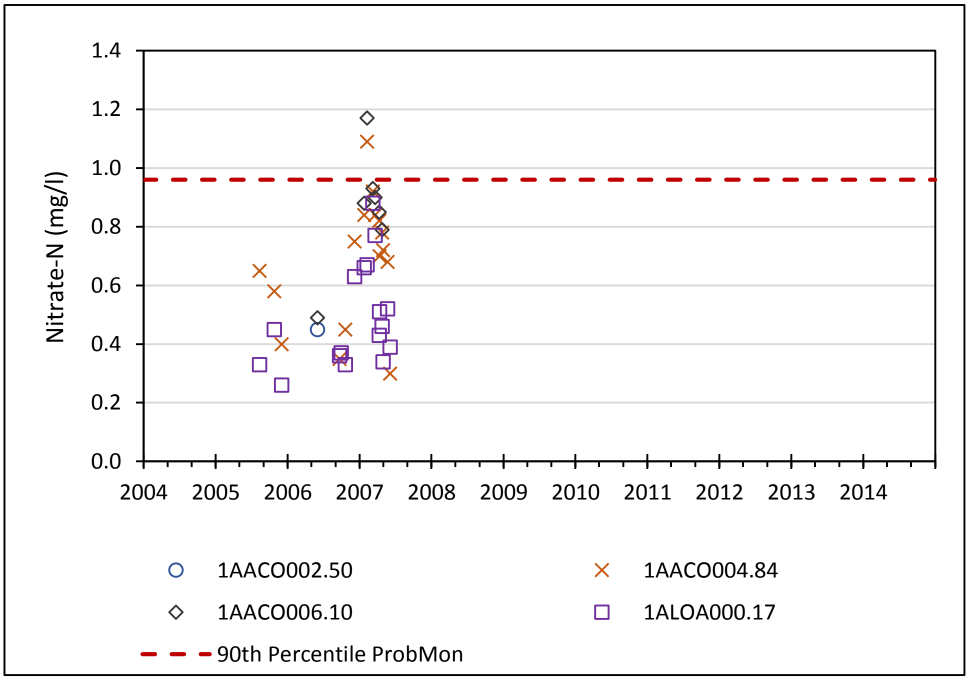


Figure 3-78: Observed Nitrate (mg/l) in Lower Accotink Creek

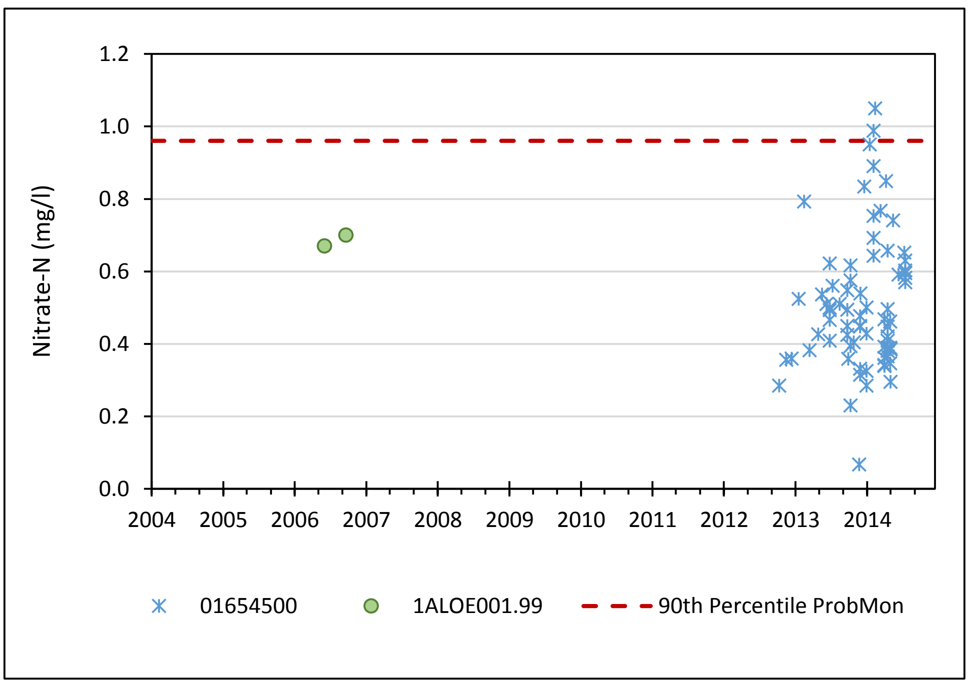


Figure 3-79: Observed Nitrate (mg/l) in Long Branch

Virginia has no water quality criteria for nitrate to protect aquatic life. The 90th percentile nitrate concentration in the ProbMon data is 0.96 mg/l. **Figure 3-80** shows the distribution of nitrate concentrations observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, compared to the 90th percentile concentration of the ProbMon data. About five percent of the concentrations observed under ambient conditions in lower Accotink Creek and Long Branch are greater than the 90th percentile of the ProbMon data, and 18% of the concentrations observed in upper Accotink Creek are above the 90th percentile of the ProbMon data.

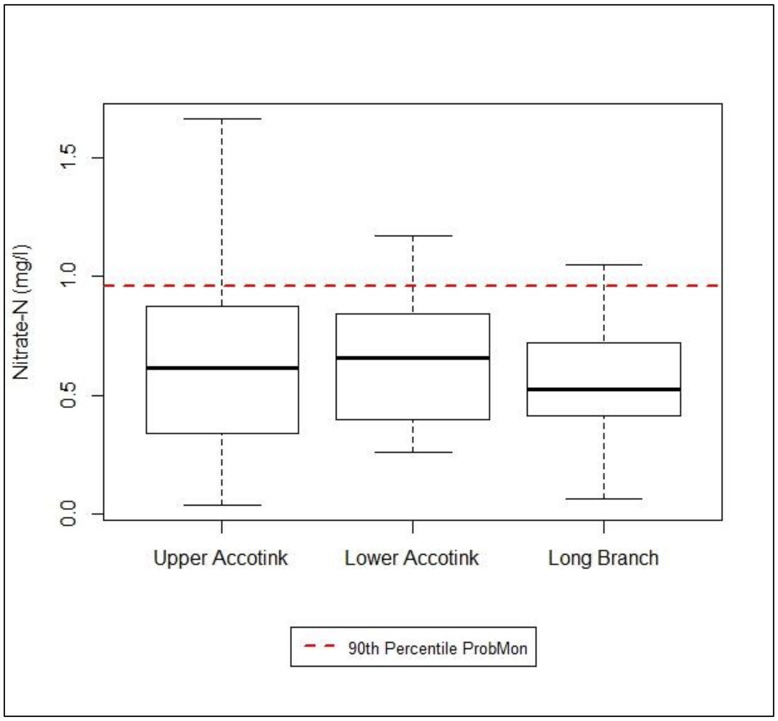


Figure 3-80: Ambient Nitrate (mg/l) in Accotink Creek Watershed

3.5.11 Total Kjeldahl Nitrogen

Figures 3-81, 3-82, and 3-83 show the total Kjeldahl nitrogen (TKN) concentrations (in nitrogen) observed in water quality samples in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Virginia has no water quality criteria for TKN. The 90th percentile TKN concentration in the ProbMon data is 0.6 mg/l. **Figure 3-84** shows the distribution of TKN concentrations observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, compared to the 90th percentile concentration of the ProbMon data. Fourteen percent, 59%, and 20% of concentrations observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively, are greater than the 90th percentile of the ProbMon data.

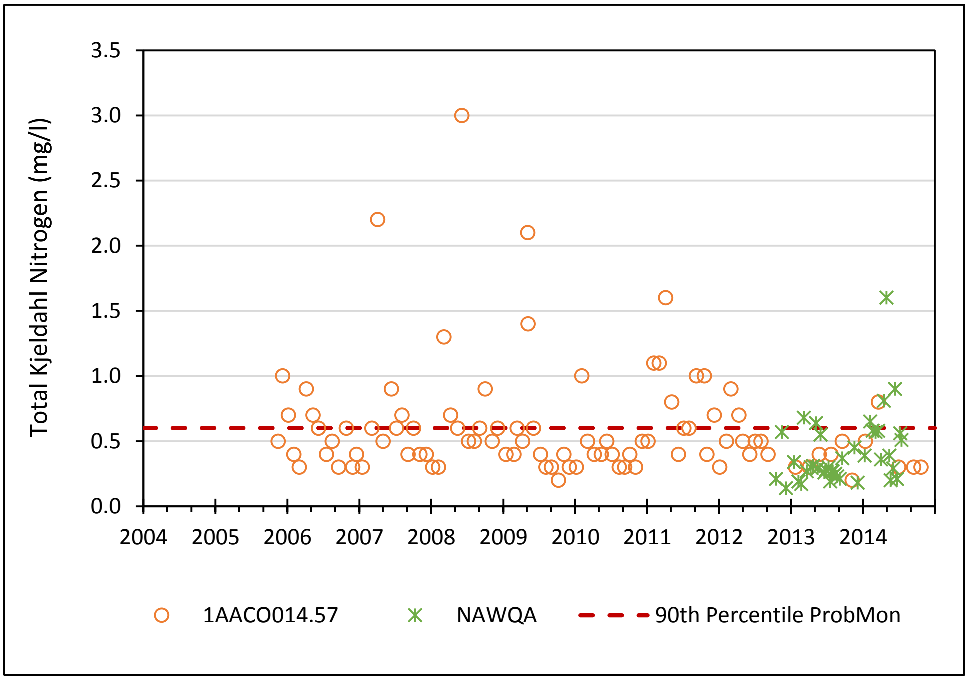


Figure 3-81: Observed Total Kjeldahl Nitrogen (mg/l) in Upper Accotink Creek

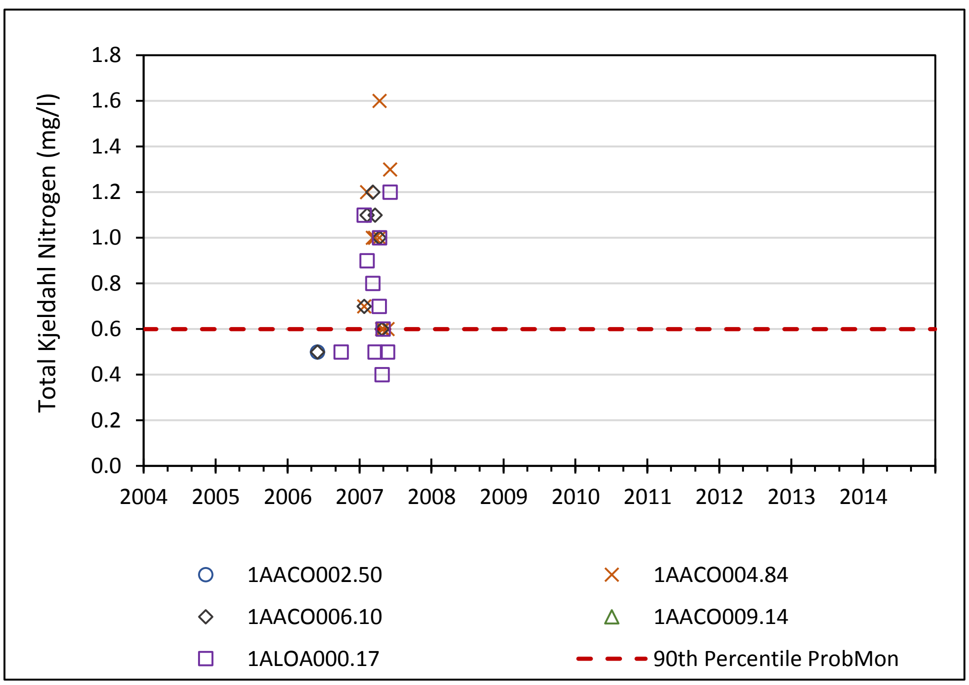


Figure 3-82: Observed Total Kjeldahl Nitrogen (mg/l) in Lower Accotink Creek

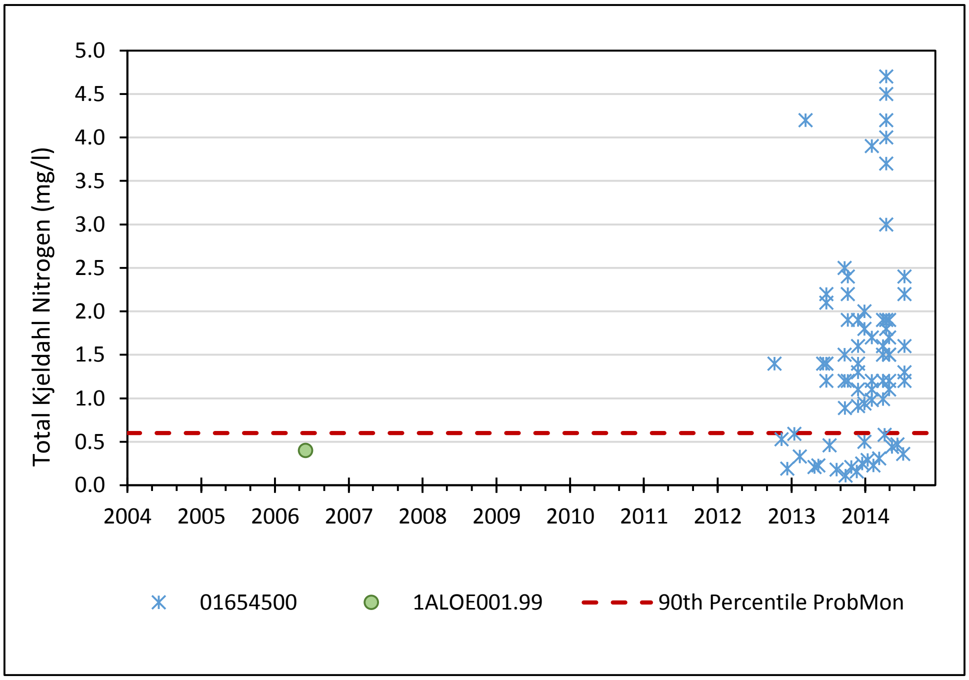


Figure 3-83: Observed Total Kjeldahl Nitrogen (mg/l) in Long Branch

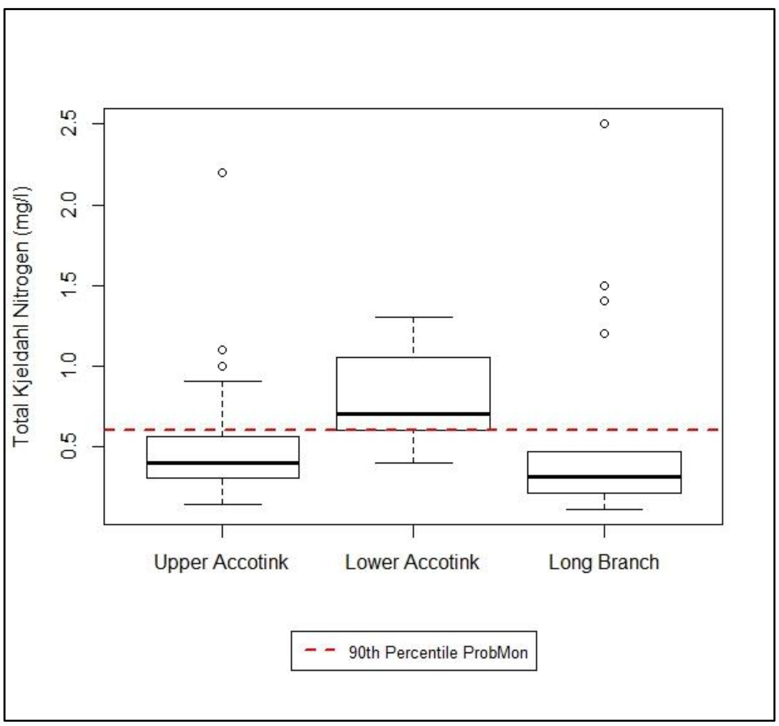


Figure 3-84: Ambient Total Kjeldahl Nitrogen (mg/l) in Accotink Creek Watershed

As **Figure 3-84** shows, TKN concentrations are dramatically higher in lower Accotink Creek. This suggests the hypothesis that Lake Accotink is converting inorganic nutrients to organic nutrients. The growth of algae in Lake Accotink would be the likely mechanism for this effect.

3.5.12 Total Nitrogen

Figures 3-85, 3-86, and 3-87 show the total nitrogen (TN) concentrations observed in water quality samples in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. Virginia has no water quality criteria for TN.

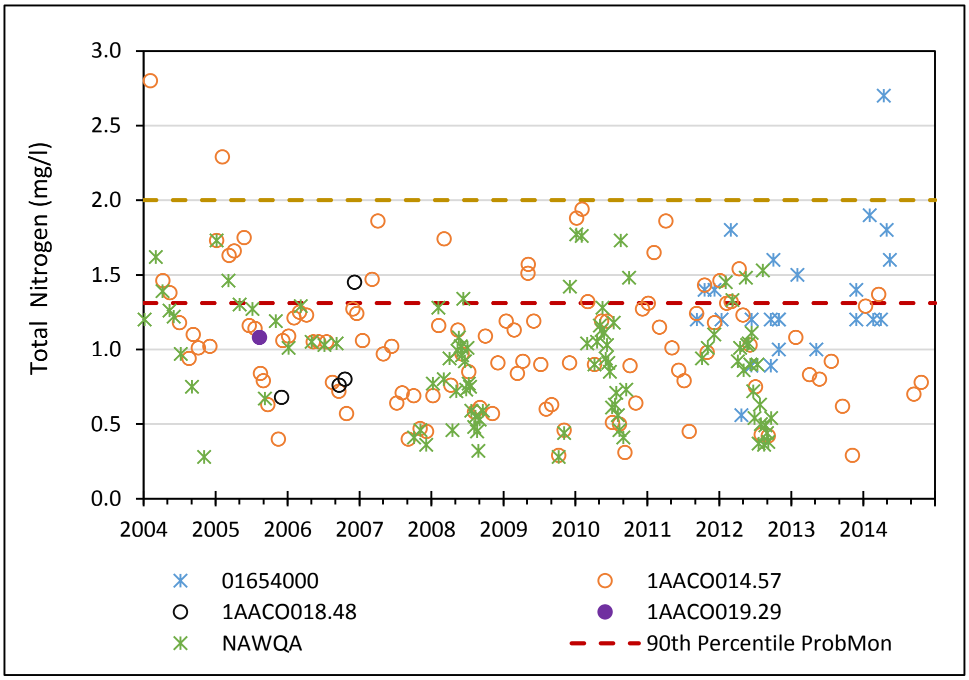


Figure 3-85: Observed Total Nitrogen (mg/l) in Upper Accotink Creek

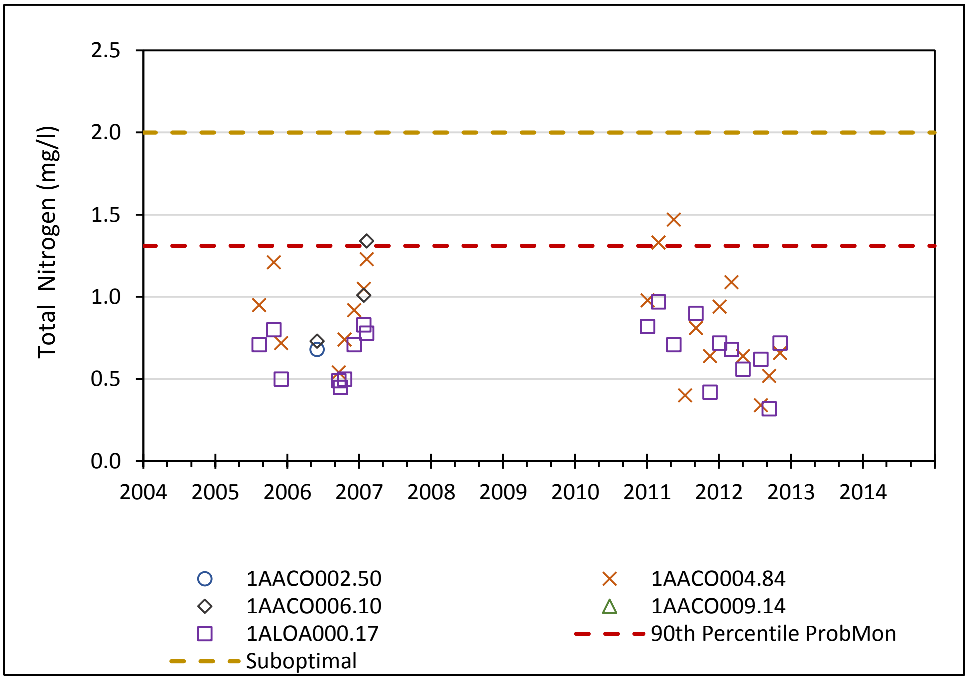


Figure 3-86: Observed Total Nitrogen (mg/l) in Lower Accotink Creek

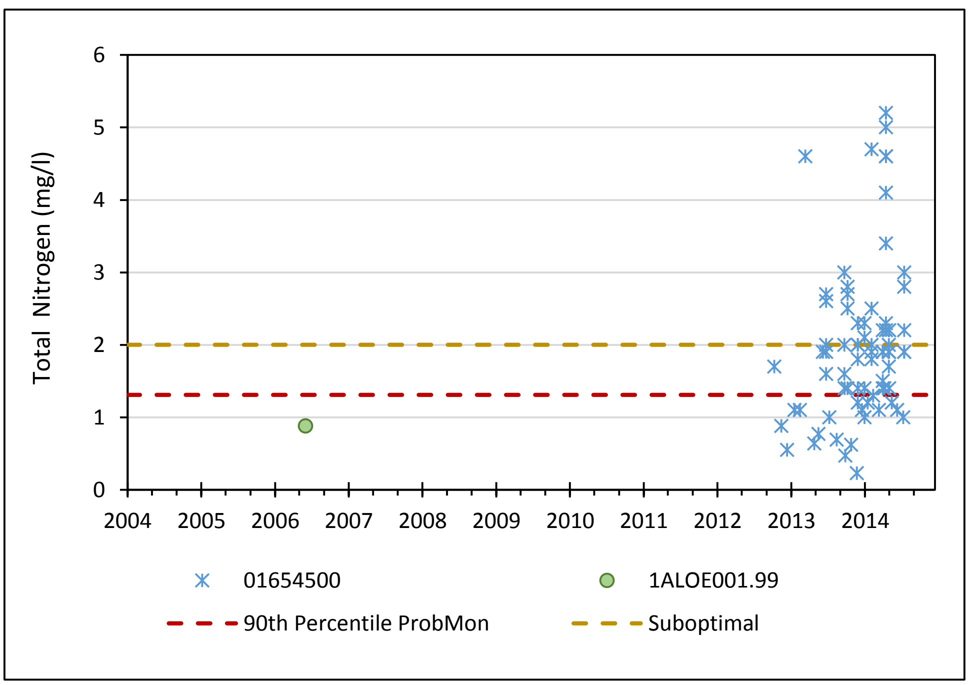


Figure 3-87: Observed Total Nitrogen (mg/l) in Long Branch

The ProbMon threshold for suboptimal conditions for TN is 2.0 mg/l, and the 90th percentile TN concentration of the ProbMon data is 1.31 mg/l. **Figure 3-88** shows the distribution of TN concentrations observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, compared to the ProbMon suboptimal threshold and 90th percentile concentration of the ProbMon data. In lower Accotink Creek, none of the concentrations observed under ambient conditions are above the suboptimal threshold but 6% are above the 90th percentile of the ProbMon data. In upper Accotink Creek, 1% of the concentrations observed under ambient conditions are above the suboptimal threshold and 15% above the 90th percentile of the ProbMon data, while in Long Branch 5% of the concentrations under ambient conditions are above the suboptimal threshold and 20% above the 90th percentile of the ProbMon data.

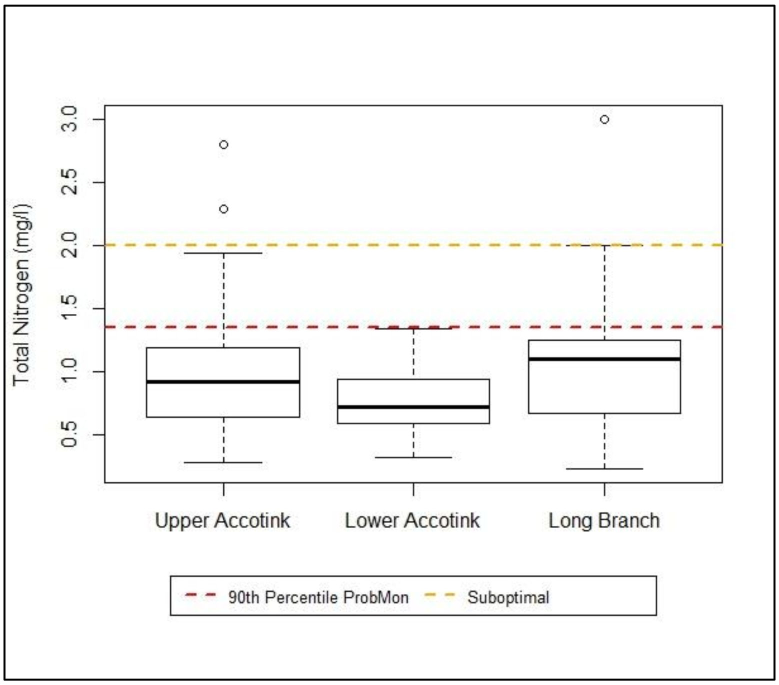


Figure 3-88: Ambient Total Nitrogen (mg/l) in Accotink Creek Watershed

3.5.13 Total Orthophosphate

Figures 3-89 and 3-90 show the total orthophosphate (PO_4) concentrations (in phosphorus) observed in water quality samples in upper Accotink Creek and lower Accotink Creek, respectively. Only DEQ analyzed samples for PO_4. Eighty-five percent of the samples in upper Accotink Creek and 83% of the samples in lower Accotink Creek were reported as below the detection limits. Samples below detection limits are represented at their detection limits in the figures. Only two samples taken in Long Branch were analyzed for PO_4 and one was below the detection limit.

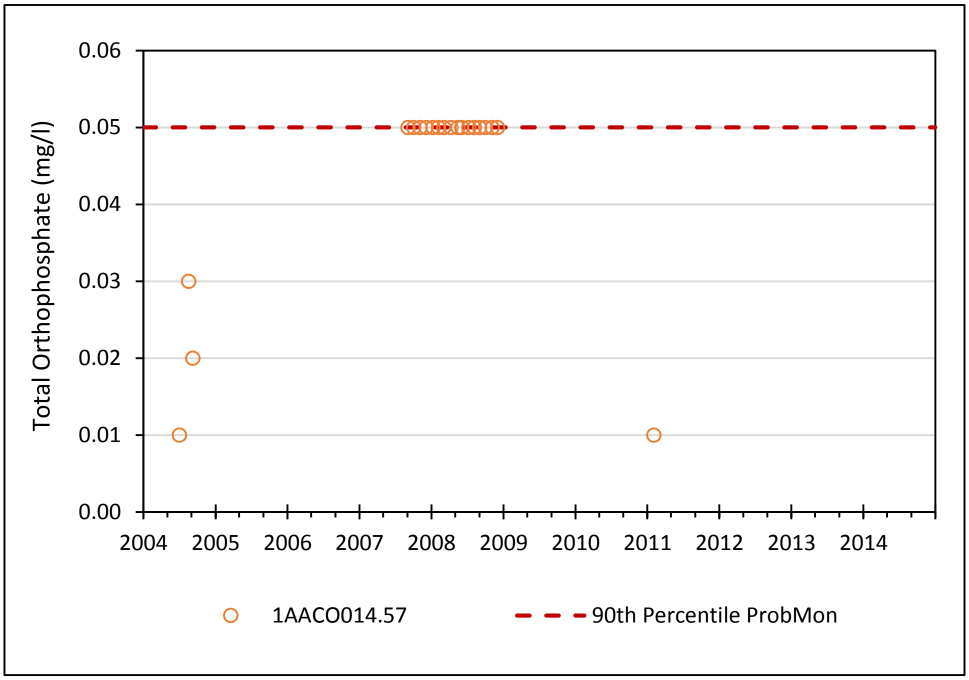


Figure 3-89: Observed Total Orthophosphate (mg/l) in Upper Accotink Creek

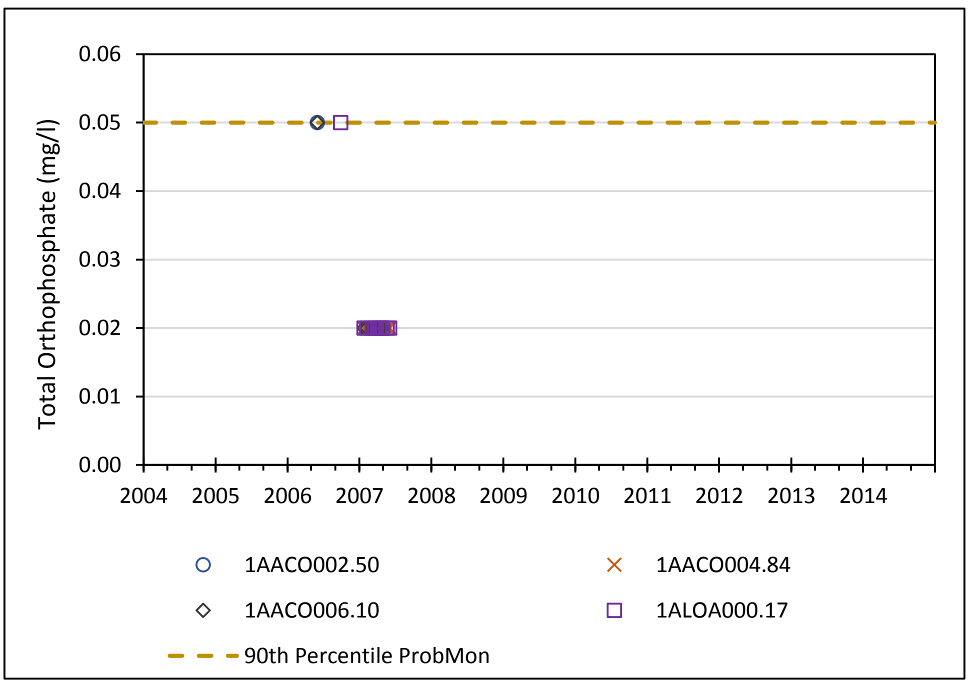


Figure 3-90: Observed Total Orthophosphate (mg/l) in Lower Accotink Creek

Virginia has no water quality criteria for PO_4. The 90th percentile PO_4 concentration in the ProbMon data is 0.05 mg/l. No concentrations observed under ambient conditions in upper

Accotink Creek, lower Accotink Creek, and in Long Branch are greater than the 90th percentile of the ProbMon data. No figure is shown comparing the distribution of observed concentrations to the 90th percentile of the ProbMon data because of the high percentage of observations below the detection limit.

3.5.14 Total Phosphorus

Figures 3-91, 3-92, and 3-93 show the total phosphorus (TP) concentrations observed in water quality samples in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. There are no water quality criteria for TP in Virginia for free-flowing streams. High concentrations of TP generally occur during storm events. The ProbMon threshold for suboptimal conditions for TP is 0.05 mg/l, and the 90th percentile TP concentration of the ProbMon data is 0.07 mg/l. **Figure 3-94** shows the distribution of TP concentrations observed under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, compared to the ProbMon suboptimal threshold and 90th percentile concentration of the ProbMon data. In upper Accotink Creek, 13% of the concentrations observed under ambient conditions are above the suboptimal threshold and 5% above the 90th percentile of the ProbMon data, while in lower Accotink Creek 8% are above the suboptimal threshold and 4% above the 90th percentile TP concentration, and 19% observations of TP in Long Branch are above both the suboptimal threshold and the 90th percentile TP concentration.

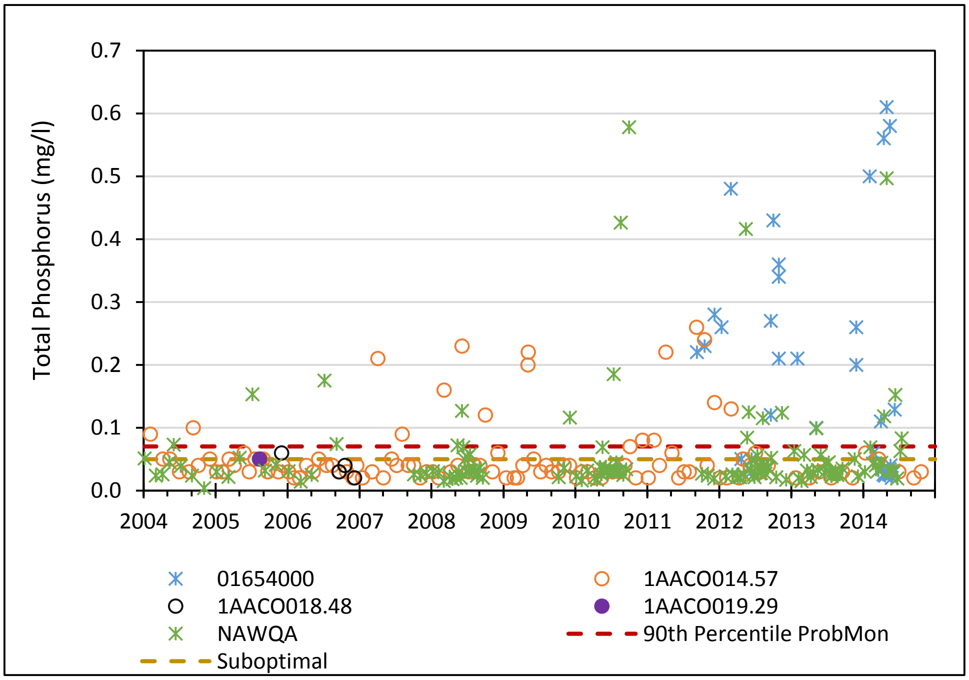


Figure 3-91: Observed Total Phosphorus (mg/l) in Upper Accotink Creek

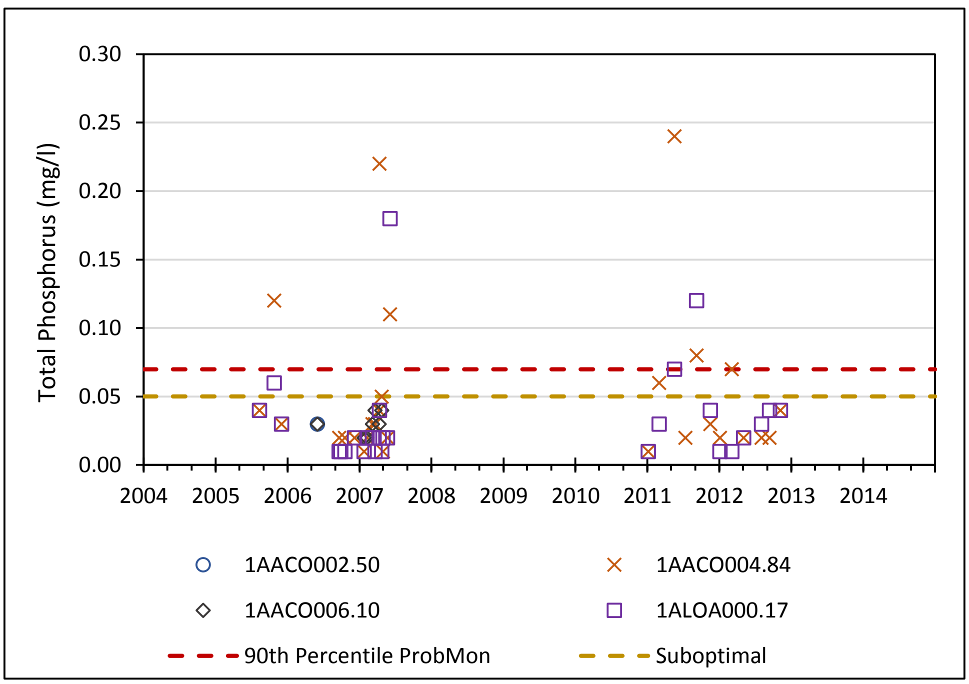


Figure 3-92: Observed Total Phosphorus (mg/l) in Lower Accotink Creek

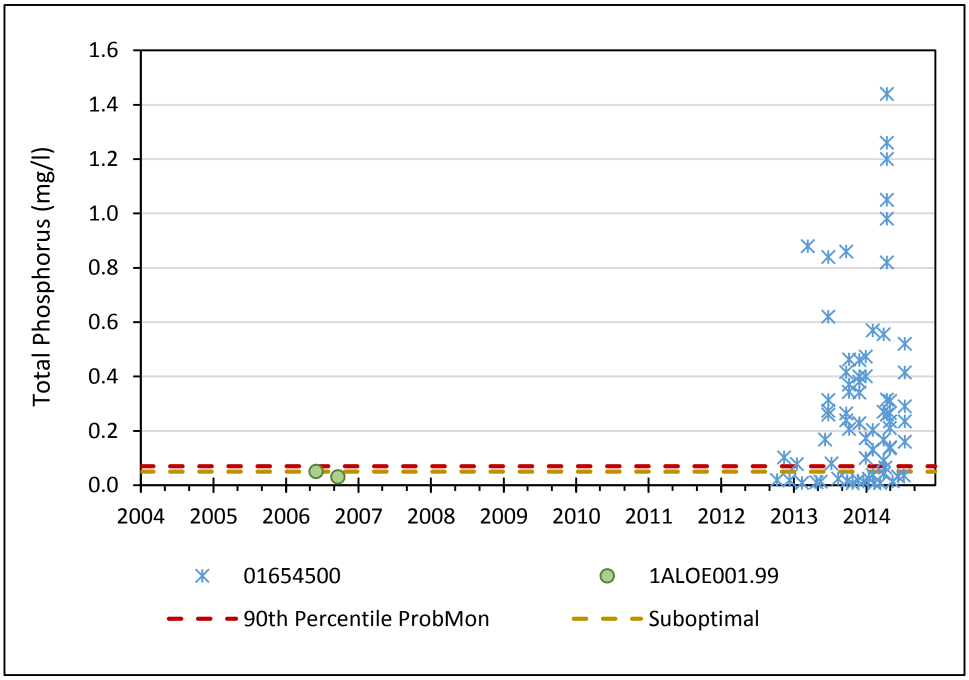


Figure 3-93: Observed Total Phosphorus (mg/l) in Long Branch

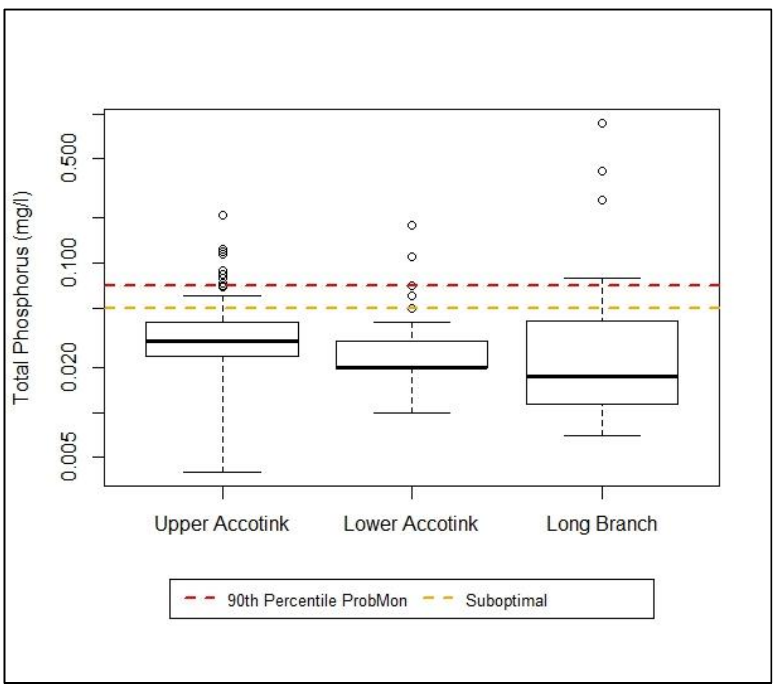


Figure 3-94: Ambient Total Phosphorus (mg/l) in Accotink Creek Watershed

3.5.15 Summary of Conventional Water Quality Data

Tables 3-36, 3-37, and **3-38** give summary statistics for nutrients and some conventional constituents observed during the period from 2004 through 2014 in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. The statistics are based on all samples (both ambient and storm) collected by DEQ and the USGS in each waterbody. Samples taken from DEQ station 1ALOA000.17 in Long Branch South are included in the analysis of lower Accotink Creek.

Table 3-36: Summary Statistics for Selected Water Quality Constituents in Upper Accotink Creek

Statistic	SC	CL	NTU	FNU	TDS	TSS	SS	NH3	NO3	TKN	TN	PO4	TP
Count	309	186	22	34	54	63	176	126	262	134	236	20	287
Minimum	35	5.7	1.0	0.8	82	< 1	< 1	< 0.01	< 0.04	< 0.14	0.28	< 0.01	< 0.00
1st Quartile	219	40.3	2.6	4.3	157	3	4	0.04	0.34	0.30	0.72	0.05	0.03
Median	300	55.1	4.2	53.0	212	14	6	0.04	0.56	0.43	1.02	0.05	0.03
3rd Quartile	387	86.2	12.8	130.0	323	121	19	0.05	0.80	0.60	1.25	0.05	0.06
Maximum	7,986	2,570	38.0	500.0	2,450	944	1,440	0.34	1.66	3.00	2.80	0.05	0.61
Average	523	135.7	9.6	104.8	392	< 98	67	< 0.05	< 0.6	< 0.55	1.02	< 0.04	< 0.07
Std Deviation	887.2	285.6	11.0	129.3	466	189	189	0.05	0.33	0.40	0.43	0.01	0.10
Count Censored	0	0	0	0	0	12	1	72	1	1	0	17	1

Table 3-37: Summary Statistics for Selected Water Quality Constituents in Lower Accotink Creek

Statistic	SC	CL	NTU	TDS	TSS	NH3	NO3	TKN	TN	PO4	TP
Count	116	34	41	29	38	41	41	29	44	29	64
Minimum	117	25.7	1.1	138	< 3	< 0.04	0.26	0.40	0.32	< 0.02	0.01
1st Quartile	211	65.2	2.8	198	3	0.04	0.43	0.60	0.61	0.02	0.02
Median	297	88.0	4.2	219	3	0.04	0.65	0.80	0.72	0.02	0.03
3rd Quartile	392	144.5	15.9	295	5	0.04	0.82	1.10	0.94	0.02	0.04
Maximum	4,781	1580	98.9	554	87	0.29	1.17	1.60	1.47	0.05	0.24
Average	470	221.8	12.3	259	< 8	< 0.06	0.63	0.84	0.78	< 0.02	0.04
Std Deviation	637	341.0	19.2	105	16	0.06	0.23	0.31	0.27	0.01	0.05
Count Censored	0	0	0	0	18	25	0	0	0	24	0

Table 3-38: Summary Statistics for Selected Water Quality Constituents in Long Branch

Statistic	SC	CL	FNU	SS	NO3	TKN	TN	TP
Count	33	8.0	22	91	77	75	75	76
Minimum	46	22.8	0.0	< 0.5	0.07	0.11	0.23	0.01
1st Quartile	162	90.6	1.1	108	0.39	0.56	1.20	0.05
Median	219	264.5	2.1	336	0.47	1.30	1.90	0.23
3rd Quartile	358	606.3	14.3	1,010	0.60	1.90	2.30	0.40
Maximum	3,229	1,010.0	760.0	3,990	1.05	4.70	5.20	1.44
Average	472.4	385.9	56.4	< 765	0.51	1.47	1.98	0.30
Std Deviation	716	374.0		981	0.18	1.11	1.09	0.32
Count Censored	0	0	0	1	0	0	0	0

Tables 3-39, 3-40, and **3-41** give the Spearman rho correlation coefficients among conventional constituents observed in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively. NH_3 and PO_4 have been excluded from the analysis because of the high percentage of non-detects in the data. Some constituents do not have correlations because they are sampled primarily by different agencies.

Two clusters of correlated constituents can be identified. As previously shown, SC, CL, and TDS tend to be positively correlated with each other. The same can be said for NTU, FNU, TSS, and SS, which also tend to be positively correlated with each other. With the exceptions of the positive correlation between TDS and NTU and TDS and TSS in upper Accotink Creek, members of one cluster tend to have a negative correlation or a weak positive correlation (< 0.5) with members of the other. The NTU-FNU-TSS-SS cluster tends to have high concentrations during storm flows, while the SC-CL-TDS cluster have higher concentrations under baseflow conditions, with the exception of winter storms and melt events, discussed in **Section 3.5**. TP tends to have a high positive correlation (> 0.5) with members of the NTU-FNU-TSS-SS cluster, while NO3 tends to have a high positive correlation with members of the SC-CL-TDS cluster. TKN tends to have a positive correlation with TSS and SS and a weaker positive correlation with FNU and NTU. TN is more strongly correlated with NO_3 than TKN in upper Accotink Creek and more strongly correlated with TKN in lower Accotink Creek and Long Branch.

Table 3-39: Spearman Rho Correlations among Selected Water Quality Constituents, Upper Accotink Creek

Constituent	SC	Cl	TDS	NTU	FNU	TSS	SS	NO_3	TKN	TN	TP
SC	1.00	0.98	0.99	0.34	-0.68	-0.42	-0.40	0.55	-0.07	0.15	-0.56
Cl	0.98	1.00	0.98	-1.00	-0.50	-0.32	-0.25	0.61	-0.18	0.24	-0.54
TDS	0.99	0.98	1.00	0.67		0.69	0.12	0.78	-0.03	0.66	-0.17
NTU	0.34	-1.00	0.67	1.00		0.78		-0.29	0.44	0.58	0.73
FNU	-0.68	-0.50			1.00	0.96	0.96	-0.37		0.81	0.97
TSS	-0.42	-0.32	0.69	0.78	0.96	1.00	0.94	-0.61	0.51	0.50	0.89
SS	-0.40	-0.25	0.12		0.96	0.94	1.00	0.02	0.58	0.56	0.76
NO_3	0.55	0.61	0.78	-0.29	-0.37	-0.61	0.02	1.00	-0.03	0.72	-0.25
TKN	-0.07	-0.18	-0.03	0.44		0.51	0.58	-0.03	1.00	0.42	0.64
TN	0.15	0.24	0.66	0.58	0.81	0.50	0.56	0.72	0.42	1.00	0.33
TP	-0.56	-0.54	-0.17	0.73	0.97	0.89	0.76	-0.25	0.64	0.33	1.00

Yellow: Negative Correlation, Green: Strong positive correlation (> 0.5)

Table 3-40: Spearman Rho Correlations among Selected Water Quality Constituents, Lower Accotink Creek

Constituent	SC	CL	TDS	NTU	TSS	NO_3	TKN	TN	TP
SC	1.00	0.98	0.99	0.06	0.13	0.72	0.44	0.25	-0.36
Cl	0.98	1.00	0.95	0.05	0.08	0.59	0.28	-1.00	-0.14
TDS	0.99	0.95	1.00	-0.15	0.03	0.67	0.38	0.67	-0.32
NTU	0.06	0.05	-0.15	1.00	0.67	0.17	0.47	0.37	0.79
TSS	0.13	0.08	0.03	0.67	1.00	0.06	0.70	0.25	0.63
NO_3	0.72	0.59	0.67	0.17	0.06	1.00	0.36	0.86	0.00
TKN	0.44	0.28	0.38	0.47	0.70	0.36	1.00	0.80	0.49
TN	0.25	-1.00	0.67	0.37	0.25	0.86	0.80	1.00	0.20
TP	-0.36	-0.14	-0.32	0.79	0.63	0.00	0.49	0.20	1.00

Yellow: Negative Correlation, Green: Strong positive correlation (> 0.5)

Table 3-41: Spearman Rho Correlations among Selected Water Quality Constituents, Long Branch

Constituent	SC	FNU	SS	NO_3	TKN	TN	TP
SC	1.00	-0.40	-0.36	0.50	-0.31	0.24	-0.67
FNU	-0.40	1.00	0.86	0.18	0.79	0.57	0.79
SS	-0.36	0.86	1.00	-0.19	0.87	0.85	0.91
NO_3	0.50	0.18	-0.19	1.00	-0.19	-0.03	-0.23
TKN	-0.31	0.79	0.87	-0.19	1.00	0.97	0.89
TN	0.24	0.57	0.85	-0.03	0.97	1.00	0.86
TP	-0.67	0.79	0.91	-0.23	0.89	0.86	1.00

Yellow: Negative Correlation, Green: Strong positive correlation (> 0.5)

3.5.16 FCDPWES Water Quality Monitoring

FCDPWES monitored temperature, DO, pH, and SC in the field concurrently with biological monitoring and habitat assessment. **Table 3-42** gives the results of the field observations taken during the probabilistic monitoring program, 2004-2013. **Figure 3-5** shows the location of these stations. FCDPWES water quality observations can be summarized as follows:

There are no exceedances of the maximum temperature criterion.

Table 3-42: FCDPWES Water Quality Monitoring Data, 2004-2013

Watershed	Waterbody	Site ID	Date	Temperature (°C)	DO (mg/l)	% DO Saturation	SC (µS/cm)	pH
Upper Accotink	Mainstem	AC1002	04/06/2010	16.8	8.9	99.5	491	7.6
	Mainstem	AC1002	Summer 2010	18.6	7.1	75.5	255	6.6
	Tributary	AC0504	03/22/2005	12.3	12.6	118.2	478	7.5
	Tributary	AC0602	03/27/2006	9.7	6.4	56.1	200	6
	Tributary	AC0702	03/26/2007	10.2	18.4	162.6	293	6.6
	Tributary	AC0801	03/18/2008	10	13.3	118.1	417	9.3
	Tributary	AC0801	Summer 2008	23.4	7.2	84.4	330	6.8
	Tributary	AC0802	03/18/2008	9.4	11.8	103.7	437	9
	Tributary	AC0802	Summer 2008	23	5.6	67	392	7.7
	Tributary	AC0901	04/10/2009	9.4	11.8	103.3	705	8.1
	Tributary	AC0901	Summer 2009	22.2	6.5	74.4	496	7.3
	Tributary	AC1001	03/30/2010	10.1	12.6	112.4	509	6.4
	Tributary	AC1001	Summer 2010	20.1	6.5	72	467	6.4
	Tributary	AC1003	03/30/2010	11.7	12.5	116	622	6.6
	Tributary	AC1101	03/23/2011	10	11.8	104	414	7.3
	Tributary	AC1102	03/23/2011	10.8	9.8	89	552	6.9
	Tributary	AC1102	Summer 2011	23.8	7.8	92.2	437	7.4
	Tributary	AC1301	03/21/2013	6.5	13.9	113.5	268	7.8
	Tributary	AC1302	03/21/2013	7.2	13.3	110.5	452	7.4
	Tributary	AC1302	Summer 2013	19.8	9.2	101.1	438	7.1
Lower Accotink	Mainstem	AC0501	03/22/2005	7.5	11	91.5	528	7.7
	Mainstem	AC0501	Summer 2005	26	5.9	72.3	154	6.8
	Mainstem	AC0603	04/06/2006	11.8	11	101	293	7.7
	Mainstem	AC0603	Summer 2006	23.2	7.8	91.9	201	7.5
	Mainstem	AC0604	03/27/2006	8.7	10.6	90.5	406	7.2
	Mainstem	AC0604	Summer 2006	17.4	8.3	86.6	184	7
	Mainstem	AC1005	04/02/2010	16.2	13.1	133.4	332	8.2
	Mainstem	AC1005	Summer 2010	21.4	5.7	64.1	259	7
	Tributary	AC0402	04/17/2004	10.6	6.5	58	301	6.7
	Tributary	AC0402	Summer 2004	19.9	10.1	110.9	318	6.8
	Tributary	AC0403	04/15/2004	11.9	9.8	90.4	250	6.7
	Tributary	AC0404	04/15/2004	8.5	10.4	89.2	151	6.6
	Tributary	AC0404	Summer 2004	19.7	9.8	107.2	168	6.6
	Tributary	AC0502	03/22/2005	9.9	12.9	114.5	331	7.5
	Tributary	AC0502	Summer 2005	21.5	6.8	77.8	258	6.8
	Tributary	AC0503	03/22/2005	12	16.5	153	556	7.8
	Tributary	AC0503	Summer 2005	22.9	5.9	68.9	321	6.9

Watershed	Waterbody	Site ID	Date	Temperature (°C)	DO (mg/l)	% DO Saturation	SC (µS/cm)	pH
	Tributary	AC0505	04/06/2005	14	10.5	102	199	6.5
	Tributary	AC0601	03/30/2006	15.9	8.8	88.8	205	5.9
	Tributary	AC1004	03/30/2010	12.6	11.4	107.4	496	7
	Tributary	AC1203	03/23/2012	16.1	9.1	92	390	6.9
Long Branch	Tributary	AC0401	04/16/2004	9.7	13.9	122.7	166	7.4
	Tributary	AC0401	Summer 2004	19.1	9.8	106	135	7.1
	Tributary	AC0703	03/19/2007	8.6	12.8	109.3	194	6.6
	Tributary	AC0704	03/19/2007	5.1	14.4	115	168	6.3
	Tributary	AC1202	03/23/2012	16.8	10.1	104.5	127	6.9

Although there were no exceedances of the minimum instantaneous DO criterion, percent DO saturation was outside the 75% to 125% range in 28% of the observations in upper watershed tributaries, 23% of observations in lower watershed tributaries, and 38% of observations taken from the lower mainstem Accotink Creek. Two of 18 observations in the upper tributaries and two of 13 observations in the lower tributaries were outside the 60% to 140% range of percent DO saturation. No observation in the upper mainstem or Long Branch watershed was outside the 75% to 125% range.

One observation in a tributary in the upper watershed exceeds the maximum pH criterion, and one observation in a tributary in the lower watershed exceeds the minimum pH criterion.

Overall, 43% of the SC measurements were greater than the 90th percentile ProbMon measurement. The rate of measurements above the 90th percentile value varied geographically; while no SC measurement in the Long Branch watershed was greater than 374 µS/cm, 78% of the measurements in the other upper watershed tributaries were greater than the 90th percentile value.

3.5.17 EPA Water Quality Monitoring

The EPA conducted continuous water quality monitoring at three locations upstream and within the stream restoration that was the focus of their study. **Figure 3-95** shows the location of their monitoring sites. In conjunction with the EPA, the USGS conducted continuous water quality monitoring at a fourth site, WQ4, downstream of the restored reach. Both agencies measured pH, SC, temperature, and turbidity during the continuous monitoring, which occurred from December 2005 to March 2008, except during times when the equipment malfunctioned. The EPA also collected discrete samples at WQ2 and WQ4, which were analyzed for chemical oxygen demand (COD), TP, PO_4, TKN, NH_3, NO_3, and bacteria.

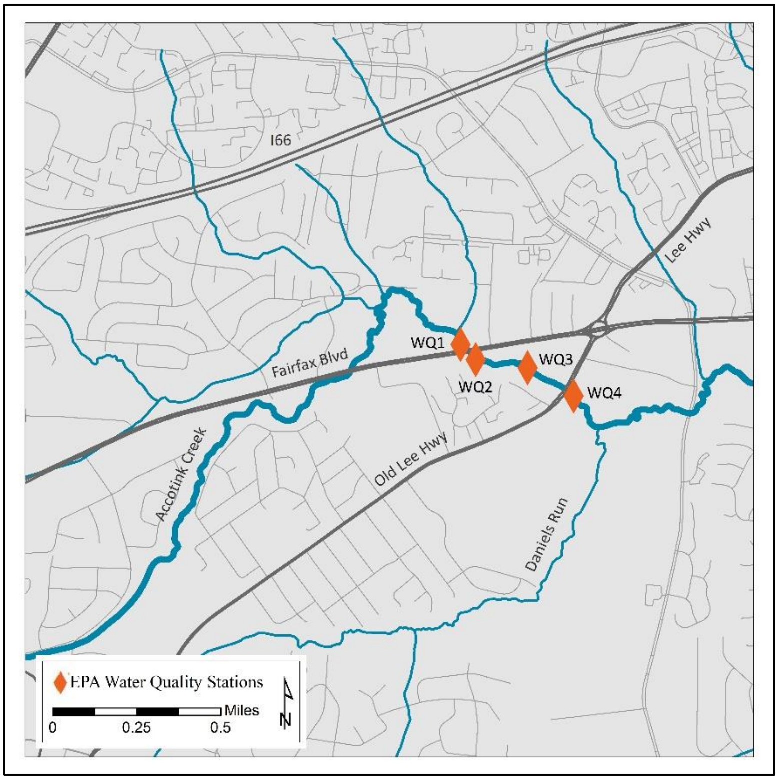


Figure 3-95: Location of EPA Water Quality Monitoring Stations in Accotink Creek

Not all the EPA data was available electronically, but Selvakumar et al. (2008) displayed the continuous monitoring results in figures and summarized some of the monitoring results from discrete samples in tables. Summary results from the USGS continuous monitoring sampling at WQ4 are available under the station ID 0165389480, Accotink Creek below Old Lee Highway. Data available include daily maximum and minimum temperature; daily maximum and minimum SC; daily median pH; and daily median turbidity.

The figures representing the continuous monitoring data (Selvakumar et al., 2008) show the pH at WQ2 exceeded both the maximum and minimum pH criteria, while the site at WQ3 exceeded the minimum pH criterion. The pH recorded at WQ4 by the USGS, in contrast, ranged from 6.8 to 7.7. There was also an exceedance of the maximum temperature criterion at WQ3. Selvakumar et al. (2008) report that after the stream restoration was completed, the probe at WQ3 was in shallower water, with the ambient flow level dropping from 85 cm to 28 cm. The change in depth might explain some of the results recorded. The maximum temperature observed at WQ4 by the USGS was only 29.1°C. Selvakumar et al.'s (2008) figures also show that SC exceeded 10,000 µS/cm at WQ1 and conductivity measurements in the thousands were not uncommon. In this case, the USGS continuous monitoring results corroborate the monitoring at WQ1. **Figure 3-96** shows the daily maximum and minimum SC recorded at WQ4. As **Figure 3-96** shows, even daily minimum SC exceeded 1,000 µS/cm on 4% of the sampling dates.

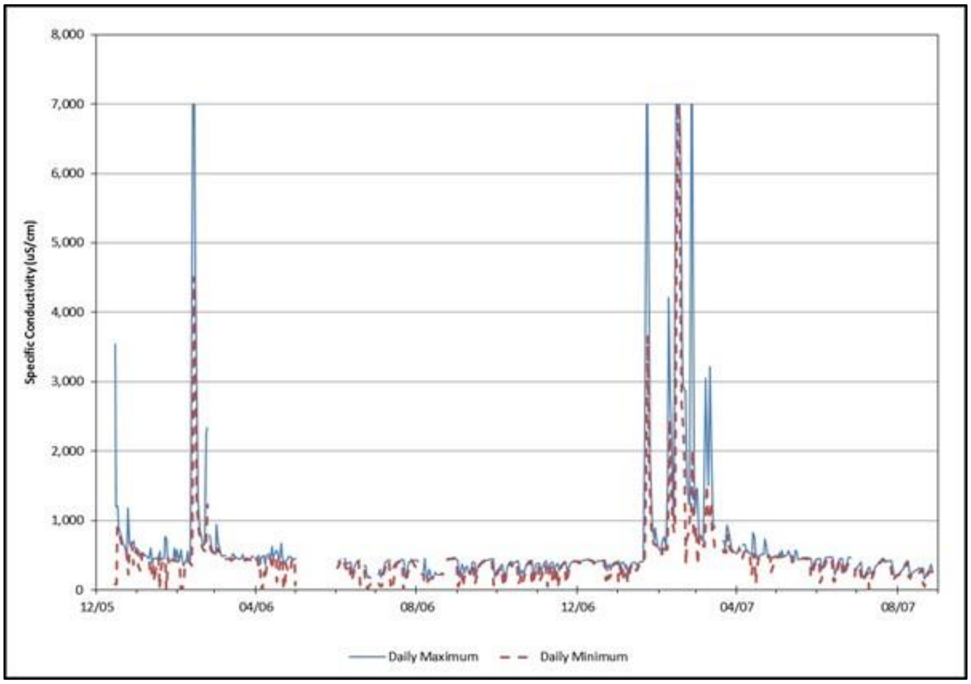


Figure 3-96: Daily Maximum and Minimum Specific Conductance, Accotink Creek Below Old Lee Highway

3.6 Analysis of Metals and Toxics Monitoring Data

This section analyzes water quality monitoring data on metals and toxic organic chemicals.

DEQ monitored metals and toxics in the water column, sediment, and fish tissue. **Figure 3-97** shows the location of the monitoring locations. All of the sediment samples and all but one of the fish tissue samples were collected in lower mainstem Accotink Creek or in Long Branch South. **Table 3-43** summarizes by species the fish tissue samples collected in Accotink Creek since 2000. Samples collected from Lake Accotink were excluded from the analysis because the fate and transport of metals and toxics in an impoundment differs from free flowing waters. Data for analysis was restricted to the last 15 years, 2000-2014, which covers the period during which fish tissue monitoring results are available from Accotink Creek.

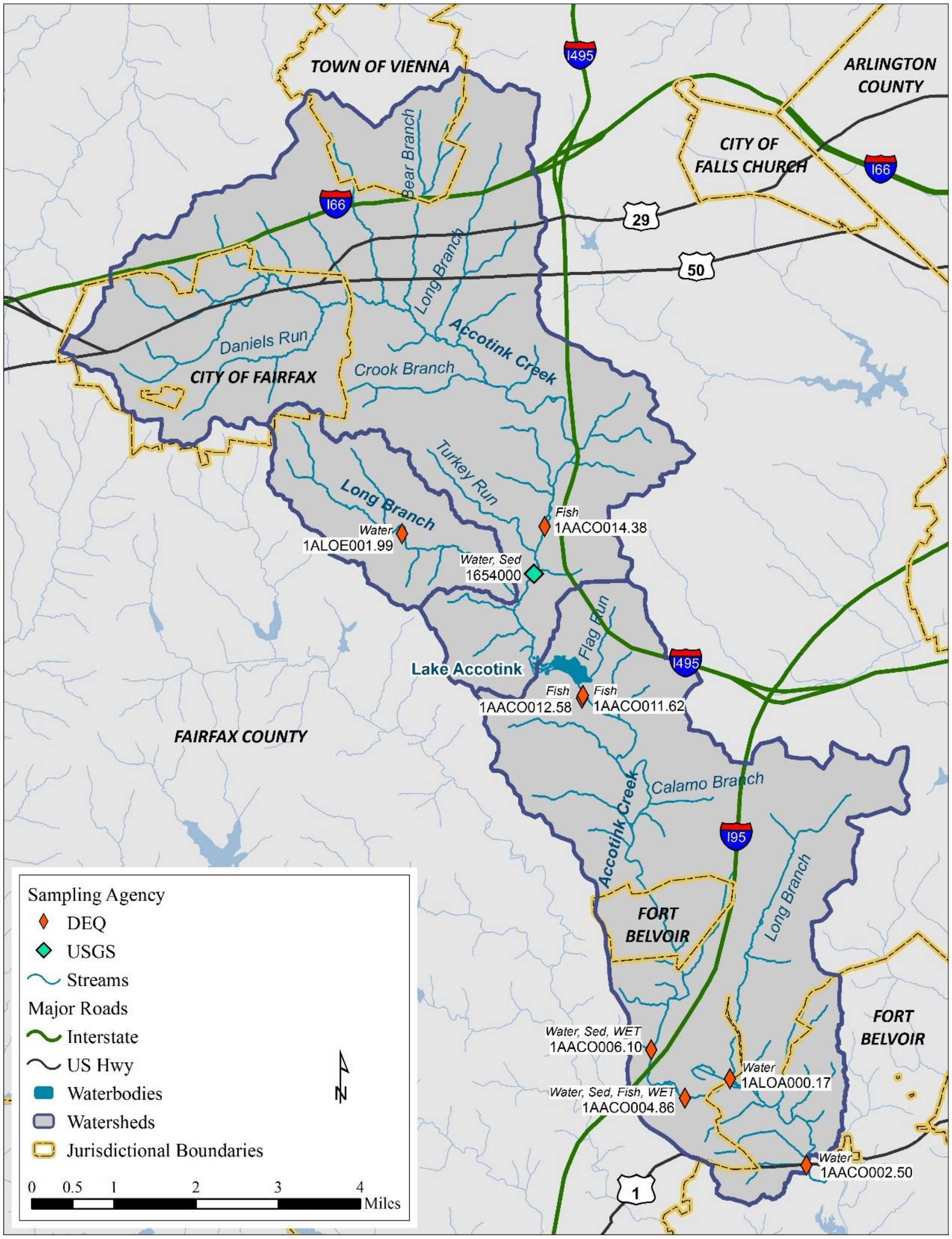


Figure 3-97: Metal and Toxics Sampling Locations in Accotink Creek

Table 3-43: Fish Tissue Samples Collected by DEQ in Accotink Creek, 2000-2014

Station	Date	Species	Number of Fish	Length (cm)	Weight (g)	Percent Water	Percent Lipids
1AACO004.86	06/20/2001	Redbreast Sunfish	8	10.5 - 14.0	24 - 56	79.0	5.18
		American Eel	10	28.8 - 64.1	44 - 622	71.2	29.85
		White Sucker	5	20.5 - 32.7	90 - 388	79.9	3.67
		Yellow Bullhead Catfish	3	17.0 - 22.8	62 - 174	82.3	4.05
	06/01/2004	Redbreast Sunfish	7	11.5 - 14.8	30 - 72	79.17	4.79
		White Sucker	3	22.5 - 25.4	130 - 194	78.75	9.82
		Rainbow Trout	1	38.1	614	75.4	14.30
		American Eel	3	21.5 – 31.1	16 - 64	70.21	38.09
1AACO011.62	03/31/2008	Rainbow Trout - 1	4	36.2 - 44.6	668 - 994	76.52	15.22
		Rainbow Trout - 2	5	34.8 - 37.2	460 - 624	76.22	14.31
		American Eel	3	53.2 - 65.7	310 - 592	71.45	35.22
1AACO012.58	09/13/2007	Yellow Bullhead Catfish	10	17.9 - 23.5	84 - 210	82.00	6.07
		Bluegill Sunfish	12	12.7 - 15.4	40 - 96	78.92	7.87
		White Sucker	5	22.2 – 27.5	118 -226	80.55	4.45
		Creek Chubsucker	5	18.5 – 20.9	90 - 136	81.28	3.41
1AACO014.38	03/31/2008	Rainbow Trout	9	22.6 - 29.8	112 - 228	80.07	5.83

Virginia's water quality standards have acute and chronic water quality criteria for metals and toxics to protect aquatic life (9VAC25-260-140). ProbMon uses the Cumulative Criterion Unit (CCU) Metals Index (Clements et al., 2000) to screen ProbMon sampling sites for the cumulative chronic biological impact of dissolved metals. A CCU is the ratio of the observed dissolved metals concentration to the EPA chronic criterion concentration; the CCU Index is the sum of the CCUs for each metal analyzed.

Samples from sediment and fish tissue, collected by DEQ's Sediment and Fish Tissue Monitoring Program, are compared to assessment benchmarks. Sediment samples are screened against Sediment Quality Guidelines (SQGs). SQGs are thresholds that indicate at what concentrations metals and toxics chemicals are likely to impact the biological community (Buchman, 2008). They do not have regulatory force, though DEQ uses the Probable Effect Concentrations (PECs) to help assess when metals or toxics are adversely impacting aquatic life (DEQ, 2014b). PECs are averages of other thresholds that represent concentrations above which adverse impacts on biota are likely to occur. Threshold Effect Concentrations (TECs) (Buchman, 2008) will also be used in this analysis. TECs are averages of other thresholds that represent concentrations below which adverse impacts are unlikely to occur. Because they are averages of other thresholds, PECs and TECs are often referred to as consensus-based values. **Figure 3-98** shows the relation between TECs and PECs.

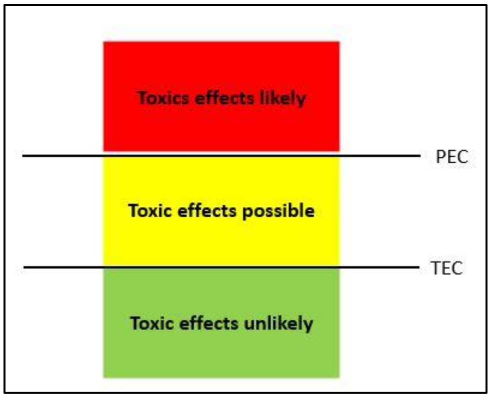


Figure 3-98: Relation between Threshold and Probable Effect Concentrations

Fish tissue samples are screened against tissue values (TVs) or tissue screening values (TSVs). These are thresholds for protecting human health under the Fish Consumption Use. TVs are the fish tissue concentrations equivalent to the water column criteria in the water quality standards for the Fish Consumption Use. TSVs are thresholds for protecting human health for constituents for which no water quality criteria have been developed but are suspected of causing health problems if consumed. Although the TVs and TSVs are used to assess the risk to human health, they will be used in this analysis to indicate the possibility of bioaccumulation and adverse impact to the biological community. Because of the mobility of fish, however, concentrations of toxics in fish tissue may not reflect the toxicity of the immediate environment in which the fish are found.

Section 3.6.1 discusses the water quality criteria, TECs, PECs, TVs, and TSVs for metals and analyzes the concentrations of metals found in the water column, sediment and fish tissue in samples collected by DEQ. **Section 3.6.2** performs the same analysis for toxics. On behalf of DEQ, the EPA's Wheeling, West Virginia Office also performed toxicity tests on two samples taken from Accotink Creek. The results of the toxicity tests are discussed in **Section 3.6.3**.

The USGS also analyzed samples collected in the water column and sediments of Accotink Creek near Annandale for metals and toxics. Analysis of their results can also be found in **Sections 3.6.1** and **3.6.2**, respectively. USGS monitoring data for metals are limited but the monitoring data for toxics, as described in **Section 3.6.2**, are quite extensive. No fish tissue samples have been collected in Accotink Creek by the USGS since 2000.

3.6.1 Analysis of Metals Monitoring Data

Table 3-44 shows the acute and chronic water quality criteria; TECs and PECs; and TVs and TSVs for metals. For many metals, the acute and/or chronic criteria apply only to dissolved metals and are a function of hardness. For those metals, **Table 3-44** shows the criterion concentration at 85 mg/l (as $CaCO_3$), which is the average hardness observed in Accotink Creek.

Table 3-44: Water Quality Criteria, Sediment Quality Guidelines, Tissue Values, and Tissue Screening Values for Metals

	Water Column (µg/l)		Sediment (ppb)		Fish Tissue (ppb)	
Metal	Acute	Chronic	PEC	TEC	TV	TSV
Aluminum	--	--	--	--	--	--
Antimony	--	--	--	--	1,600	--
Arsenic	340	150	33	9.79	--	270
Barium	--	--	--	--	--	800,000
Beryllium	--	--	--	--	--	--
Cadmium	3.26	1.00	4.98	0.99	--	4,000
Chromium (III)	498.74	64.88	111	43.40	--	6,000,000
Chromium (IV)	16	11	111	43.40	--	12,000
Copper	11.53	7.79	149	31.60	--	--
Iron	--		--	--	--	--
Lead	96.68	10.98	128	35.80	--	--
Manganese	--	--	--		--	--
Mercury	1.40	--	1.06	0.18	300[1]	--
Nickel	158.93	17.66	48.6	22.70	220,000	--
Selenium	20	5	--	--	20,000	--
Silver	2.61	--	--	--	--	--
Thallium	--	--	--	--	54	--
Zinc	102.10	102.94	459	121.00	1,200,000	--

[1]Methyl mercury as mercury

Table 3-45 shows for each metal, the number of observations of the dissolved fraction from samples collected in the water column by DEQ, the number of observations above the detection limit, and the number exceeding the acute or chronic criteria to protect aquatic life, since 2000. Hardness concentrations were determined from observations of dissolved calcium and magnesium and expressed as $CaCO_3$ equivalents. Six of the samples were collected in the lower mainstem of Accotink Creek, five in Long Branch South, and one sample in Long Branch. There are no exceedances of acute criteria and there is one observation of copper which exceeds the chronic criteria. The analysis of dissolved mercury used methods capable of detecting trace levels at very low detection limits. **Table 3-46** shows the dissolved metals concentrations observed in the Accotink Creek watershed. Samples from 4/12/07 were collected under storm flow conditions.

Table 3-45 also shows for each metal, the number of observations from samples collected in sediment by DEQ, the number of observations above the detection limit, and the number exceeding the TEC or PEC to protect aquatic life. There were only three samples collected since 2000, and all were in lower mainstem Accotink Creek. No metal concentration in the sediments was above the corresponding TEC or PEC.

Finally, **Table 3-45** shows for each metal, the number of observations from samples collected in fish tissue by DEQ, the number of observations above the detection limit, and the number exceeding the TV or TSV to protect human life. All but one observation is from lower Accotink Creek. All observations are below the corresponding TV or TSV except for one observation of arsenic in yellow bullhead catfish in lower Accotink Creek.

Table 3-45: Summary of Metals Observed in DEQ Monitoring of Accotink Creek Watershed, 2000-2014

Metal	Water Colum				Sediment				Fish Tissue		
	Number Samples	Number > ND	Number > Acute	Number > Chronic	Number Samples	Number > ND	Number > TEC	Number > PEC	Number Samples	Number >ND	Number > TV or TSV
Aluminum	12	11	--	--	2	0	--	--	0	--	--
Antimony	12	1	--	--	3	3	--	--	0	--	--
Arsenic	12	12	0	0	3	2	0	0	11	1	1
Barium	12	12	--	--	0	--	--	--	0	--	--
Beryllium	12	1	--	--	0	--	--	--	0	--	--
Cadmium	12	0	0	0	3	2	0	0	11	0	--
Chromium	12	10	0	0	3	3	0	0	11	1	0
Copper	12	12	0	1	3	3	0	0	0	--	--
Iron	12	5	--	--	0	--	--	--	0	--	--
Lead	12	8	0	0	3	1	0	0	11	0	0
Manganese	12	12	--	--	1	1	--	--	0	--	--
Mercury	12	5	0	0	3	3	0	0	11	8	0
Nickel	12	12	0	0	3	2	0	0	0	--	--
Selenium	12	3	0	0	3	0	--	--	11	0	0
Silver	12	0	0		3	2	--	--	0	--	--
Thallium	12	0	--	--	2	0	--	--	0	--	--
Zinc	12	11	0	0	3	3	0	0	0	--	--

Table 3-46: Observed Dissolved Metals (µg/l) in Accotink Creek Watershed, 2000-2014

Waterbody	Lower Accotink											Long Branch
Station	1AACO002.50	1AACO004.84	1AACO004.84	1AACO004.84	1AACO004.84	1AACO006.10	1ALOA000.17	1ALOA000.17	1ALOA000.17	1ALOA000.17	1ALOA000.17	1ALOE001.99
Date	06/01/06	04/10/07	04/12/07	04/30/07	06/04/07	06/01/06	09/28/06	04/10/07	04/12/07	04/30/07	06/04/07	06/01/06
Hardness[1]	60.0	62.0	64.7	70.6	57.8	65.0	87.0	1.0	62.0	69.4	28.3	39.0
Aluminum	1.6	2.5	6.2	2.6	6.3	1.7	<1	8.2	17.5	1.5	8.2	3.1
Antinomy	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5
Arsenic	0.4	0.2	0.5	0.2	0.8	0.4	0.2	0.5	0.2	0.2	0.4	0.4
Barium	30.4	32.2	29.1	30.3	25.8	20.7	69.7	65.3	46.9	69.9	32.6	16.5
Beryllium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cadmium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium	0.1	0.2	0.2	0.3	0.4	< 0.1	< 0.1	0.1	0.3	0.2	0.7	0.1
Copper	1.5	1.6	1.9	1.7	2.4	1.5	1.0	1.6	2.8	1.0	3.8	0.8
Iron	< 50	< 50	66.6	< 50	< 50	< 50	< 50	403	116	< 50	83	136
Lead	0.1	0.1	0.1	0.1	0.1	< 0.1	< 0.1	0.3	0.2	< 0.1	0.2	0.1
Manganese	45	97.7	208	74.9	84.9	32.9	77.8	131	120	100	58.4	27.5
Mercury[2]	<1.5	<1/5	<1.5	1.9	<1.5	<1.5	<1.5	<1.5	14.8	2.3	2.2	3.2
Nickel	0.9	0.9	0.9	0.8	1.1	0.6	1.7	3.3	2.6	2.4	2.2	1.1
Selenium	< 0.5	< 0.5	< 0.5	< 0.5	0.7	< 0.5	< 0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5
Silver	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Thallium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Zinc	1.1	1.5	2.1	1.0	2.8	1.0	4.3	14.7	32.1	6.3	11.9	1.9

[1]mg/l
[2]ng/l

ProbMon classifies a CCU Index score less than one as optimal and a score greater than two as suboptimal. **Figure 3-99** compares the CCU Metals Index, calculated for each sample of dissolved metals collected by DEQ since 2000, with the ProbMon suboptimum threshold of 2.0. All of the values of the metals index from Accotink Creek are below 2.0. All but two of the observations of the metals index are even below the ProbMon optimum threshold of 1.0.

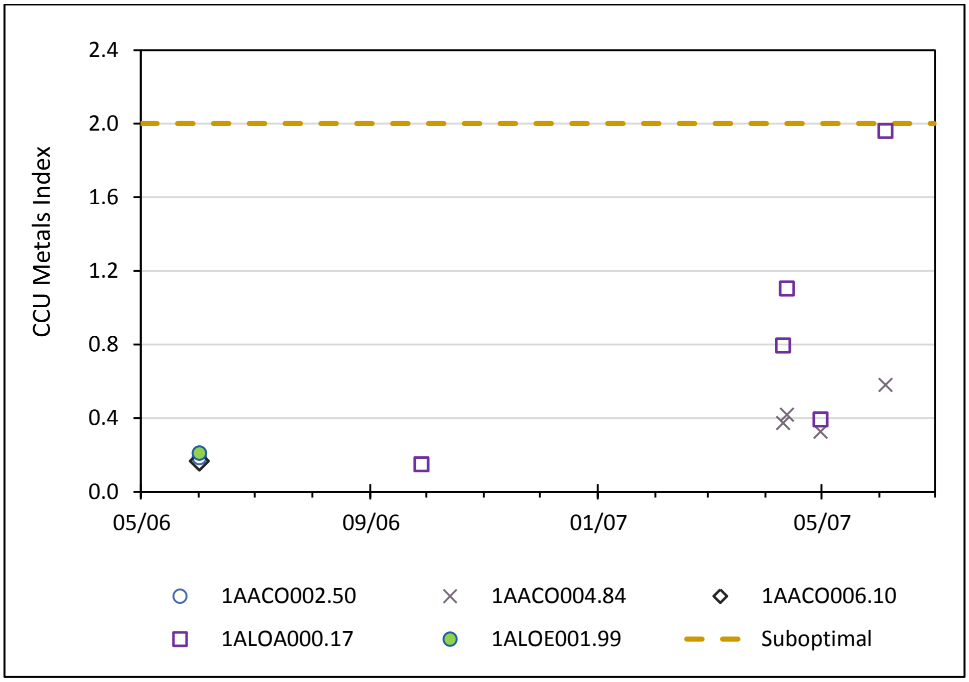


Figure 3-99: Cumulative Criterion (CCU) Metals Index, Accotink

The USGS's NAWQA program measured dissolved metals in samples taken in Accotink Creek near Annandale, 2012-2014. Only two metals measured had water quality criteria to protect aquatic life: arsenic and selenium. None of the 38 observations of arsenic was below the detection limit, and none exceeded either Virginia's acute or chronic criteria for arsenic. Of the 40 observations of selenium, 18 were below the detection limit. None of the observations exceeded either Virginia's acute or chronic criteria for selenium. No sediment samples have been analyzed for metals since 2000.

3.6.2 Analysis of Toxics Monitoring Data

Table 3-47 shows the acute and chronic water quality criteria; TECs and PECs; and TVs and TSVs for organic pollutants which DEQ has monitored in the water column, sediment and fish tissue. The organic toxics include polychlorinated biphenyls (PCBs), pesticides, and polycyclic aromatic hydrocarbons (PAHs). Most of the pesticides in **Table 3-48** belong to the family of organochlorine insecticides whose use has been prohibited by law because of their toxicity and persistence in the environment. Generally, the compounds listed in **Table 3-48** have low solubilities, tend to bind to organic matter in soils and sediments, and accumulate in the fatty tissue of fish and other animals.

Table 3-47: Water Quality Criteria, Sediment Quality Guidelines, Tissue Values, and Tissue Screening Values for Toxic Compounds

	Water Column (µg/l)		Sediment (ppb)		Fish Tissue (ppb)	
Compound	**Acute**	**Chronic**	**TEC**	**PEC**	**TV**	**TSV**
PCB, Total	--	0.014	59.8	676	20	--
Chlordane, Total	--	--	3.24	17.6	110	--
DDD	--	--	4.88	28	170	--
DDE	--	--	3.16	31.3	120	--
DDT	1.1	0.001	4.16	62.9	120	--
DDE+ DDD+ DDT	--	--	5.28	572	--	--
Dichloromethyldiphenylether	--	--	--	--	--	--
Dieldrin	0.24	0.056	1.9	61.8	2.5	--
Endosulfan	0.22	0.056	--	--	24,000	--
Endrin	0.086	0.036	2.22	207	240	--
Heptachlor	0.52	0.0038	--	--	8.9	--
Heptachlor epoxide	0.52	0.0038	2.47	16	4.4	--
Hexachlorobenzene (BHC)	--	--	3	--	25	--
Lindane (gamma BHC)	0.95	--	2.37	4.99	240	--
Methoxy triclosan	--	--	--	--	--	--
Mirex		0	--	--	--	8,000
Octachlorodibenzodioxin (OCDD)	--	--	--	--	--	--
Oxychlordane	--	--	--	--	--	--
Pentachloroanisole	--	--	--	--	--	--
Polybrominated diphenyl ether (PBDEs)	--	--	--	--	--	5,000
PAH (sum 34 reported)	--	--	1,610	22,800	--	--
PAH (sum 27 reported)	--	--	--	--	--	--
PAH Potency Equivalence Factor	--	--	--	--	--	15
Acenaphthene	--	--	--	--	240,000	--
Acenaphthylene	--	--	--	--	--	--
Anthracene	--	--	57.2	845	12,000,000	--
Benz(a)anthracene	--	--	108	1,050	5.5	--
Benzo(a)pyrene	--	--	150	1,450	5.5	--
Benzo(b)fluoranthene	--	--	--	--	5.5	--
Benzo(e)pyrene	--	--	--	--	--	--
Benzo(ghi)perylene	--	--	--	--	--	--
Benzo(k)fluoranthene	--	--	--	--	5.5	--
Biphenyl	--	--	--	--	--	--
Chyrsene	--	--	166	1,290	5.5	--
Dibenz(a,h)anthracene	--	--	33	--	5.5	--
Dibenzofuran	--	--	--	--	--	--
Dibenzothiophene	--	--	--	--	--	--
2,6-Dimethylnaphthalene	--	--	--	--	--	--

Compound	Water Column (µg/l)		Sediment (ppb)		Fish Tissue (ppb)	
	Acute	Chronic	TEC	PEC	TV	TSV
1,3-Dimethylnaphthalene	--	--	--	--	--	--
1,6-Dimethylnaphthalene	--	--	--	--	--	--
1,2-Dimethylnaphthalene	--	--	--	--	--	--
1,5-Dimethylnaphthalene	--	--	--	--	--	--
1,8-Dimethylnaphthalene	--	--	--	--	--	--
1,4- & 2,3-Dimethylnaphthalene	--	--	--	--	--	--
Diphenyl ether	--	--	--	--	--	--
Fluoranthene	--	--	423	2,230	160,000	--
Fluorene	--	--	77.4	536	8.9	--
Indeno(1,2,3-cd)pyrene	--	--	--	--	5.5	--
Methylfluorene	--	--	--	--	--	--
2-Methylnaphthalene	--	--	--	--	--	--
1-Methylnaphthalene	--	--	--	--	--	--
1-Methylphenanthrene	--	--	--	--	--	--
2-Methylphenanthrene	--	--	--	--	--	--
Naphthalene	--	--	176	561	--	--
Phenanthrene	--	--	204	1,170	--	--
Pyrene	--	--	195	1,520	120,000	--
Perylene	--	--	--	--	--	--
2,3,5-Trimethylnaphthalene	--	--	--	--	--	--

Table 3-48 shows for each toxic compound, the number of observations from samples collected in the water column by DEQ, the number of observations above the detection limit, and the number exceeding the acute or chronic criteria to protect aquatic life, where applicable. All observations were below the detection limit. All of the samples were collected in the lower mainstem of Accotink Creek or in Long Branch South. Two of the samples were collected under storm-flow conditions.

Table 3-48: Summary of Toxic Compounds Observed in DEQ Monitoring of Accotink Creek, 2000-2014

	Water Colum (µg/l)				Sediment (ppb)				Fish Tissue (ppb)		
Compound	**#Samples**	**# > ND**	**# > Acute**	**# > Chronic**	**# Sample**	**# > ND**	**# > TEC**	**# > PEC**	**# Sample**	**# > ND**	**# > TV or TSV**
PCB, Total	4	0	--	--	3	3	0	0	16	16	8
Chlordane, Total	4	0	--	--	2	2	1	0	13	13	1
DDD	0	--	--	--	1	0	0	0	11	11	0
DDE	0	--	--	--	2	1	0	0	13	13	0
DDT	0	--	--	--	2	1	0	0	6	6	0
DDE+ DDD+ DDT	0	--	--	--	0	--	--	--	13	13	0
Dichloromethyldiphenylether	0	--	--	--	0	--	--	--	1	1	--
Dieldrin	4	0	--	--	1	0	--	--	1	1	1
Endosulfan	0	--	--	--	0	--	--	--	2	2	0
Endrin	4	0	--	--	1	0	--	--	1	1	0
Heptachlor	4	0	--	--	1	1	--	--	1	1	0
Heptachlor epoxide	4	0	--	--	2	1	0	--	7	7	2
Hexachlorobenzene (BHC)	4	0	--	--	1	1	--	--	5	5	0
Lindane (gamma BHC)	4	0	--	--	1	0	--	--	1	1	0
Methoxy triclosan	0	--	--	--	0	--	--	--	3	3	--
Mirex	0	--	--	--	0	--	--	--	1	1	--
Octachlorodibenzodioxin (OCDD)	0	--	--	--	1	1	--	--	0		--
Oxychlordane	0	--	--	--	0	--	--	--	2	2	--
Pentachloroanisole	0	--	--	--	0	--	--	--	3	3	--
Polybrominated diphenyl ether (PBDEs)	0	--	--	--	1	1	--	--	13	13	0
PAH (sum 34 reported)	0	--	--	--	2	2	2	0	7	7	--
PAH (sum 27 reported)	0	--	--	--	1	1	1	0	3	3	--
PAH (High MW)	0	--	--	--	2	2	--	--	0	--	--
PAH (Low MW)	0	--	--	--	2	2	--	--	0	--	--
PAH Potency Equivalence Factor	0	--	--	--	0	--	--	--	7	7	0
Acenaphthene	4	0	--	--	3	2	--	--	7	7	0
Acenaphthylene	4	0	--	--	3	2	--	--	7	5	--
Anthracene	4	0	--	--	3	2	1	0	7	6	0
Benz(a)anthracene	4	0	--	--	3	3	3	0	7	6	0
Benzo(a)pyrene	8	0	--	--	3	3	3	0	7	3	0

Compound	Water Colum (µg/l)				Sediment (ppb)				Fish Tissue (ppb)		
	#Samples	# > ND	# > Acute	# > Chronic	# Sample	# > ND	# > TEC	# > PEC	# Sample	# > ND	# > TV or TSV
Benzo(b)fluoranthene	4	0	--	--	3	3	--	--	7	4	0
Benzo(e)pyrene	0	--	--	--	3	3	--	--	7	3	--
Benzo(ghi)perylene	4	0	--	--	3	3	--	--	7	1	--
Benzo(k)fluoranthene	4	0	--	--	3	3	--	--	7	4	0
Biphenyl	0	--	--	--	3	3	--	--	7	6	--
Chyrsene	4	0	--	--	3	3	3	0	7	6	0
Dibenz(a,h)anthracene	4	0	--	--	3	3	3	--	7	0	--
Dibenzofuran	0	--	--	--	0	--	--	--	3	2	0
Dibenzothiophene	0	--	--	--	1	1	--	--	3	0	--
2,6-Dimethylnaphthalene	0	--	--	--	1	1	--	--	1	1	--
1,3-Dimethylnaphthalene	0	--	--	--	2	2	--	--	1	1	--
1,6-Dimethylnaphthalene	0	--	--	--	0	--	--	--	1	1	--
1,2-Dimethylnaphthalene	0	--	--	--	0	--	--	--	1	1	--
1,5-Dimethylnaphthalene	0	--	--	--	0	--	--	--	1	0	--
1,8-Dimethylnaphthalene	0	--	--	--	0	--	--	--	1	0	--
1,4- & 2,3-Dimethylnaphthalene	0	--	--	--	1	0	--	--	1	0	--
Diphenyl ether	0	--	--	--	0	--	--	--	3	2	--
Fluoranthene	4	0	--	--	3	3	3	0	7	7	0
Fluorene	4	0	--	--	3	3	0	0	7	7	0
Indeno(1,2,3-cd)pyrene	4	0	--	--	3	3	--	--	7	1	0
Methylfluorene	0	--	--	--	1	1	--	--	0	--	--
2-Methylnaphthalene	0	--	--	--	3	3	--	--	7	6	--
1-Methylnaphthalene	0	--	--	--	3	3	--	--	7	6	--
1-Methylphenanthrene	0	--	--	--	3	3	--	--	7	6	--
2-Methylphenanthrene	0	--	--	--	0	--	--	--	1	0	--
Naphthalene	4	0	--	--	3	2	0	0	7	6	--
Phenanthrene	4	0	--	--	3	3	3	0	7	7	--
Pyrene	4	0	--	--	3	3	3	0	7	7	0
Perylene	0	--	--	--	3	3	--	--	7	0	--
2,3,5-Trimethylnaphthalene	0	--	--	--	2	2	--	--	6	4	--

Since 2000, DEQ also analyzed four or more samples for 54 other organic compounds, including:

- organophosphorus insecticides
- herbicides
- phthalate esters
- phenols
- halogenated aliphatic and monocyclic aromatic hydrocarbons

Most of the pesticides either are less harmful to aquatic life or less persistent in the environment than the chlorinated insecticides shown in **Tables 3-47** and **3-48** (Smith et al., 1988). None of the pesticides or any of the other 54 organic compounds were detected in any of the water column samples.

Table 3-48 also shows for each toxic compound, the number of observations from samples collected in sediment by DEQ, the number of observations above the detection limit, and the number exceeding the TEC or PEC. There were only three samples collected since 2000, and all were in lower mainstem Accotink Creek. No toxics concentration in the sediments was above the corresponding PEC, though concentrations of chlordane and many PAHs were above the TEC, indicating that toxic effects cannot be ruled out. One sediment sample collected at 1AACO006.10 on 06/01/2006 was analyzed for 81 additional organic compounds in the same categories as the water column samples discussed in the previous paragraph. The only compounds detected were two phthalate esters, di-n-butyl phthalate and butyl benzyl phthalate. These compounds are used in making plastic and are commonly found in the environment (Smith et al., 1988).

Finally, **Table 3-48** shows for each toxic compound, the number of observations from samples collected in fish tissue by DEQ, the number of observations above the detection limit, and the number exceeding the TV or TSV to protect human life. Eight of 16 observations of total PCBs in fish tissue exceeded the TV of 20 ppb. As noted in **Section 1**, lower Accotink Creek is not supporting its Fish Consumption Use because of PCBs. One fish tissue sample of American eel, taken on 03/31/2008 at 1AACO011.62, exceeded TV for both total chlordane and heptachlor epoxide. Another fish tissue sample from American eel, taken on 06/20/2001 at 1AACO004.86, also exceeded the heptachlor epoxide TV, while a fish tissue sample from white sucker taken on the same date and in the same location exceeded the TV for dieldrin. No other observations in fish tissue exceeded a TV or TSV for a pesticide or PAH compound.

The USGS's NAWQA program assessed water quality in the Potomac River basin, 1992-1996 (Ator et al., 1998). Nutrients and pesticides were the focus of their study. As part of the assessment, pesticides and other organic compounds were extensively monitored in Accotink Creek. Ator et al. (1998) identified Accotink Creek as an example of an urban stream affected by pesticide applications. The following results were the highlights of their findings:

- The herbicide simazine was the most frequently detected pesticide. It was also detected at the highest concentrations, including concentrations over the EPA's Maximum Contaminant Level (MCL) of 4 µg/l to protect finished drinking water.
- Concentrations of the herbicides oryzalin and MCPA (4-chloro-2-methylphenoxy acetic acid) were the highest detected by the NAWQA program.
- Concentrations of the insecticides diazinon and malathion were the highest detected by the NAWQA program in the Potomac River basin.

Other herbicides detected include atrazine, metolachor, and prometon, and other insecticides detected include carbaryl and chlorpyrifos. These pesticides are generally less harmful to aquatic life, more tightly bound to application sites, or less persistent in the environment than chlorinated insecticides shown in **Tables 3-47** and **3-48** (Smith et al., 1988). NAWQA also analyzed samples for a wide variety of other pesticides and other organic compounds that were not detected or detected at a much lower frequency than those discussed above. Ator et al. (1998) has a complete list of the organic toxics analyzed in the NAWQA study.

The NAWQA program stopped analyzing samples from Accotink Creek for oryzalin and MCPA in 1997, but continued to monitor simazine, malathion, and diazinon through 2001. Eighteen samples were analyzed for simazine in 2000 and 2001. One was below the detection limit. The maximum concentration observed was 1.24 µg/l, below the MCL. Of the 19 samples analyzed for malathion, only one sample had concentrations above the detection limit. All of the 19 samples analyzed for diazinon, 2000 through 2001, were above the detection limit; the maximum concentration was 0.35 µg/l.

Water column monitoring under the NAWQA program has focused mainly on pesticides currently in use. Water column samples collected since 2000 were analyzed for only two pesticides shown in **Table 3-47**: dieldrin and endosulfin. All 153 observations of dieldrin were below the detection limit. The alpha and beta forms of endosulfin were determined separately in 19 samples collected since 2000; in the remaining 77 samples, only the alpha form was reported. None of the observations were above the detection limits.

Under the NAWQA program the USGS also analyzed one sediment sample from Accotink Creek since 2000. The sample was analyzed for the following compounds:

DDD	Hexachlorobenzene (BHC)	trans-Nonachlor
DDE	Lindane (gamma BHC)	cis-Chlordane
DDT	Aldrin	trans-Chlordane
Dieldrin	Mirex	Aroclor 1016 plus Aroclor 1242
Endosulfan	Toxaphene	Aroclor 1254
Endrin	Methoxychlor	Aroclor 1260
Heptachlor	alpha-HCH	beta-HCH
Heptachlor epoxide		

None of the compounds were observed in concentrations above the detection limit. Arochlors are commercial mixtures of PCBs. Cis- and trans-chlordane, as well as nonachlor, are components of total chlordane. Because PCBs and chlordane are represented only by some of their components, the detection limits could not be compared to the TECs; otherwise, where applicable, all of the detection limits were below the TECs for the compound.

The USGS resumed monitoring Accotink Creek near Annandale for organic chemicals in 2014. Five water column samples were collected and analyzed for a variety of toxic chemicals and pesticides, including several PAH compounds shown in **Table 3-47**. **Table 3-49** summarizes the results. **Table 3-49** distinguishes the reporting limit, which is the lowest limit at which a concentration can be reported unqualified, from the detection limit, which is the lowest concentration at which the presence of a substance can be detected. Reporting limits in the 2014 USGS data are one to two orders of magnitude lower than the limits used in the DEQ water column samples, and several of the PAHs were detected in the samples, although below the reporting limit. There is some agreement between the results of **Table 3-49** and DEQ sediment sample results in **Table 3-48**: Fluoranthene and pyrene, the PAHs most frequently detected by the USGS in the water column, are also among the PAHs most frequently exceeding their TECs in the sediment, while naphthalene, whose concentrations in the sediment were below the TEC, was not detected in the water column.

Table 3-49: Summary of PAHs Observed in USGS Monitoring of Accotink Creek, 2014

Compound	Number of Samples	Greater than Reporting Limit	Between Reporting Limit and Detection Limit	Detected in Sample Blank	Total Detected
Anthracene	5	0	1	1	2
Benzo[a]pyrene	5	1	0	0	1
Fluoranthene	5	3	1	0	4
2-Methylnaphthalene	5	0	0	0	0
Naphthalene	5	0	0	0	0
Phenanthrene	5	0	0	2	2
Pyrene	5	1	2	0	3

The USGS also analyzed five water column samples collected in Accotink Creek in 2014 for diazinon. None of the samples had concentrations above the detection limit of 0.32 µg/l. No observations of malathion or simazine, or MCPA have been made in Accotink Creek since 2001.

One sample from Accotink Creek collected in 2014 was analyzed for pharmaceuticals, with concentrations and detection limits expressed in nanograms per liter. Only two compounds were detected which were not also detected in the corresponding laboratory blanks: metformin, a drug used to treat diabetes, and tolyltriazole (methyl-1H-benzotrizole), an intermediate compound in the production of pharmaceuticals.

3.6.3 Toxicity Tests

Toxicity testing was performed using two samples collected from Accotink Creek at DEQ monitoring stations 1AACO004.84 and 1AACO006.10 on October 24, 2005 (Bailey et al., 2005). Toxicity tests compare the response of test species to the water from sampled streams against the response from a control sample with no toxic substances present. In this case, the test species were water fleas (*Ceriodaphnia dubia*) and fathead minnows (*Pimephales promelas*). The biological response of water fleas to the stream samples was measured in terms of the survival rate and number of young produced. The response of fathead minnows was measured in terms of survival rate and change in biomass. The tests are run for seven days, using test samples diluted to a range of strengths from 0% sample water (control) to 100% sample water. The tests assume that there is a monotonically increasing dose-response relationship between the percent sample water and adverse biological impacts. Based on test results, a variety of statistical measures of the impact of the sample water on the test organisms can be determined, including IC25, or the concentration of the sample that cause a 25% reduction in growth or reproduction; LOEC (Lowest-Observable-Effects-Concentration), the lowest concentration of the sample at which there is a statistically significant biological impact; or NOEC (No-Observable-Effect-Concentration), the highest concentration of the sample at which there is no statistically significant biological impact.

No statistically significant biological impacts were observed on water fleas from either sample from Accotink Creek. The survival and biomass of fathead minnows using the sample from 1AACO004.84 were statistically different from the laboratory control. Bailey et al. (2005) state that these results were "probably biologically significant" but that "the data should be compared to other available water quality parameters…to determine the presence of toxicity." The survival of fathead minnows, but not their biomass, showed statistically significant differences from the control in tests using the sample from 1AACO006.10. Bailey et al. (2005) state that because of the mixed results these differences "may not be indicative of a toxic effect. "

3.7 Periphyton Monitoring

Periphyton refers to the microbial community of algae, bacteria, and fungi growing in a mat or biofilm on submerged surfaces. Both the USGS and DEQ have analyzed periphyton samples in Accotink Creek for Chlorophyll a (CHLa) and ash free dry mass (AFDM).

Since 2000, the USGS has analyzed six periphyton samples from Accotink Creek near Ranger Road. **Table 3-50** shows the results of the analysis of the samples. Both CHLa and AFDM were measured. The values of CHLa and AFDM are fairly low. CHLa and AFDM are measured in the ProbMon program, and the 90th percentile values from the ProbMon dataset, 2001-2009, are 88.9 mg/m^2 and 48.1 g/m^2, respectively. The 75th percentile of CHLa and AFDM, measured at 120 reference sites used in the EPA's Environmental Monitoring and Assessment Program (EMAP) for the Mid-Atlantic region, are 68.9 mg/m^2 and 11.8 g/m^2, respectively (Stevenson et al., 2009). The low values of CHLa and AFDM may be the result of light limitation at the Ranger Road monitoring location. The monitoring station is in a park and a fairly full tree canopy covers the stream in June, July, and August, when the periphyton monitoring occurred.

DEQ analyzed a single periphyton sample in Long Branch at monitoring station 1ALOE001.99. CHLa and AFDM concentrations were also low compared to the 90th percentile ProbMon concentrations or the 75th percentile of the EMAP reference sites.

Table 3-50: Periphyton Samples from Accotink Creek Watershed

Impaired Segment	Agency	Station	Date	Chlorophyll a (mg/m^2)	Biomass (AFMD) (g/m^2)
Upper Accotink Creek	USGS	0165389205	07/09/2003	1.8	2.4
			07/06/2004	48.2	NA
			08/18/2005	46	17.9
			07/17/2008	18	6
			06/30/2010	9.2	4.9
			06/10/2014	27.9	2.7
Long Branch	DEQ	1ALOE001.99	09/19/2006	5.5	5.46

4 Stressor Identification Analysis

Biological monitoring in mainstem Accotink Creek and Long Branch has determined that these waterbodies are not supporting their aquatic life use, but biological monitoring does not determine the causes of the biological impairments in these waterbodies. Until the cause(s) of the biological impairments have been determined, it is not possible to take any action to address the impairments with regard to a TMDL or an alternative approach. The purpose of a SI is to determine the stressor(s) to the biological community. Once the stressors have been identified, TMDLs for the stressors can be developed, assuming that the identified stressors are pollutants. TMDLs can only be developed for pollutants. If the identified stressor(s) are not pollutants, alternative approaches can be developed to address the water quality impairment.

The SI for mainstem Accotink Creek and Long Branch follows the steps outlined in the EPA's guidance document, *Stressor Identification Guidance Document* (EPA, 2000). The first step is to list candidate stressors. The stressors which were considered for Accotink Creek and Long Branch are listed below:

Temperature	Metals
pH	Toxics
Dissolved Oxygen	Nutrients
Chloride	Sediment
Hydromodification	Habitat Modification

The second step is to analyze existing monitoring data to determine the evidence for each candidate cause. The existing monitoring data has been reviewed in **Section 3**. The third step is to use a weight-of-evidence approach to determine the strength of the causal link between each candidate stressor and the biological impairment.

The result of the SI is a classification of candidate stressors into one of the following three categories:

1. **Least Probable Stressors**: Stressors with data indicating normal conditions, without water quality exceedances, or without any observable impacts usually associated with stressors.
2. **Possible Stressors**: Stressors with evidence indicating possible link to the biological impairment, but the evidence is inconclusive.

3. **Most Probable Stressors**: Stressor(s) with the most consistent evidence linking them to the biological impairment.

Each category of stressor will be discussed in the sections below.

4.1 Least Probable Stressors

An examination of water quality monitoring data shows that all but one of the candidate stressors that can be directly compared to a Virginia water quality standard protecting aquatic life are meeting that standard. The stressors included in the least probable stressor category are: temperature, pH, DO, and metals.

4.1.1 Temperature

Elevated temperatures can cause increased mortality and other stresses in aquatic organisms. Streams in urbanized watersheds like Accotink Creek are particularly vulnerable to temperature-induced stresses. Stormwater sewers transport water with elevated temperatures from contact with hot pavement in the summer, and urban streams with poor riparian buffers frequently lack a developed tree canopy to shade them from direct sunlight.

Virginia water quality standards specify that water temperature should not be greater than 32°C. Temperature was measured both in discrete samples and continuous monitoring in the Accotink Creek watershed. As discussed in **Section 3.5.1**, there is no observation of temperature above the maximum criterion in either discrete samples or continuous monitoring analyzed by DEQ or USGS in the Accotink Creek watershed. (The EPA recorded temperatures above the 32°C maximum criterion in their continuous monitoring of Accotink Creek, but the location of the probe may have been compromised by stream restoration.) Virginia water quality standards also specify that the maximum hourly temperature change should not exceed 2°C (9VAC25-260-70). Only nine hourly temperature changes recorded during continuous monitoring in Accotink Creek exceed the maximum hourly change criterion, a rate (< 0.1% of all hourly observations) consistent with meeting water quality standards for temperature. A third component of the temperature water quality standard is the requirement that discharges not raise temperature more than 3°C above natural conditions. **Section 3.5.1** shows that, although Accotink Creek frequently has daily changes in temperature in excess of 3°C, these changes in temperature are more likely to occur under ambient conditions than during storm events. Therefore, there is no evidence that stormwater discharges are raising the temperature of mainstem Accotink Creek or Long Branch excessively.

The monitoring data described in **Section 3.5.1** shows that mainstem Accotink Creek and Long Branch are meeting the temperature water quality standards to protect aquatic life, and therefore, there is no evidence that temperature is a stressor in Long Branch or Accotink Creek.

4.1.2 pH

Aquatic organisms have a tolerance range for pH that is reflected in Virginia water quality standards, which set a maximum pH criterion of 9.0 and a minimum criterion of 6.0. pH was measured in both discrete samples and continuous monitoring in the Accotink Creek watershed. As discussed in **Section 3.5.2**, the ranges of pH observed in the lower mainstem of Accotink Creek and Long Branch are within the minimum and maximum pH criteria, and extensive continuous monitoring in the upper mainstem of Accotink Creek exceeds the maximum pH criterion only on a handful of days, a rate consistent with meeting water quality standards, according to EPA guidance (1997). Therefore, discrete and continuous monitoring data strongly support that Virginia water quality standards for pH are met in Accotink Creek and Long Branch, and that pH is not a stressor of the biological community in mainstem Accotink Creek or Long Branch.

4.1.3 Dissolved Oxygen

Aquatic organisms need a minimum dissolved oxygen concentration to survive. Virginia's water quality standards set a minimum instantaneous concentration of 4 mg/l and a minimum daily average concentration of 5 mg/l to protect aquatic life. DO was measured in both discrete samples and continuous monitoring in the Accotink Creek watershed. As discussed in **Section 3.5.3**, the minimum DO concentrations observed in the lower mainstem Accotink Creek or Long Branch are above 5 mg/l. No observations of DO in discrete samples from upper mainstem Accotink Creek are less than 4 mg/l, but there are observations of DO concentrations below 4 mg/l on 1.2% of the days on which continuous monitoring of DO in upper Accotink Creek was performed and five days on which the daily average DO concentration was less than 5 mg/l. According to EPA (1997) and DEQ guidance (2014b), however, the infrequent occurrence of low DO concentrations is consistent with meeting DO water quality standards for protecting aquatic life. There is, therefore, no evidence that low DO concentrations are a stressor in Long Branch or Accotink Creek.

Continuous monitoring also shows that there are significant fluctuations of percent saturation of dissolved oxygen in Accotink Creek near Ranger Road, but not in Long Branch. These fluctuations will be discussed in **Section 4.2.1**, which describes the evidence that nutrients are a possible stressor of the biological community in the Accotink Creek watershed.

4.1.4 Metals

Dissolved metals in the water column can be toxic to benthic macroinvertebrates and fish, and Virginia's water quality standards set water quality acute and chronic criteria for metals to protect aquatic life. As discussed in **Section 3.6.1**, DEQ has monitored metals in the lower mainstem of Accotink Creek and Long Branch under a variety of hydrological conditions. No exceedances of acute criteria were observed. There was one observation of copper at a concentration higher than the chronic criterion, but no other evidence that copper concentrations sustain a four-day average above the criterion necessary to induce chronic effects.

ProbMon uses the CCU Metals Index to evaluate the cumulative chronic biological impact of dissolved metals. The index for all but two of the twelve samples of dissolved metals in the Accotink Creek watershed are in the optimal range, while none are in the suboptimal range, indicating the risk of failing VSCI scores caused by chronic metal toxicity is minimal.

Three sediment samples from lower mainstem Accotink Creek were analyzed for metals. The concentrations of all metals detected in the samples were below the TEC benchmark, indicating the metals are unlikely to have adverse impacts on the biota.

Ten fish tissue samples from lower mainstem Accotink Creek and one fish tissue sample from upper mainstem Accotink Creek were analyzed for metals. Mercury was the only metal regularly detected in the samples, but no concentration of mercury was above the TV threshold for human health. No lead, selenium, or cadmium was detected in any fish tissue sample, and chromium, at a concentration below the TV threshold, was detected in one sample. Of the 11 samples analyzed for arsenic, one sample from lower mainstem Accotink Creek had a concentration above the TV threshold, while the concentrations of arsenic in the other six samples were below the detection limit. The USGS, which monitors arsenic in Accotink Creek near Ranger Road, did not find any exceedances of the acute or chronic water quality criteria in the 38 samples they have collected since 2000.

In summary, the observations of metals in the water column demonstrate that water quality standards for metals are met, and the observations of metals in sediment and fish tissue provide little evidence that metals are adversely impacting biota.

4.2 Possible Stressors

Nutrients and toxics are categorized as possible stressors because there may be some evidence implicating them in the biological impairments in the Accotink Creek watershed; however, the weight of evidence suggests they are not the primary causes of the impairments. In contrast to the most probable stressors, the evidence for their possible impacts is sometimes limited to a particular waterbody. If they are having impacts, the impacts are most likely episodic, confined in scope in space and time.

4.2.1 Nutrients

Excess nutrients can adversely impact the biota in several ways. Excess nutrients can lead to increases in primary production, which can result in wide diurnal swings in DO concentrations, as algae and plants release oxygen in the daytime during photosynthesis and consume it through respiration during the night. Increases in algae and plants can also alter the food web and community structure, increasing herbivores at the expense of other groups. Excess nutrients can fuel increases in bacteria, fungi, and benthic algae in periphyton mats which can foul substrate for macroinvertebrates. Increases in bacteria can also increase the spread of diseases in macroinvertebrates and fish.

Virginia has no water quality criteria for total nitrogen or total phosphorus to protect aquatic life in streams. There are also no water quality criteria for any nutrient species for protection of aquatic life except ammonia, and the water quality standards for ammonia are met in mainstem Accotink Creek and Long Branch.

Sections 3.5.9 through **3.5.12** discuss the nitrogen concentrations found in the Accotink Creek watershed, while **Sections 3.5.13** and **3.5.14** discuss phosphorus concentrations. In comparison with the 90^{th} percentiles of concentrations observed in the ProbMon program, the concentrations of some nitrogen species under ambient conditions in Accotink Creek are high relative to concentrations found in other Virginia streams. Twenty percent of the observed concentrations under ambient conditions in Long Branch are greater than the 90^{th} percentile ProbMon TN and TKN concentrations. In the upper mainstem Accotink Creek, 18% of the NO_3 concentrations are above the 90^{th} percentile ProbMon concentration. In lower mainstem Accotink Creek, 6% of the observations of TN under ambient conditions are above the 90^{th} percentile concentration, but 59% of the TKN concentrations under ambient conditions are above the 90^{th} percentile of the ProbMon data. As discussed in **Section 3.5.11**, it is possible that Lake Accotink is acting as a sink for nutrients and that algal growth in the lake is also converting dissolved inorganic nutrients to organic nutrients.

The ProbMon program sets suboptimal threshold TN concentration at 2.0 mg/l in Virginia's Integrated Report. None of the observations of TN under ambient conditions in lower mainstem Accotink Creek is above the threshold, and only 5% and 1% of the observations in Long Branch and the upper mainstem, respectively, are above the threshold.

The suboptimal threshold TP concentration is 0.05 mg/l. The ProbMon program calculated that the relative risk of a biological impairment associated with suboptimal TP concentrations was 2.5 mg/l. Nineteen percent and 13% of the TP concentrations under ambient conditions observed in Long Branch and upper mainstem Accotink Creek, respectively, are above the TP suboptimal threshold, while only 8% of the concentrations in lower Accotink Creek are above the threshold. Five percent, 4% and 19% of the TP concentrations under ambient conditions in upper Accotink Creek, lower Accotink Creek, and Long Branch, respectively, are above the 90th percentile ProbMon concentration.

As **Figure 3-34** demonstrates, continuous monitoring of DO in upper mainstem Accotink Creek near Ranger Road exhibits wide fluctuations in DO saturation, although these fluctuations are not severe enough to prevent water quality standards for DO from being met. It is not unusual for DO saturation to be in excess of 140%. Supersaturated DO concentrations at Ranger Road are most likely to occur in April. Periphyton CHLa and AFDM measurements taken in June, July, and August in Accotink Creek near Annandale, however, are low relative to similar measurements made in the ProbMon dataset and at EMAP reference sites (See **Section 3.7**). Both monitoring sites are wooded parkland, and it may be that excess primary production occurs mainly in April before there is a full canopy over the stream to limit available light. Since inadequate buffers are characteristic of the upper Accotink Creek watershed (See **Sections 3.2.2** and **4.3.2**), reaches on the upper mainstem Accotink Creek and its tributaries that are without adequate forested buffers may experience excess primary production throughout the growing season, and possibly diurnal swings in DO concentrations which do exceed the DO water quality criteria. Continuous monitoring of DO in Long Branch (see **Section 3.5.3**) shows that wide diurnal swings in DO concentration and supersaturated DO concentrations above 140% are far less common than in the upper mainstem of Accotink Creek, even though nutrient concentrations tend to be higher in Long Branch. Other factors, such as the frequency of high flow events that scour periphyton, may be limiting primary production at the Long Branch monitoring site. There is no continuous monitoring in lower mainstem Accotink Creek, although on one date in April FCDPWES observed DO saturation in excess of 125% (see **Section 3.5.16**).

To summarize, the evidence in favor of nutrients being a major stressor of the biological community is conflicting and inconclusive:

- The concentrations of nitrogen species in Accotink Creek can be high relative to other Virginia streams, but most TN concentrations in the Accotink Creek watershed are below the ProbMon suboptimal threshold, implying the relative risk of biological impairment from these high concentrations are low.
- The concentrations of TP are not as high relative to other Virginia streams as nitrogen, but a significant fraction of observed TP concentrations are above the ProbMon suboptimal threshold in upper Accotink Creek and Long Branch, implying a higher relative risk of biological impairment.
- In upper mainstem Accotink Creek the nutrient concentrations are sufficient to fuel excess primary production, with wide swings in diurnal DO concentrations and supersaturated DO concentrations above 140%, although DO water quality standards are still met.
- Diurnal variations in DO concentrations observed in continuous monitoring data from Long Branch are significantly smaller than those observed in upper Accotink Creek, although nutrient concentrations are higher in Long Branch.
- There is neither continuous monitoring data nor data on diurnal fluctuations in DO from lower Accotink Creek. In addition, Lake Accotink may be acting as a sink for dissolved, bioavailable nutrients, which may mean that the possibility of excess primary production is less in lower Accotink Creek.

Since nutrient concentrations are sufficient to generate wide diurnal swings in DO, it is possible that in inadequately buffered reaches, DO water quality criteria are exceeded episodically. It is unlikely, however, that these events are a primary cause of the adverse impacts to the biological community in Accotink Creek or Long Branch.

4.2.2 Toxics

Toxicity tests and monitoring results from samples collected in the water column, sediment, and fish tissue in Accotink Creek provide some evidence that toxic compounds may be having a limited adverse impact on the biota.

Section 3.6.3 discussed the results of the toxicity tests performed on water fleas and fathead minnows using two water samples from Accotink Creek. No evidence of chemical toxicity was detected by toxicity tests on water fleas. One toxicity test on minnows had "biologically significant" results, which the laboratory suggested needed to be corroborated with water quality monitoring data; the other toxicity test on minnows had an ambiguous result.

Section 3.6.2 discusses the results of toxics monitoring in the water column, sediments, and fish tissue. As mentioned in **Section 1.2**, lower Accotink Creek is not supporting its Fish Consumption Use because of observed PCB concentration in fish tissue. Eight of fifteen fish tissue samples from lower Accotink Creek had concentrations in excess of the TV for PCBs. The PCB concentration in the one fish tissue sample taken from upper Accotink Creek was below the TV. PCB concentrations in sediment samples were below the TEC, and no PCBs have been detected in the water column in Accotink Creek, 2000-2014.

PAHs, such as fluoranthene and pyrene, were detected in sediment in lower Accotink Creek at concentrations above the TEC but below the PEC benchmarks, indicating possible adverse effects on aquatic life. The USGS also detected PAHs at very low concentrations in the water column in upper Accotink Creek. PAHs were not detected in any fish tissue samples from Accotink Creek above their TVs.

Among chlorinated pesticides, concentrations of chlordane, heptachlor epoxide, and dieldrin were measured in fish tissue above their TVs. Chlordane was also observed in a sediment sample from lower Accotink Creek above the TEC but below the PEC, indicating possible toxic effects on biota. Chlordane and heptachlor epoxide were not detected by DEQ in the few water column samples analyzed for these toxics, 2000-2014. Water column samples have been frequently analyzed for dieldrin, but it has never been observed above the detection limit.

The USGS (Ator et al., 1998) reported measuring high concentrations of the herbicides simazine, oryzalin, and MCPA and the insecticides diazinon and malathion in the period 1992-1996. No samples of oryzalin and MCPA have been collected since the 1990's, but concentrations of simazine, diazinon, and malathion in samples collected after 2000 did not have concentrations in the range reported for the early 1990's. Since the monitoring of pesticides is infrequent after 2002, it is possible that pesticides are having an adverse impact on biota. Such impacts, if they occur, are likely to be episodic, because the pesticides currently in use tend not to be as persistent in the environment as chlorinated insecticides like chlordane, whose use was banned in 1988.

No other toxic organic compounds have been detected in the water column of Accotink Creek at concentrations that can be identified, by comparison with water quality criteria or other benchmarks, as harmful to aquatic life.

Because of the mobility of fish, tissue samples may be an imperfect indicator of bioaccumulation of toxics in the location where the fish are found. The toxicity tests and sediment samples, however, do indicate possible adverse impacts of toxics on aquatic life. Ambiguous results from the toxicity tests and the fact that toxics concentrations in the sediment were below the PEC benchmarks indicate that toxics are not a major stressor of the biota in the Accotink Creek watershed.

4.3 Most Probable Stressors

The most probable stressors in upper Accotink Creek, lower Accotink Creek, and Long Branch are chloride, hydromodification, habitat modification, and sediment. Unlike the possible stressors discussed in the previous section, there is solid evidence that these four stressors are adversely impacting the biota in all three waterbodies.

4.3.1 Chloride

Elevated concentrations of chloride and other ions can disrupt the osmotic regulation of aquatic organisms. Virginia has acute and chronic water quality criteria for CL. These criteria are based on EPA recommendations derived from toxicological studies on a wide variety of aquatic organisms (EPA, 1988; Siegel, 2007). **Section 3.5.6** presents direct evidence that the acute water quality criterion for CL has been exceeded seven times in upper Accotink Creek, twice in lower Accotink Creek, and once in Long Branch. The chronic criterion was also exceeded twice in each watershed during two events monitored by DEQ in the winter of 2016.

Chloride and other ions occur naturally in waters as a function of mineral composition of soils and bedrock. In urban watersheds, however, de-icing salt is the primary source of CL (Paul and Meyer, 2001). As shown in **Sections 3.5.5 and 3.5.6**, chlorides are highly correlated with total dissolved solids and specific conductance. The seasonal pattern of CL, SC, and TDS, described in **Sections 3.5.4** through **3.5.6**, also indicate that de-icing salt applications are the source of high CL, TDS, and SC. The fact that SC concentrations can rapidly rise during the winter, but tend to decrease during summer storm events is best explained by identifying salt applications as the source of SC. Chloride, sodium, and calcium—the major ions constituting de-icing salt applications—are likely major constituents of both TDS and SC.

As described in **Sections 3.5.4**, **3.5.5**, and **3.5.6**, concentrations of SC, TDS, and CL under ambient conditions are high compared to other Virginia streams. All but two of the observations of CL in the Accotink Creek watershed are above the 90th percentile of the ProbMon data. Seventy-eight percent of the ambient observations of TDS in lower Accotink Creek and 68% of the observations in upper Accotink Creek are above the 90th percentile of the ProbMon data. Twenty-eight percent, 30%, and 23% of the ambient observations of SC in grab samples in upper mainstem Accotink Creek, lower mainstem Accotink Creek, and Long Branch, respectively, are above the 90th percentile of the ProbMon data; however, continuous monitoring of SC in upper mainstem Accotink Creek and Long Branch show elevations of SC concentrations in winter months reaching 10,000 µS/cm and 5,000 µS/cm, respectively.

Virginia has no water quality criteria for TDS or SC to protect aquatic life. As discussed in **Section 3.5.5**, TDS concentrations above 350 mg/l are considered suboptimal according to ProbMon classification of streams for Virginia's Integrated Report. According to ProbMon data, the relative risk of a biological impairment is 4.5, which means that a VSCI score below 60 is 4.5 times more likely when TDS concentration is in the suboptimal range. The only TDS observation in Long Branch is below the suboptimal threshold, but 20% of the TDS observations under ambient conditions in upper Accotink Creek and 19% of the observations in lower Accotink Creek are in the suboptimal range.

Strong indirect evidence that both the acute and chronic water quality criteria for CL frequently are exceeded can be derived from (1) continuous monitoring data of SC, described in **Section 3.5.4**; and (2) the strong correlation between SC and CL, shown in **Section 3.5.6**. As **Figures 3-53, 3-54,** and **3-55** show, linear regression of CL on SC grab samples in upper and lower Accotink Creek yield CL:SC ratios of 0.32, 0.32, and 0.33, respectively. These results are consistent with a study of the neighboring watershed of Difficult Run, where Sanford et al. (2011) found that the ratio of CL to SC was 0.33 when SC is greater than 1,000 µS/cm. Applying the corresponding CL:SC regression equation to the SC continuous monitoring data from upper Accotink Creek, lower Accotink Creek, and Long Branch yields estimated CL concentrations shown in **Figures 4-1, 4-2,** and **4-3**, respectively, where estimated CL concentrations below 40 mg/l have been set to 40 mg/l, which is approximately the average concentrations observed in the summer months, as shown by Figure **3-52**. **Table 4-1** shows the frequency at which the estimated CL concentrations exceed the acute criterion and chronic criterion in each watershed during November through April, the months in which snow has fallen at least once during the last 30 years in the Washington metropolitan area.

To meet the acute criterion for CL, which allows no more than one CL concentration exceeding 860 mg/l every three years, would require reductions of 77%, 31%, and 69% in upper Accotink Creek, lower Accotink Creek, and Long Branch. The chronic criterion tends to be exceeded at a higher frequency than the acute criterion. To meet the chronic criterion for CL, which allows no more than one four-day average CL concentration exceeding 230 mg/l every three years, would require reductions of 84%, 68%, and 72% in upper Accotink Creek, lower Accotink Creek, and Long Branch.

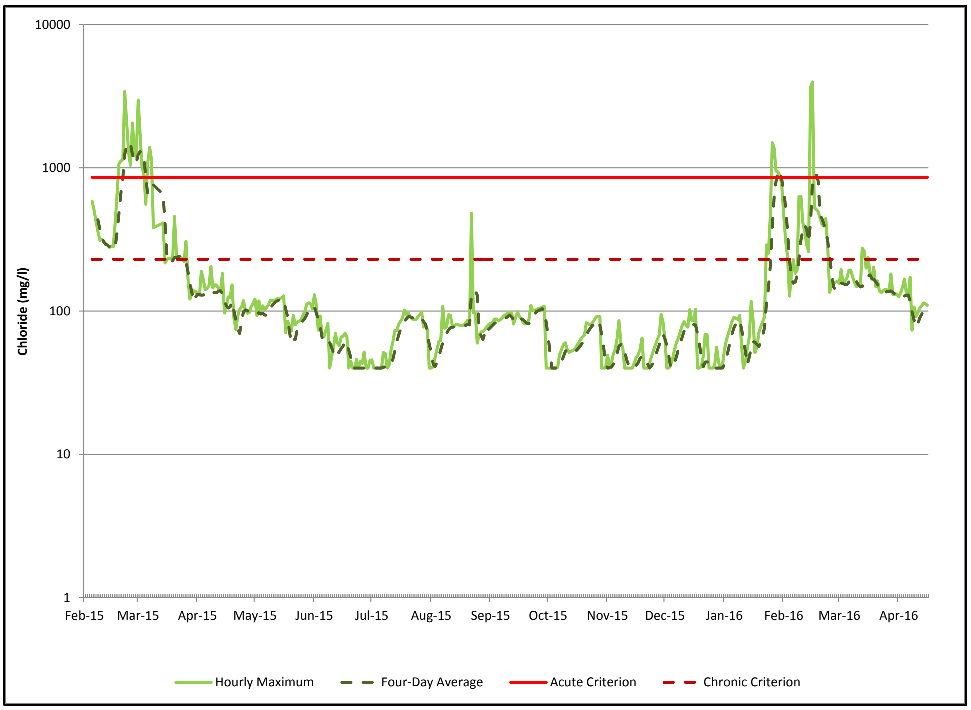


Figure 4-1: Predicted Chloride (mg/l), Upper Accotink Creek

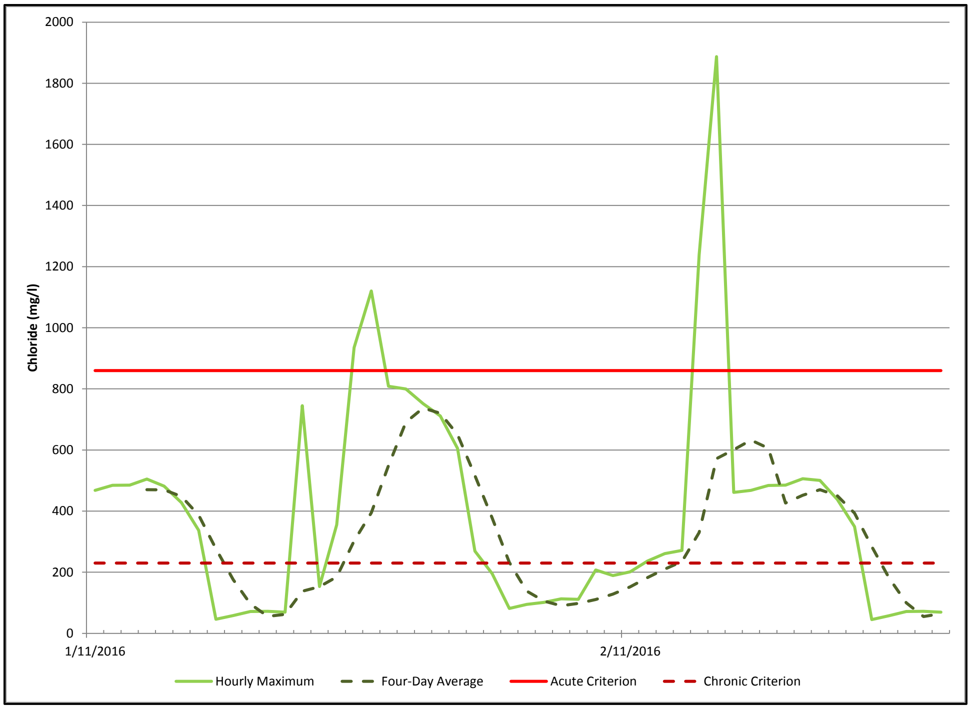


Figure 4-2: Predicted Chloride (mg/l), Lower Accotink Creek

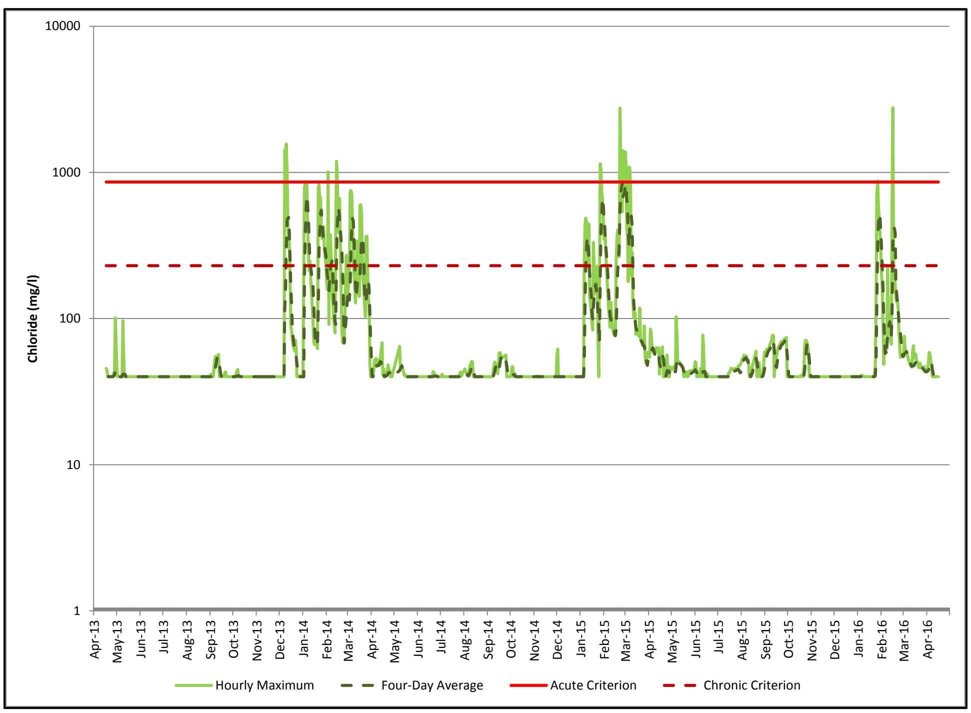


Figure 4-3: Predicted Chloride (mg/l), Long Branch

Table 4-1: Exceedances of Chloride Criteria by Estimated Chloride Concentrations, November through April

Criterion	Exceedances	Upper Accotink (2/5/15-4/16/16)	Lower Accotink (1/11/16-2/29/16)	Long Branch (4/17/13-4/16/16)
Acute Criterion	Total Days	249	50	533
	Days with Exceedances	24	8	20
	Percent Exceedance	10%	16%	4%
Chronic Criterion	Total Days	249	50	533
	Days with Exceedances	64	27	86
	Percent Exceedance	26%	54%	16%

4.3.2 Hydromodification

Streams in urban environments have been modified by development. Hydromodification in this context means the wholesale modification, not only of the stream channel, but of the entire drainage network. Hydromodification comprises three elements: (1) flow alteration, (2) channelization, and (3) replacement of small-order streams by a storm sewer drainage system.

As is well-known, the increase in impervious area and the conveyance of the associated overland flow by storm sewers increases both the peak flow during storm events and the frequency at which storm flows occur that are capable of scouring periphyton assemblages or dislocating benthic invertebrates. The extent of impervious area and the consequent reduction in groundwater recharge can also result in lower baseflow and can even lead to the disconnection of urban streams from groundwater. Lower baseflow can lead to greater fluctuations in temperature. Lower baseflow also implies less biological processing of nutrients and organic matter in the hyporheic zone, where groundwater and surface water interact. Overall, 87% of the Accotink Creek watershed draining to the impaired segments consists of commercial, industrial, transportation, or residential land with lots less than two acres. These land uses are served by storm sewers. Overall, the watershed draining to the impaired segments has 28% impervious cover. It is often thought that adverse impacts of imperviousness are likely to occur when impervious cover is greater than 10% (Walsh et al., 2005).

Artificially straightening channels negatively impacts aquatic life by decreasing habitat diversity. Channelization disrupts the alternating pattern of pools and riffles that are critical to habitat in healthy streams. According to the SPA habitat assessment, discussed in **Section 3.2.2**, stream channels in Accotink Creek and its tributaries have been extensively altered. The average channel alteration score for upper Accotink Creek and its tributaries was in the Marginal range;

average scores for the lower mainstem Accotink Creek, Long Branch, and their tributaries were in the Suboptimal range. Lower mainstem Accotink Creek on average had the best channel alteration score of 12.45.

The loss of headwater streams and their replacement by storm sewers has many detrimental environmental consequences, among which the alteration of flow may be the most widely recognized, but not necessarily the most severe. Meyer and Wallace (2001) and Meyer et al. (2007) document the environmental benefits and services of small headwater streams. One of the most important ecological functions of headwater streams is the processing of organic carbon. Under natural conditions, small-order streams in Virginia are heterotrophic systems. The primary source of carbon or energy is terrestrial plant litter. This litter decomposes through the leaching of dissolved organic carbon compounds, bacterial or fungal colonization, and shredding by macroinvertebrates. Bacteria, fungi, and shredder macroinvertebrates, in turn, support higher-order secondary consumers and higher levels of the food web (Allan, 1995). The carbon cycle is truncated when smaller-order streams are lost (Meyer et al., 2007). As a consequence, the food web is disrupted, reducing biological diversity (Freeman et al., 2007). In addition, organic matter retention is lower in urbanized streams, resulting in a reduction in the biological uptake of nutrients (Meyer et al., 2005). Storm sewer systems may, in some cases, effectively convey leaf litter to urban streams, but the breakdown of litter occurs by flow abrasion, not by shredders or other biologically-based processes (Walsh et al., 2005).

Drift is another important process in aquatic ecosystems, which is disrupted by the replacement of headwater streams with storm sewers. Benthic macroinvertebrates and other aquatic organisms have a tendency to drift downstream. This process provides both a source of food to predators and a source of colonists to restock populations depleted by disturbances (Meyer et al., 2007). The lack of colonists in drift from headwater streams makes it more difficult for the biological community to recover from flow-related disturbances. Therefore, in urban streams, not only are flow-related disturbances more frequent, but the recovery time from disturbances is probably longer, because of the lack of colonists from headwater streams.

4.3.3 Habitat Modification

Habitat assessments by DEQ and FCDPWES have documented marginal or inadequate habitat in the Accotink Creek watershed. Bank stability, sedimentation deposition, substrate variety, flow, embeddedness, and bank vegetation have the highest percentage of marginal or poor scores in DEQ assessments. Nine of the 16 habitat assessments performed by DEQ since 2006 have total habitat scores below the ProbMon Suboptimal threshold. The ProbMon program has calculated that VSCI scores below 60 are over four times more likely if habitat is Suboptimal.

According to the SPA, over two-thirds of the assessed stream miles in the Accotink Creek watershed have Fair, Poor, or Very Poor habitat. On average, habitat is in Good condition in both the lower mainstem and its tributaries in the Coastal Plain, but in the Piedmont portion of the watershed substrate quality, flow alteration, sedimentation, embeddedness, bank stability, and bank vegetation are the habitat metrics with the lowest scores.

As discussed in **Section 3.2.2**, inadequate riparian buffers are common in the Accotink Creek watershed, particularly in the tributaries in the Piedmont portion of the watershed. According to the SPA, 36% of the streams in the Accotink Creek watershed have inadequate buffers. Long Branch mainstem had the least amount of inadequate buffers, 10%, while more than 50% of the tributaries to upper Accotink Creek had inadequate buffers. Just as the storm sewer system in effect cuts Accotink Creek and its tributaries off from the ecological benefits and services of headwaters, poor riparian habitat cuts them off from the benefits and services of the landscape. Forested riparian buffers have three environmental benefits that are connected with biological impairments in the Accotink Creek watershed. They reduce overland flow and sediment transport. They contribute the leaf litter that is the primary source of energy for aquatic ecosystems in small Piedmont streams like Accotink Creek. They also provide large woody debris (LWD), which is a key component of habitat diversity in undisturbed streams. LWD can help form pools, dissipate stream energy, and trap sediment and detritus (Center for Watershed Protection, 2003). Forest buffers can have additional benefits. They provide shade that moderates temperature in streams. Vegetative buffers can also remove nutrients from groundwater discharging to streams.

Habitat modification is related to two other most probable stressors in Accotink Creek. Poor bank stability and channel alterations are an effect of hydromodification, discussed in **Section 4.3.2**. Embeddedness and sediment deposition are an effect of sediment transport in Accotink Creek, which is discussed below in **Section 4.3.4**. Inadequate bank vegetation is both a cause and an effect of sediment transport.

4.3.4 Sediment

Both suspended sediment and deposited sediment can adversely impact stream biota. Suspended sediment contributes to increased turbidity, which limits the light available for photosynthesis and reduces visibility for predators. Elevated sediment concentrations can interfere with filter-feeding organisms by reducing the quality of available food or directly clogging filtering organs. Increased suspended sediment concentrations during high flows enhance the scour of periphyton and macroinvertebrates. Suspended sediment also enhances drift, making colonization by macroinvertebrates less likely (Bilotta and Brazier, 2008). The abrasive action of suspended sediment can also damage stalks and other plant structures, the bodily parts of invertebrates, and the gills of fish. Deposited sediment can directly bury periphyton, macroinvertebrates, and fish eggs or larvae. In addition, deposited sediment can cover larger substrate that is favored as habitat by many sensitive macroinvertebrates, fill in spaces between substrate that provide refuge for macroinvertebrates and small fishes, or reduce the supply of gravel or clean substrate necessary for spawning by trout or other species.

There is ample evidence that in the mainstem of Accotink Creek and its tributaries, sediment is being transported and deposited in sufficient quantities to adversely impact the aquatic community. As described in **Section 3.3.2**, the SPA classified over 90% of the stream reaches assessed in mainstem Accotink Creek, Long Branch, and their tributaries as Type III according to the Channel Evolution Model. Type III reaches are no longer responding to increases in the magnitude and frequency of peak storm events by incising their channel, but are actively widening the channel by eroding their banks. The following results from the SPA habitat survey and stream survey, described in **Sections 3.2.2 and 3.3.2**, also corroborate the erosion and instability in stream reaches:

- Average bank stability and average bank vegetation were in the Poor or Marginal range for all waterbodies except lower mainstem Accotink Creek;
- Twenty-three percent of the reaches assessed had sites with active bank erosion two feet in height or greater;
- There are twelve active head cuts in the tributaries to Accotink Creek and Long Branch.

DEQ's geomorphic assessment of three sites in lower mainstem Accotink Creek, discussed in **Section 3.3.1**, and the DEQ habitat survey, described in **Section 3.2.1**, confirm the two key elements of the Type III CEM classification, a stable streambed and eroding banks. The LRBS at all three sites indicated a stable channel bed. In contrast, bank stability was assessed as Marginal or Poor in all but one of the sixteen habitat assessments that DEQ performed since 2000 in the Accotink Creek watershed.

While the positive LRBS scores at the three sites evaluated indicate the removal of fine sediment by flashier flows and the armoring of the streambed, there is ample evidence, however, to indicate that sediment deposition is impacting the biota at other locations, and even at the LRBS evaluation sites at other times. The degree of sediment deposition is indicated by the embeddedness and sediment deposition habitat metrics, described in **Section 3.2**. In habitat assessments DEQ has conducted since 2000, seven of 16 have Marginal or Poor embeddedness scores, and 12 of 16 have Marginal or Poor scores for sediment deposition. The SPA habitat survey, which assessed almost 80% of the reaches in the Accotink Creek watershed, confirms these results. The average embeddedness scores were Marginal everywhere in the Piedmont portion of the watershed, except in lower mainstem Accotink Creek and the mainstem of Long Branch. Length-averaged sediment deposition scores were also marginal in the mainstem and tributaries of upper Accotink Creek and the tributaries to Long Branch.

The SPA survey (see **Section 3.3.2)** found that in the upper and lower mainstem of Accotink Creek, the percent of stream length in which sand or finer material were the dominant grain size was 36% and 32%, respectively. In the tributaries to the upper mainstem, the percent of stream length in which sand or finer material were the dominant grain size was 32%. In Long Branch and the lower mainstem tributaries, bed material was coarser: in Long Branch and the lower mainstem tributaries, the percent stream reaches with sand or finer material as the dominant grain size was 15% and 16%, respectively, whereas there were no reaches with sand or finer material as the dominant grain size in Long Branch tributaries.

As discussed in **Section 3.1.3**, FCDPWES biological monitoring generally found that Oligochaeta and Chironomidae were the dominant taxa in the Accotink Creek watershed. Many of the members of these two taxa are burrowers whose preferred habitat is sand, silt, mud, or detritus. Their dominance may be due to the availability of their preferred habitat or to the fact that sand, silt, or mud provides better refuge from high flow events that scour more sensitive taxa, which prefer larger substrate as their habitat.

4.3.5 Summary of the Stressors to the Biological Community in the Accotink Creek Watershed

Meyer et al., 2005 and Walsh et al., 2005 have identified what they call "the urban stream syndrome," which is characterized by the following symptoms:

- Flashier flows

- Elevated nutrient and/or contaminant concentrations
- Fewer smaller streams and lower stream density
- Altered channel morphology
- Reduction in biological diversity with increases in pollution-tolerant taxa

Meyer et al. (2005) add that conductivity and chloride concentrations are elevated in urban streams, particularly where sodium chloride is used to deice roads; elevated conductivity and chloride concentrations are so strongly associated with urbanization that it has been suggested they can be used as indicators of urban impacts.

The stressor identification analysis for upper Accotink Creek, lower Accotink Creek, and Long Branch has confirmed that the streams in the watershed suffer from the urban stream syndrome. **Table 4-2** gives the results of the stressor identification analysis for upper Accotink Creek, lower Accotink Creek, and Long Branch. Chlorides, hydromodification, poor habitat, and sediment have been identified as the most probable stressors of the biological communities in the Accotink Creek watershed. Nutrients and toxics may also be making a contribution to the impairment of the benthic communities in Accotink Creek, at least episodically, but are probably not the primary causes of the impairment.

Table 4-2: Categorization of Potential Stressors in Accotink Creek Watershed

Category	Stressor	
Least Probable Stressors	Temperature Dissolved Oxygen	pH Metals
Possible Stressors	Nutrients	Toxics
Most Probable Stressors	Chloride Sediment	Hydromodification Habitat Modification

Virginia's acute criterion for chloride has been exceeded in upper Accotink Creek and lower Accotink Creek, while the chronic criterion has been exceeded in upper Accotink Creek, lower Accotink Creek, and Long Branch. Continuous monitoring of conductivity in upper Accotink Creek, lower Accotink Creek, and Long Branch, in conjunction with the strong correlation between conductivity and chloride, provides strong indirect evidence that exceedances of Virginia's chloride criteria are frequent occurrences during winter months.

Hydromodification refers to altered hydrology, channelization, and the replacement of natural headwater streams and tributaries by storm sewers. Increasing peak flows and frequency of flow disturbances, which are the most noticeable results of hydromodification, reduce the number of sensitive macroinvertebrates. This problem is exacerbated by the lack of macroinvertebrate colonists drifting downstream from headwaters and tributaries. Excess sediment from bank erosion enhances both of these effects.

Channelization leads to a reduction of pool and riffle structure and of the diversity of stream habitat. Poor riparian buffers lead to a shortage of large woody debris and a reduction of the diversity of habitat. Sediment deposition further reduces the quality and variety of habitat. The reduction in habitat diversity, in turn, contributes to a reduction of diversity in macroinvertebrate taxa.

The reduction of diversity in taxa is also caused by the lack of environmental benefits and services from headwater streams and small tributaries, including a truncation of the processing of terrestrial plant litter, to which poor riparian habitat also contributes. The degraded supply of energy sources cannot support a diverse macroinvertebrate community.

The reduction of biological diversity and increases in pollutant-tolerant taxa are therefore symptoms of the urban stream syndrome, brought about by the urbanization of Accotink Creek watershed and the accompanying changes in watershed hydrology and stream network; habitat modification; high seasonal chloride concentrations; and increased erosion, sediment transport, and sediment deposition.

4.4 Recommendations

Section 1.3 discusses the CWA distinction between pollutants and pollution. TMDLs can only be developed for pollutants, not pollution in general. The SI has identified four most probable stressors: chloride, sediment, habitat modification, and hydromodification. Of the four most probable stressors, only chloride and sediment are pollutants. As specified in the CWA, TMDLs should be developed for sediment for each of the three impaired segments in the Accotink Creek watershed.

TMDLs should also be developed for chloride for upper Accotink Creek, lower Accotink Creek, and Long Branch, since monitoring data indicates that Virginia's water quality standards, shown in **Table 3-31**, are not met by chloride. Observed chloride concentrations in all three watersheds have exceeded Virginia's chronic chloride criterion to protect aquatic life at least twice in a three year period. Observed chloride concentrations in upper Accotink Creek and lower Accotink Creek also have exceeded the acute chloride criterion at least twice in a three year period. Moreover, chloride concentrations estimated from continuous monitoring of specific conductance strongly indicates that in all three watersheds exceedances of the acute and chronic chloride criteria is a frequent occurrence.

Habitat modification and hydromodification are pollution, but not pollutants, and therefore do not qualify for TMDLs under the CWA. As discussed in **Sections 4.3.2-4.3.4**, the adverse effects of hydromodification, habitat modification, and sediment are intertwined. Higher peak flows and their more frequent occurrence is a primary cause of bank erosion. The geomorphic disequilibrium described by the CEM is the direct consequence of hydromodification caused by the development of the Accotink Creek watershed. It is likely then, that measures implemented to address the sediment impairments in Accotink Creek will require addressing impacts of hydromodification. Excess sediment is also responsible for aspects of degraded habitat captured in the marginal and poor metric scores for bank stability, bank vegetation, embeddedness, and sediment deposition. Addressing sediment impairments in Accotink Creek will probably also lead to improvements in habitat. While the stressors of habitat modification and hydromodification are not appropriate for TMDL development, these stressors should be considered during the implementation of the sediment and chloride TMDLs.

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