Distributions of Per- and Polyfluoroalkyl Substances (PFAS) in South Carolina Surface Waters, 2022-2023

S.C. Department of Health and Environmental Control

Environmental Affairs
Bureau of Water
Columbia, SC 29201

December 2023

Technical Report No. 009-2023

Publication and Contact Information

This report is available at the South Carolina Department of Health and Environmental Control's Bureau of Water PFAS website at:
https://scdhec.gov/environment/polyfluoroalkyl-substances-pfas/pfas-bureau-water

Data for this project are available at: http://gis.dhec.sc.gov/pfas

The Quality Assurance Project Plan for this project is available at:
https://gis.dhec.sc.gov/Water_Web_Docs/PFAS/SW_PFAS_QAPP.pdf

Additional PFAS related information and resources are available at the Environmental Affairs PFAS website: https://scdhec.gov/environment/polyfluoroalkyl-substances-pfas

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Cover Photo: Charleston Harbor from James Island (Charleston, South Carolina)

On May 19, 2023, South Carolina Senate Bill S399 (S.399) was signed into law. The law dissolves the South Carolina Department of Health and Environmental Control into two separate agencies, creating the South Carolina Department of Public Health and the South Carolina Department of Environmental Services. The information on this page will be updated following agency restructuring.

Distributions of Per- and Polyfluoroalkyl Substances (PFAS) in South Carolina Surface Waters, 2022-2023

Final Report of the Ambient Surface Water Project

by

Matthew S. Baumann, Ph.D.

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Bureau of Water
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Executive Summary

During 2022 and 2023, the South Carolina Department of Health and Environmental Control conducted a statewide study to determine the presence of per- and polyfluoroalkyl substances (PFAS) in the South Carolina aquatic environment. Seasonal sampling from July 2022 through June 2023 at more than 100 streams, rivers, lakes, and estuarine surface water sites indicated that PFAS are ubiquitous in South Carolina. PFAS were detected at varying concentrations at nearly all surface water sites. In general, PFAS concentrations were highest in summer and lowest in winter, possibly related to reduced summertime stream flows and higher rates of wintertime precipitation.

The six PFAS the United States Environmental Protection Agency (EPA) is currently proposing to regulate in drinking water were routinely present in surface water across the state. Perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) represented on average 20% and 12% of total PFAS (ΣPFAS, sum of the 26 PFAS analytes tested as part of this study), respectively, in surface water samples across the state. Average PFOS was 11.2 ng/L and average PFOA was 8.9 ng/L at these sites. Both averages were higher than the current EPA proposed drinking water maximum contaminant level (MCL) of 4 ng/L for each compound. EPA is proposing to regulate perfluorobutane sulfonic acid (PFBS), perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), hexafluoropropylene oxide dimer acid (HFPO-DA or Gen-X) as a mixture using a hazard index. PFBS comprised 11% of ΣPFAS (average = 6.4 ng/L). PFHxS averaged 6% (average = 4.1 ng/L) while PFNA represented 1% (average = 0.8 ng/L) of ΣPFAS. Gen-X represented 2% of ΣPFAS with an average concentration of 2.4 ng/L, however, constituted a relatively high percentage at certain sites, particularly in the Broad, Saluda, and Pee Dee river basins.

PFAS were also detected in filet and whole tissue freshwater fish samples across more than a dozen species throughout the state. While PFAS concentrations varied among species, PFOS was the most prevalent PFAS in freshwater fish. PFOS was also the most dominant PFAS in blue crab soft tissue at coastal sites from Winyah Bay to Port Royal. PFAS concentrations in oyster soft tissue samples collected throughout the coastal environment were relatively low.

The results of this study support the following recommendations:

- Establish a statewide long-term surface water monitoring program for PFAS,
- Continue to gather PFAS data in freshwater fish to help develop species-specific consumption advisories,
- Develop an understanding of sources that contribute PFAS to the environment, and
- Find approaches to limit or reduce PFAS release to the environment.

Acknowledgments

The author of this report thanks the following people for their contributions to this study:

- Taylor Shearer, Caitlin Smith, Eric Lachenmyer, Chad Altman, and Ronnie Martin of the DHEC Bureau of Water for assistance with project management, surface water sampling, freshwater fish sampling, and sample chain of custody and transport.
- DHEC regional ambient sampling teams for assisting with surface water sampling.
- Mike Marshall, Dennis Sechler, Ryan Reed, Josh Reid, Matthew DeVita, Bryant Barnhill, Micah Thorne, and B.J. Norman of the DHEC Shellfish Monitoring Program for collecting oyster samples.
- Dr. Michael Kendrick, Dr. Peter Kingsley-Smith, Kimberly Sitta, Elizabeth Scott, Jeff Good, and Jeff Brunson of the South Carolina Department of Natural Resources Marine Resources Research Institute for collecting blue crab samples.

Introduction

Per- and polyfluoroalkyl substances (PFAS) are a broad class of several thousand man-made organic chemicals that contain carbon-fluorine bonds. The chemical properties of PFAS give them the unique ability to repel both oil and water and as such have been widely used in commercial products. Commercial uses for PFAS include coatings for nonstick cookware, food packaging, stain-resistant fabrics, water-resistant clothing, and metal plating. PFAS are also used in firefighting foams, cosmetics, and industrial surfactants. PFAS are highly persistent in the environment and resist degradation. Hence, PFAS are commonly referred to as *forever chemicals*. PFAS are present in most waste streams and are dispersed through natural processes (e.g., watershed and airshed dynamics). Among the documented sources of PFAS to the environment, four are considered primary pathways for this study: fire training/response sites (military bases, civilian airports), industrial sites, landfills, and wastewater treatment plants (WWTPs).

PFAS are ubiquitous in the environment due to their long-standing use in consumer, commercial, and industrial products and applications. Because the compounds are stable and mobile, they can be present in most environmental media including air, soil and sediment, groundwater, surface water, and biota (plants and animals). However, the distributions and concentrations of PFAS in environmental media are dependent on proximity to a potential source of release, nature of the source, and local geology, hydrology, and water chemistry.

PFAS have been found in the blood of animals and humans worldwide. The primary non-occupational route of exposure to PFAS is diet, meaning PFAS may also pose risks to wildlife as they are present in most food webs. The Agency for Toxic Substances and Disease Registry notes possible associations between specific PFAS and several health outcomes including liver damage, increased total and low-density lipoprotein cholesterol, pregnancy-induced hypertension and preeclampsia, thyroid disease, decreased antibody response to vaccines, increased risk of asthma, decreased fertility, and decreased birthweight. In early 2023, the United States Environmental Protection Agency (EPA) announced proposed drinking water standards for six PFAS: perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), hexafluoropropylene oxide dimer acid (HFPO-DA or Gen-X), perfluorohexane sulfonic acid (PFHxS), perfluorobutane sulfonic acid (PFBS), and perfluorononanoic acid (PFNA).[1] The EPA anticipates finalizing the regulation by the end of 2023.

The prevalence of PFAS in the South Carolina environment is largely unknown, including in surface water and associated biota. The results of this study provide the first statewide survey of PFAS in surface water and in the tissues of recreationally and commercially important groups of aquatic animals. These groups include freshwater fish, oysters, and blue crabs. An important objective of this study is to understand how changes in seasonal conditions such as stream flows and weather may impact distributions and concentrations of PFAS in surface waters.

[1] Per- and Polyfluoroalkyl Substances (PFAS): Proposed PFAS National Primary Drinking Water Regulation. Docket: EPA-HQ-OW-2022-0114-002. March 29, 2023.

Study Design

Surface Water

Routine Sites

From July 2022 through June 2023, a series of 107 surface water sites (Figure 1) were sampled approximately quarterly (once every three months) and analyzed for 26 PFAS analytes including the six compounds EPA is currently proposing to regulate in drinking water (Table 1). Selection of routine sampling sites was guided using a series of 48 watersheds (United States Geological Survey Hydrologic Unit Code – 10; HUC-10). These 48 HUC-10 level watersheds were identified based on distributions of past and present sources that may have released or may release PFAS to the environment.[2] The watersheds were roughly equally distributed among the eight primary river basins within South Carolina (Figure 1): Broad (9800 km^2), Catawba (6000 km^2), Edisto (8200 km^2), Pee Dee (20300 km^2), Salkehatchie (7400 km^2), Saluda (8300 km^2), Santee (7800 km^2), and Savannah (12800 km^2). These basins include the river drainage areas within state boundaries.

The quarterly sampling design was implemented to capture how seasonal changes in stream flows, hydrology, and geochemical conditions (*e.g.*, water temperature, dissolved oxygen, pH) and prevailing climate and weather patterns in the annual cycle for South Carolina may impact distributions and concentrations of PFAS in surface waters. In general, winter conditions tend to result in higher rainfall totals, increased stream flows, lower water temperatures, and higher dissolved oxygen levels, while summer weather tends to be drier and warmer which yields reduced stream flows, warmer water temperatures, and lower dissolved oxygen levels. These seasonal differences in weather impact stream flushing, stream metabolic rates and assimilation capacity of organic matter, and stream chemistry. To enhance understanding of changes in seasonal physical and chemical conditions, *in situ* measurements of temperature, pH, dissolved oxygen, and specific conductivity were collected at a 44-site subset of the routine network during each site visit.

[2] Bureau of Water, South Carolina Department of Health & Environmental Control (2021). Strategy to Assess the Impact of Per- and Polyfluoroalkyl Substances on Ambient Surface Waters in South Carolina. https://scdhec.gov/sites/default/files/media/document/BOW_PFAS_SurfaceWaterStrategy_0.pdf.

Table 1. List of PFAS analyzed for this study. N-Methyl perfluorooctane sulfonamide (NMeFOSA) was analyzed only in surface water samples.

Abbreviation	Chemical Name	CAS Number
Short-Chain Perfluoroalkyl acids (PFAA)		
PFBA	Perfluorobutanoic acid	375-22-4
PFBS	Perfluorobutane sulfonic acid	375-73-5
PFPeA	Perfluoropentanoic acid	2706-90-3
PFPeS	Perfluoropentane sulfonic acid	2706-91-4
PFHxA	Perfluorohexanoic acid	307-24-4
PFHpA	Perfluoroheptanoic acid	375-85-9
Long-Chain Perfluoroalkyl acids (PFAA)		
PFHxS	Perfluorohexane sulfonic acid	355-46-4
PFHpS	Perfluoroheptane sulfonic acid	375-92-8
PFOA	Perfluorooctanoic acid	335-67-1
PFOS	Perfluorooctane sulfonic acid	1763-23-1
PFNA	Perfluorononanoic acid	375-95-1
PFNS	Perfluorononane sulfonic acid	68259-12-1
PFDA	Perfluorodecanoic acid	335-76-2
PFDS	Perfluorodecane sulfonic acid	335-77-3
PFUnDA	Perfluoroundecanoic acid	2058-94-8
PFDOA	Perfluorododecanoic acid	307-55-1
PFTrDA	Perfluorotridecanoic acid	72629-94-8
PFTDA	Perfluorotetradecanoic acid	376-06-7
Per- and Polyfluoroether carboxylic acids (PFEA)		
HFPO-DA Gen-X	Hexafluoropropylene oxide dimer acid	13252-13-6
Fluorotelomer sulfonic acids (FTS)		
4:2 FTS	1H, 1H, 2H, 2H-Perfluorohexane sulfonic acid	757124-72-4
6:2 FTS	1H, 1H, 2H, 2H-Perfluorooctane sulfonic acid	27619-97-2
8:2 FTS	1H, 1H, 2H, 2H-Perfluorodecane sulfonic acid	39108-34-4
Perfluorooctane sulfonamides (FOSA)		
PFOSAm	Perfluorooctane sulfonamide	754-91-6
NMeFOSA	N-Methyl perfluorooctane sulfonamide	31506-32-8
Perfluorooctane sulfonamidoacetic acids (FOSAA)		
NMeFOSAA	N-Methyl perfluorooctane sulfonamido acetic acid	2355-31-9
NEtFOSAA	N-Ethyl perfluorooctane sulfonamido acetic acid	2991-50-6

Adaptive Management Sites

The objective of adaptive management site sampling was to identify where PFAS may originate in the waterbody or watershed in an area of interest. A series of 61 additional, or adaptive management sites (Figure 1), were sampled at least once from January through June 2023 to provide enhanced watershed

or waterbody resolution in areas of interest identified during the first six months of the project (July through December 2022). An area of interest may be identified by a relatively high concentration of ΣPFAS (sum of the 26 analytes) or by a relatively high concentration of a particular PFAS analyte. ΣPFAS is a measure specific to this study and is based on the list of analytes selected for analysis (Table 1). It provides information related to cumulative PFAS exposure on a site-by-site or sample-by-sample basis and is useful as a first-order comparison parameter for this complex dataset. The number of sites sampled varied by area of interest and depended on watershed complexity. Sampling of adaptive management sites often included additional sample collection at routine surface water sites. A complete list of routine and adaptive management sites is presented in Appendix A.

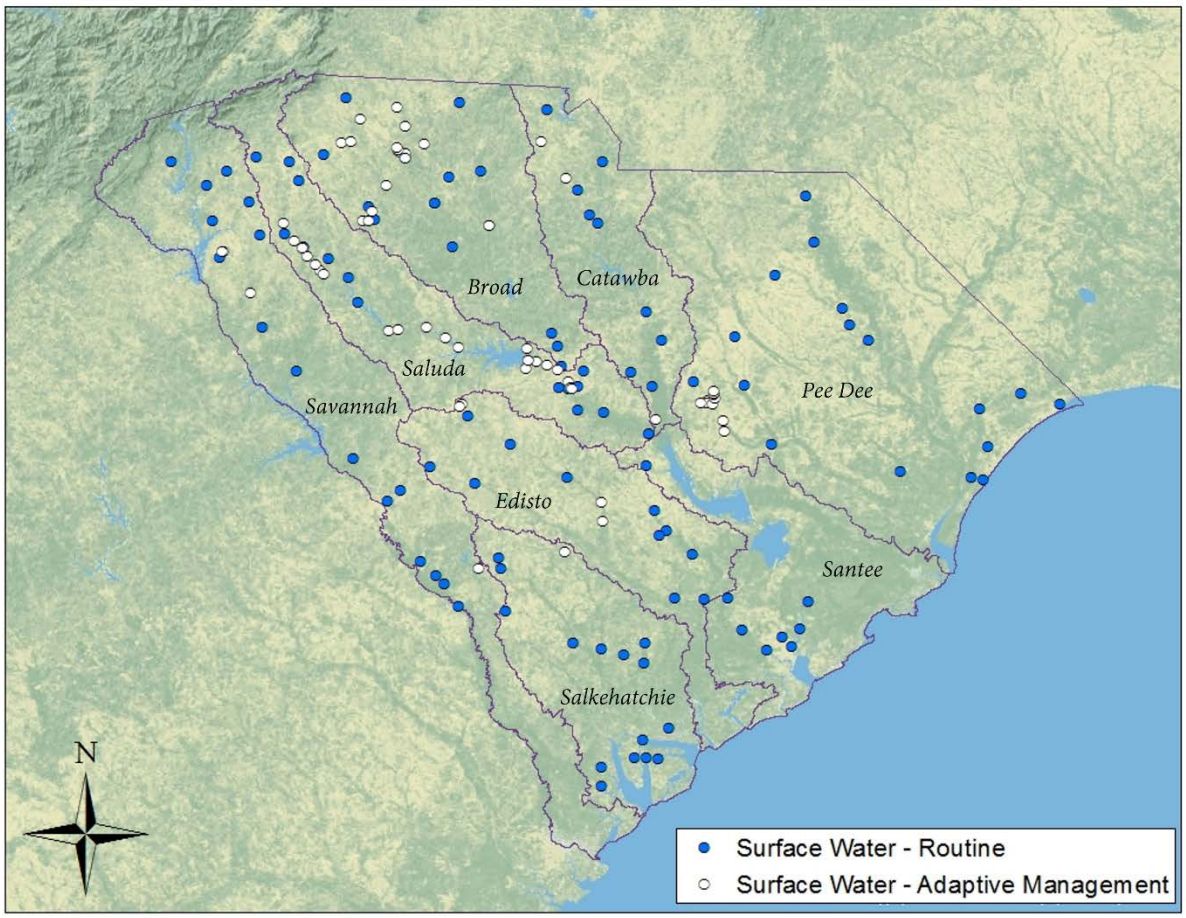


Figure 1. Routine and adaptive management surface water sampling locations within major river basins.

Biological Tissue

Freshwater Fish

Freshwater fish samples from 21 waterbodies were collected from October 2022 through June 2023 (Table 2, Figure 2). Waterbodies were sampled in seven of the eight river basins and consisted of large lakes (*e.g.,* Lake Marion in the Santee River Basin), major rivers (*e.g.,* Broad and Savannah rivers), wetland areas (Conestee Nature Preserve in the Saluda River Basin), and small streams (*e.g.,* Gills Creek in the Saluda River Basin).

Samples were analyzed for 25 PFAS analytes in either individual filet tissue or whole tissue composite portions (Table 1). The list of analytes for tissue samples is the same as for surface water samples except that N-methyl perfluorooctane sulfonamide (NMeFOSA) is not included for tissue. Individual filet tissue samples were analyzed in the size ranges of species generally targeted for human consumption. Whole tissue composite samples generally consisted of three smaller individuals of similar size (difference in length between largest and smallest individuals was within 10% of the length of the largest individual). Due to sampling constraints, two whole tissue composite bluegill samples from Lake Conestee consisted of two individuals (Table 2).

Table 2. Freshwater fish sampling locations, number of samples, and sample types/species. If a waterbody was sampled more than once, a site ID is provided with the waterbody name.

Waterbody	Basin	Date Sampled	No. of Samples	Filet Tissue	Whole Tissue Composite
Goose Creek Reservoir	Santee	10/11/2022	4	LB, Bf, ReS	GoS
Lake Marion	Santee	10/17/2022	4	LB, Bf, ReS	WP
Wateree River-CW-214	Catawba	11/7/2022	4	LB, Bf, ReS	RbS
Congaree River	Saluda	11/14/2022	4	LB, CC, ReS	GiS
Lake Greenwood	Saluda	11/21/2022	3	LB, ReS	Bg
Fishing Creek Reservoir	Catawba	11/28/2022	4	LB, CC, ReS	Bg
Pee Dee River	Pee Dee	12/12/2022	3	LB, Bf, Bg	-
Ashley River	Santee	12/19/2022	3	LB, Bg	ReS
Waccamaw River-CSTL-553	Pee Dee	1/3/2023	3	LB, ReS	Bg
Lake Secession	Savannah	2/7/2023	4	LB, CC, Bg	ReS
Wateree River-CW-206	Catawba	2/14/2023	3	LB, CC, BC	-
Gills Creek	Saluda	3/2/2023	3	-	Bg, Wm, RbS
Savannah River	Savannah	3/6/2023	4	LB, Bf, ReS, BC	-
Broad River-B-222	Broad	3/14/2023	4	LB, ReS, BC	Bg
Waccamaw River-CSTL-556	Pee Dee	3/28/2023	4	LB, Bf, ReS	ReS
Lake Conestee/Conestee Nature Preserve	Saluda	3/30/2023	5	LB, Bg	Bg (L)*, Bg (S)*, Wm
Broad River-B-311	Broad	4/11/2023	6	LB, CC, ReS, Bg	Bg (L), Bg (S)
Pocotaligo River	Pee Dee	6/15/2023	4	LB, Bf, Wm	SS
North Fork Edisto River	Edisto	6/19/2023	3	LB, Bf, CP	-
South Fork Edisto River	Edisto	6/23/2023	1	LB	-
Four Hole Swamp	Edisto	6/28/2023	4	LB, Bf, BC, Bg	-

*Two individual composite.
(L) = larger sized individuals at site; (S) = smaller sized individuals at site.
LB = largemouth bass; Bf = bowfin; ReS = redear sunfish; GoS = golden shiner; WP = white perch; RbS = redbreast sunfish; CC = channel catfish; GiS = gizzard shad; Bg = bluegill sunfish; Wm = warmouth sunfish, BC = black crappie; CP = chain pickerel; SS = spotted sunfish.

Oyster

Oyster samples were collected from 24 sites from mid-July through early September 2022 (Table 3). Sites were distributed along the entirety of the South Carolina coast (Figure 2). Samples consisted of a soft

tissue composite of 12 - 24 oysters, which depended on site oyster availability and laboratory compositing requirements.

Table 3. Oyster sampling sites and date(s) sampled.

Site	Waterbody/Description	Date Sampled
Site-01-05	Dunn Sound Creek	7/19/2022
Site-01-17	42nd Avenue – Cherry Grove	7/20/2022
Site-03-01	Withers Swash	7/15/2022
Site-04-03A	Main Creek	7/22/2022
Site-04-24	Oaks Creek	7/22/2022
Site-05-07	Jones Creek at Mud Bay	7/21/2022
Site-05-14	Mid Channel Island, Bly Creek	7/21/2022
Site-06A-4B	North Santee River – SW of Cane Island	7/21/2022
Site-07-06	Five Fathom Creek	7/21/2022
Site-08-29	Anderson Creek	7/21/2022
Site-09A-26	Hamlin Creek	7/21/2022
Site-09B-16	Confluence of Martin Creek and Nowell Creek	7/21/2022
Site-11-06	Abbapoola Creek	7/22/2022
Site-12A-40	Pine Creek	7/22/2022
Site-12B-45	Toogoodoo Creek	7/22/2022
Site-13-04	St. Pierre Creek at Peters Pt.	7/25, 9/7/2022
Site-15-02	Mulligan Creek at Brickyard Creek	7/27, 9/7/2022
Site-15-03A	Albergottie Creek	7/27, 9/7/2022
Site-15-33	McCalley Creek	7/27, 9/7/2022
Site-16B-22	Skull Creek near Pritchards Inlet	7/28, 9/8/2022
Site-17-25	Hazzard Creek	7/21/2022
Site-18-17	Okatie River	7/21/2022
Site-19-11	Bull Creek at Savage Creek	7/27, 9/6/2022
Site-20-16	Broad Creek	7/18/2022

Blue Crab

Blue crab samples were collected from eight sites from August through November 2022 (Table 4). Sites were distributed from Winyah Bay near Georgetown to Port Royal Sound near Beaufort. Samples generally consisted of a soft tissue composite (offal) composite of three mature individuals. Due to blue crab availability, Whale Branch on 10/24/2022 consisted of a two mature individual composite and the Rathall Creek sample on 11/4/2022 consisted of one immature individual. One immature individual was included in the three-individual composite for four additional samples: Winyah Bay on 10/18/2022, Dawho River on 11/2/2022, Bulls Bay on 11/7/2022, and Ashepoo River on 11/21/2022 (Table 4). Site coordinates for all biological tissue sites are listed in Appendix B.

Table 4. Blue crab sampling locations, dates, and composite descriptions.

Waterbody	Date Sampled	Composite Description No. of Individuals: Maturity/Sex
Upper Ashley River	8/19/2022	3: MM, MM, MM
Lower Ashley River	10/11/2022	3: MM, MM, MF
Dawho River	10/13/2022 11/2/2022	3: MM, MF, MF 3: MM, MF, IF
Winyah Bay	10/18/2022 11/16/2022	3: MF, MF, IF 3: MM, MM, MM
Whale Branch	10/24/2022	2: MM, MF
Rathall Creek	11/4/2022	1: IM
Bulls Bay	11/7/2022	3: MM, MF, IF
Ashepoo River	11/21/2022	3: MM, MF, IF

Maturity/Sex: MM = mature male, MF = mature female, IM = immature male, IF = immature female.

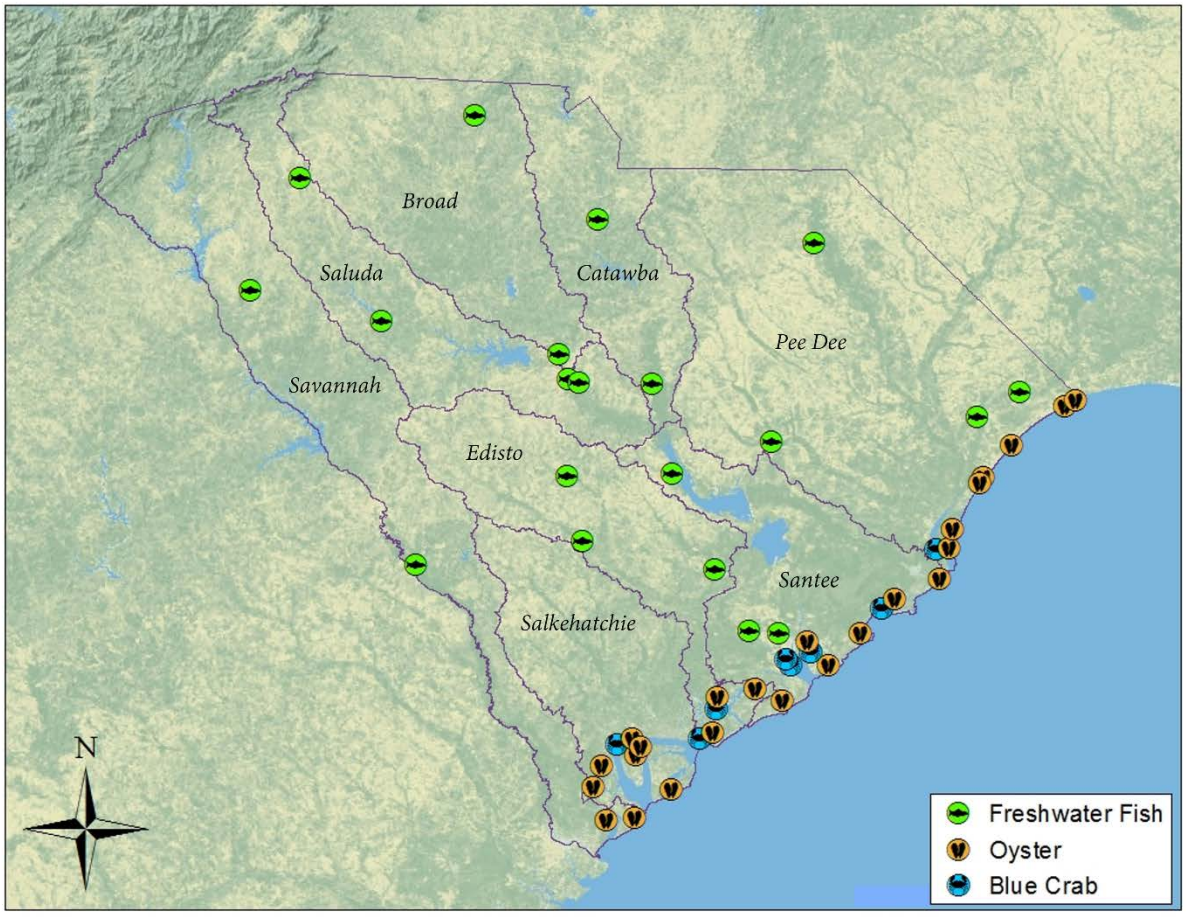


Figure 2. Biological tissue sampling locations: freshwater fish (green symbols), oyster (orange symbols), and blue crab (blue symbols).

Methods

Sample Collection and Preparation

All samples and field measurements were collected, handled, and prepared following methods and standard operating procedures described in the Quality Assurance Project Plan (QAPP) for this project.[3] Changes to the surface water sampling design are detailed in the revision history of the QAPP. Minor changes in biological tissue collection sites occurred due to logistical constraints. No major deviations to the project plan occurred.

Laboratory Analysis of PFAS Samples

All surface water and tissue samples were processed and analyzed by GEL Laboratories, LLC (Charleston, SC). Surface water samples, fortified with internal standards, were extracted using solid phase extraction (SPE) and analyzed by liquid chromatography mass spectrometry/mass spectrometry (LC MS/MS) using isotope dilution for enhanced precision. Tissue samples, fortified with internal standards, were extracted using an ammonia/methanol solution. Centrifuged sample extracts were then passed through a SPE cartridge and analyzed by LC MS/MS using isotope dilution for enhanced precision.

Results were reported down to the detection limit for each specific analyte for each sample. Field blanks and field duplicates were routinely collected as checks on background/field contamination and data precision/reproducibility. Data were reviewed by the project manager as they were received. All analytical data were deemed usable for intended purposes.

[3] Baumann, M.S. (2022). Ambient Surface Water PFAS Sampling and Analysis Project Quality Assurance Project Plan Rev. 1.1. Date of Initiation: July 1, 2022. Bureau of Water and Bureau of Environmental Health Services, South Carolina Department of Health and Environmental Control.

Results and Discussion

Surface Water

Field Duplicates

Field duplicates for PFAS analysis were collected in each project quarter as a check on field result reproducibility. A total of ten field duplicates were collected ranging in ΣPFAS (sum of all 26 PFAS analytes in the sample) from 14.9 to 973 ng/L (average of primary sample and corresponding field duplicate) representing a reasonable range in concentrations observed across the project area. The panel of PFAS detected in the field duplicate generally matched the panel of the primary surface water sample for all paired measurements. The difference in concentrations between individual detected PFAS in the primary sample and individual detected PFAS in the field duplicate was on average 10.0% (10.0 ± 8.3%, average ± 1 standard deviation) indicating strong reproducibility and agreement between the primary and field duplicate samples. There were nine occurrences across all field duplicate samples where an individual PFAS analyte was detected in one sample (primary or field duplicate) and not in the other. These typically occurred at low concentrations near the analytical detection limit for the respective analyte in the sample. Of the nine instances, seven occurred in one relatively high ΣPFAS concentration primary/field duplicate pair (ΣPFAS average = 765 ng/L). The relative difference in ΣPFAS for this sample pair was 5.3% indicating good agreement in bulk PFAS between the primary sample and field duplicate. All PFAS analytes detected in one sample and not the other were < 2.1 ng/L and near analytical detection limits thus representing a relatively small fraction of ΣPFAS.

Routine Sites – Seasonal Patterns in PFAS

A total of 435 samples were collected at routine surface water sites across all project quarters. PFAS were detected in at least one sample at all routine sites except Little River (SV-203) in the upper Savannah River basin. Individual sample total concentrations (ΣPFAS) ranged from all analytes below analytical detection limit to 7664 ng/L (Table 5). PFAS concentrations were highest in summer and lowest in winter based on weighted averages (Table 5). This observation is likely related to reduced stream flow during summer months and higher stream flow and greater dilution in winter. Higher average instream specific conductivities in summer and fall (92.3 - 93.8 µS/cm) compared to winter and spring (71.8 - 77.2 µS/cm) support reduced stream flow and dilution in summer and fall (Table 6). Daily discharge patterns over the study period at United States Geological Survey (USGS) gaging stations in major rivers confirm the seasonal flow pattern. For example, average daily summer month (July-September 2022) flow at Broad River gage SC-02161000 north of Columbia was 2325 cfs (cubic feet per second) while winter month (January-March 2023) flow was 8389 cfs, a factor of 3.6 higher than in summer.[4]

Seasonal ΣPFAS weighted averages were higher than corresponding median values indicating dataset skewness (or non-normal distribution) from high concentration samples. Across all seasons, the Pee Dee River basin demonstrated the highest average and median ΣPFAS concentrations while the Salkehatchie River basin was lowest in both metrics. Based on basin-wide median ΣPFAS, the Broad River basin was highest in summer and fall, while the Pee Dee River basin was highest in winter and spring (Table 5; Figure

[4] United States Geological Survey river monitoring gage: SC-0216100, Broad River at Alston, SC. https://waterdata.usgs.gov/monitoring-location/02161000/#parameterCode=00065&period=P7D&showMedian=true

3). The Salkehatchie River basin was lowest in summer and fall and summer and the Edisto River basin was lowest in winter and spring (Table 5; Figure 3).

Figure 4 presents average PFAS concentrations by basin for all routine sites with detected PFAS (420 of 435 routine samples) across all seasons. The chart highlights the six individual compounds EPA is currently proposing to regulate in drinking water. The remaining 20 compounds are totaled and are represented as 'All Other PFAS'. The six most prevalent PFAS represented on average 83% of site ΣPFAS across all basins and seasons (Figure 4). Perfluorooctane sulfonic acid (PFOS) was the largest individual contributor to ΣPFAS representing on average 20% of the total. For all routine site samples, average PFOS was 11.2 ng/L. Perfluorooctanoic acid (PFOA) contributed on average 12% to ΣPFAS (average = 8.9 ng/L), followed by perfluorobutane sulfonic acid (PFBS, 11%; average = 6.4 ng/L). Perfluorohexane sulfonic acid (PFHxS), contributed 6% to ΣPFAS with an average concentration of 4.1 ng/L. Hexafluoropropyleneoxide dimer acid (HFPO-DA or Gen-X) represented a lower fraction at 2% of ΣPFAS (average = 2.4 ng/L), however it constituted a relatively high percentage at certain sites, particularly in the Broad, Saluda, and Pee Dee river basins. Perfluorononanoic acid (PFNA) was generally present in low relative proportions (1% of ΣPFAS) and in low concentrations (average = 0.8 ng/L).

Three PFAS not currently subject to EPA's current proposed drinking water regulations represented at least 10% of ΣPFAS on average: perfluorobutanoic acid and (PFBA, 17%), perfluoropentanoic acid (PFPeA, 12%), and perfluorohexanoic acid (PFHxA, 11%). These compounds are included in 'All Other PFAS' in Figure 4.

Table 5. Surface water site ΣPFAS summary statistics by season and major river basin: summer (July-September 2022), fall (October-December 2022), winter (January-March 2023), and spring (April-June 2023). Summary statistics include all routine site data (n = number of samples by basin and season). A limited number of routine sites were sampled more than once per quarter as part of additional or adaptive management field activities. A dash (-) in Minimum indicates all analytes in the lowest concentration sample(s) were below respective analytical detection limits.

River Basin	ΣPFAS ng/L				n
	Average	Median	Minimum	Maximum	
Summer (July-September 2022)					
Broad	72.6	63.3	1.7	265	15
Catawba	69.4	31.7	2.2	306	9
Edisto	54.3	21.1	12.4	383	11
Pee Dee	485	56.4	1.7	7664	18
Salkehatchie	27.2	16.7	3.8	133	15
Saluda	70.4	53.2	0.8	329	15
Santee	37.9	38.1	2.9	77.2	8
Savannah	80.0	23.7	-	754	15
All Basins	**132.2**	**30.7**			**106**
Fall (October-December 2022)					
Broad	150	67.6	2.3	781	17
Catawba	63.8	39.4	1.8	234	10
Edisto	91.9	18.3	7.5	813	11
Pee Dee	113	45.3	4.9	976	17
Salkehatchie	13.1	8.7	-	31.3	15

River Basin	ΣPFAS ng/L				n
	Average	Median	Minimum	Maximum	
Saluda	95.6	55.3	8.3	317	15
Santee	33.4	31.4	2.3	68.3	8
Savannah	106	19.9	-	1010	15
All Basins	**89.0**	**32.2**			**108**
Winter (January-March 2023)					
Broad	68.2	40.5	1.7	271	16
Catawba	31.2	23.6	1.0	97.9	9
Edisto	26.6	11.3	3.6	144	12
Pee Dee	80.6	60.9	0.5	401	21
Salkehatchie	22.2	12.6	2.7	101	15
Saluda	46.5	37.3	5.3	205	15
Santee	27.0	32.7	2.1	46.0	8
Savannah	66.3	21.3	-	745	16
All Basins	**50.8**	**26.1**			**112**
Spring (April-June 2023)					
Broad	81.4	47.3	-	322	16
Catawba	47.6	34.5	-	214	9
Edisto	17.1	11.4	-	59.3	11
Pee Dee	87.2	73.3	-	298	19
Salkehatchie	21.9	14.0	-	93.3	15
Saluda	71.6	58.6	5.1	267	16
Santee	40.7	36.7	18.4	86.9	8
Savannah	47.1	28.3	-	346	15
All Basins	**55.8**	**36.5**			**109**

Table 6. Seasonal average values for field measured parameters: specific conductivity (µS/cm), ambient water temperature (°C), pH (su; standard units), and dissolved oxygen (mg/L). Field data were collected at a subset of routine sites. Specific conductivity measurements for three routine estuarine (salt water) sites were not included in the average values for that parameter.

Season	Specific Conductivity µS/cm	Water Temperature °C	pH su	Dissolved Oxygen mg/L
Summer	93.8	25.3	6.8	6.3
Fall	92.3	15.4	6.9	7.7
Winter	71.8	10.4	6.8	10.0
Spring	77.2	19.3	6.8	7.6

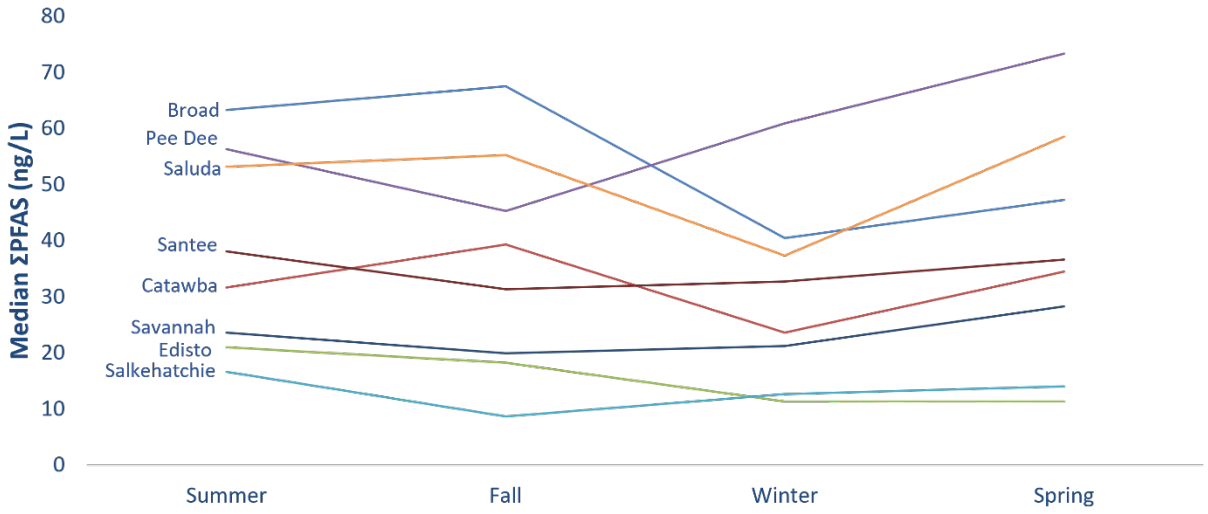


Figure 3. Median site ΣPFAS (ng/L) by season for the major river basins. The chart includes all routine site data.

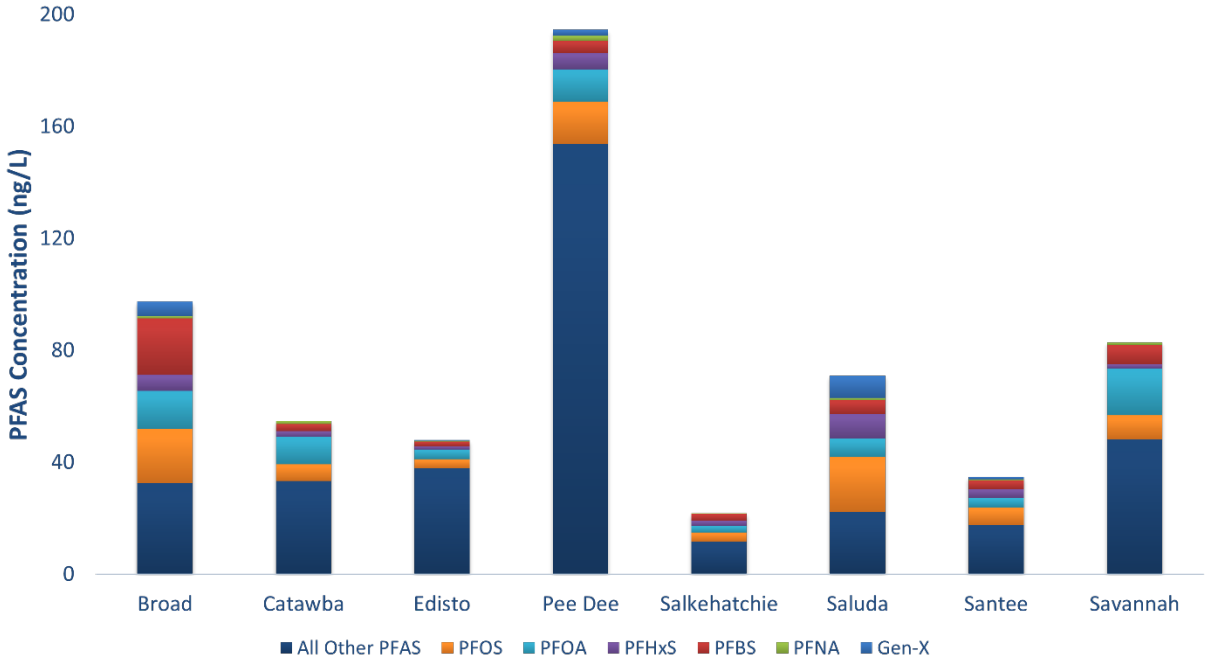


Figure 4. Individual average PFAS concentrations by major river basin (ng/L). The six individual PFAS correspond to those EPA is currently proposing to regulate in drinking water. All Other PFAS is the sum of the remaining 20 PFAS analyzed as part of this project. The chart includes all routine site data for all quarters. A limited number of routine sites were sampled more than once per quarter as part of additional or adaptive management field activities.

Freshwater Fish

In total, 77 freshwater fish samples across 13 species were collected from 21 waterbodies (Table 2). PFAS were analyzed in 57 filet samples from eight species. The remaining 20 samples represented whole tissue composites from eight species. Three species (bluegill, redear, and warmouth sunfish) were included in both sample types (Table 7).

For filet samples and for species sampled more than once (n > 1), bluegill demonstrated the highest average ΣPFAS (sum of 25 PFAS analytes) at 64.2 ng/g (n = 6) followed by largemouth bass (average = 41.5 ng/g; n = 20), black crappie (average = 31.2 ng/g; n = 3), and redear sunfish (average = 25.0 ng/g; n = 11). Demersal fish (channel catfish and bowfin) were lowest in ΣPFAS with average concentrations of 5.9 ng/g (n = 5) and 5.1 ng/g (n = 9), respectively (Table 7).

For whole tissue composite samples and for species sampled more than once (n > 1), warmouth sunfish yielded the highest average ΣPFAS at 355 ng/L (n = 2). The sample size for this species was relatively low, however. Bluegill represented the largest whole tissue composite sample size (n = 9) and demonstrated an average ΣPFAS of 243 ng/g. Two other species were sampled more than once, redbreast sunfish (n = 2) and redear sunfish (n = 3). Average ΣPFAS for these species were 47.2 ng/g and 18.7 ng/g, respectively (Table 7).

PFOS was detected in 54 of 57 filet samples. In general, this analyte contributed most to ΣPFAS representing 65% of the total for 56 of 57 filet samples with detected PFAS (one bowfin sample from the Waccamaw River was non-detect for all analytes). The average PFOS concentration across filet samples was 21.7 ng/g (0 ng/g concentrations were substituted for three samples with PFOS below analytical detection limit). PFOS was detected in 17 of 20 whole tissue composite samples, also representing 65% of ΣPFAS for this sample type. Average PFOS was 140 ng/g for whole tissue composite samples (0 ng/g concentrations were substituted for three samples with PFOS below analytical detection limit).

Largemouth bass were collected at 20 of 21 sites (Gills Creek excepted) and represents the most comprehensive species-specific data set for freshwater fish. All samples for this species were individual filets. Site-by-site results are presented in Figure 5. Average ΣPFAS for largemouth bass filet samples was 41.6 ng/g (Tabe 7). For this dataset, PFOS was detected in each sample and represented on average 69% of ΣPFAS (average PFOS = 28.6 ng/g). ΣPFAS concentrations were highest in filet samples collected from the Pee Dee River (119 ng/g; PFOS = 49.1 ng/g), Pocotaligo River (112 ng/g, PFOS = 86.2 ng/g), and Conestee Nature Preserve (110 ng/g, PFOS = 88.2 ng/g) and lowest in samples from South Fork Edisto River (5.1 ng/g, PFOS = 3.6 ng/g), Savannah River (5.1 ng/g, PFOS = 3.7 ng/g), and Waccamaw River (3.3 ng/g, PFOS = 2.2 ng/g) (Figure 5). Of the remaining five compounds EPA is currently proposing to regulate in drinking water, PFOA, PFBS, and Gen-X were not detected. PFNA was detected in one sample and PFHxS was detected in two samples at low concentrations (all < 1 ng/g) (Figure 5).

Bluegill filet samples were collected at six sites. Site-by-site results are presented in Figure 6 (left panel). Average ΣPFAS for this sample set was 64.2 ng/g (Tabe 7). PFOS was detected in each sample and represented on average 82% of ΣPFAS (average PFOS = 54.5 ng/g), a higher percentage than observed in largemouth bass filets. Conestee Nature Preserve and Broad River near Columbia yielded the highest ΣPFAS concentrations of 186.1 ng/g (PFOS = 162 ng/g) and 98.7 ng/g (PFOS = 87.9 ng/g), respectively. The lowest bluegill filet ΣPFAS concentrations were measured at Lake Secession (16.2 ng/g, PFOS = 12.6 ng/g) and Four Hole Swamp (9.8 ng/g, PFOS = 8.5 ng/g). PFOA, PFBS, Gen-X, PFNA, and PFHxS were not detected in any bluegill filet sample (Figure 6).

Nine bluegill whole tissue composite samples were collected at seven sites. Site-by-site results are presented in Figure 6 (right panel). Two whole tissue composite samples were collected at two sites: Conestee Nature Preserve and Broad River near Columbia (B-311). At these sites, the composite of larger sized individuals is identified with '(L)' and the smaller sized individuals composite is denoted with '(S)'. Average ΣPFAS for the whole tissue composite dataset was 243 ng/g with a range of 26.6 to 871 ng/g

(Table 7). PFOS was detected in eight of nine samples (Fishing Creek Reservoir excepted) and contributed 67% to ΣPFAS. However, removing the 0% (below detect) PFOS contribution from the Fishing Creek Reservoir sample increases average PFOS to 83% of ΣPFAS, which is similar to the bluegill filet PFOS percent contribution.

The highest bluegill whole tissue composite ΣPFAS and PFOS concentrations were observed in the Broad River near Gaffney (B-222, ΣPFAS = 871 ng/g, PFOS = 732 ng/g), Conestee Nature Preserve (larger composite ΣPFAS = 456 PFOS = 404 ng/g, smaller composite ΣPFAS = 215 ng/g, PFOS = 184 ng/g), and Broad River near Columbia (B-311, larger individual composite ΣPFAS = 289, PFOS = 265 ng/g, smaller individual composite ΣPFAS = 153 ng/g, PFOS = 126 ng/g) (Figure 6). For Conestee Nature Preserve and Broad River near Columbia, the larger sized individuals whole tissue composite was higher in ΣPFAS and PFOS than the composite of smaller individuals, which in-turn was higher than the corresponding site filet sample results (Figure 6). Certain types of PFAS, specifically perfluoroalkyl acids (PFAA), have a tendency to accumulate in protein rich tissues including liver and blood and may explain why higher ΣPFAS and PFOS concentrations were observed in whole tissue composites compared to filet samples.

PFOA, PFNA, and PFBS were occasionally detected with concentrations < 1 ng/g. PFHxS was detected in four samples. A concentration of 9.3 ng/g was measured in the Broad River near Gaffney, the highest PFHxS in the bluegill whole tissue composite dataset while three additional detects were < 1.5 ng/g. Gen-X was not detected in any sample (Figure 6).

Demersal fish (bowfin or channel catfish) filet samples were collected at 15 sites. Site-by-site results are presented in Figure 7 (left panel = bowfin, right panel = channel catfish). ΣPFAS among this population was lowest among filet sample species. PFOS was detected in all but one bowfin filet sample (Waccamaw River) and one channel catfish filet sample (Fishing Creek Reservoir). Average filet ΣPFAS was 5.1 ng/g (PFOS = 2.4 ng/g) for bowfin and 5.9 ng/g (PFOS = 2.3 ng/g) for channel catfish (Table 7). PFHxS was detected in one bowfin filet sample but was < 1 ng/g. PFOA, PFNA PFBS, and Gen-X were not detected in any bowfin or channel catfish sample (Figure 7).

Table 7. Freshwater fish ΣPFAS sample summary statistics by species and sample type (filet tissue or whole tissue composite). Summary statistics represent samples from a variety of individual (individual filet or whole tissue composites) sizes and total wet weights (n = number of samples by species and sample type). All filet samples represent one individual and whole tissue composite samples represent three like-sized individuals except as noted in Table 2. A dash (-) in Minimum indicates all analytes in the lowest concentrations sample(s) were below respective analytical detection limits.

Species	Sample Type	ΣPFAS ng/g				n
		Average	Standard Deviation	Minimum	Maximum	
Black crappie	Filet	25.2	14.4	7.3	42.2	4
Bluegill	Filet	64.2	68.2	9.8	186	6
	Whole Composite	243	274	26.6	871	9
Bowfin	Filet	5.1	4.3	-	11.8	9
Chain pickerel	Filet	11.3	-	11.3	11.3	1
Channel catfish	Filet	5.9	3.3	3.0	11.1	5
Gizzard shad	Whole Composite	13.2	-	13.2	13.2	1
Golden shiner	Whole Composite	21.8	-	21.8	21.8	1
Largemouth bass	Filet	41.5	39.3	3.3	119	20
Redbreast sunfish	Whole Composite	47.2	45.4	15.1	79.3	2
Redear sunfish	Filet	25.0	15.3	1.5	51.0	11
	Whole Composite	18.7	14.3	4.2	32.8	3
Spotted sunfish	Whole Composite	277	-	277	277	1
Warmouth	Filet	37.2	-	37.2	37.2	1
	Whole Composite	355	370	93.7	617	2
White perch	Whole Composite	37.2	-	37.2	37.2	1

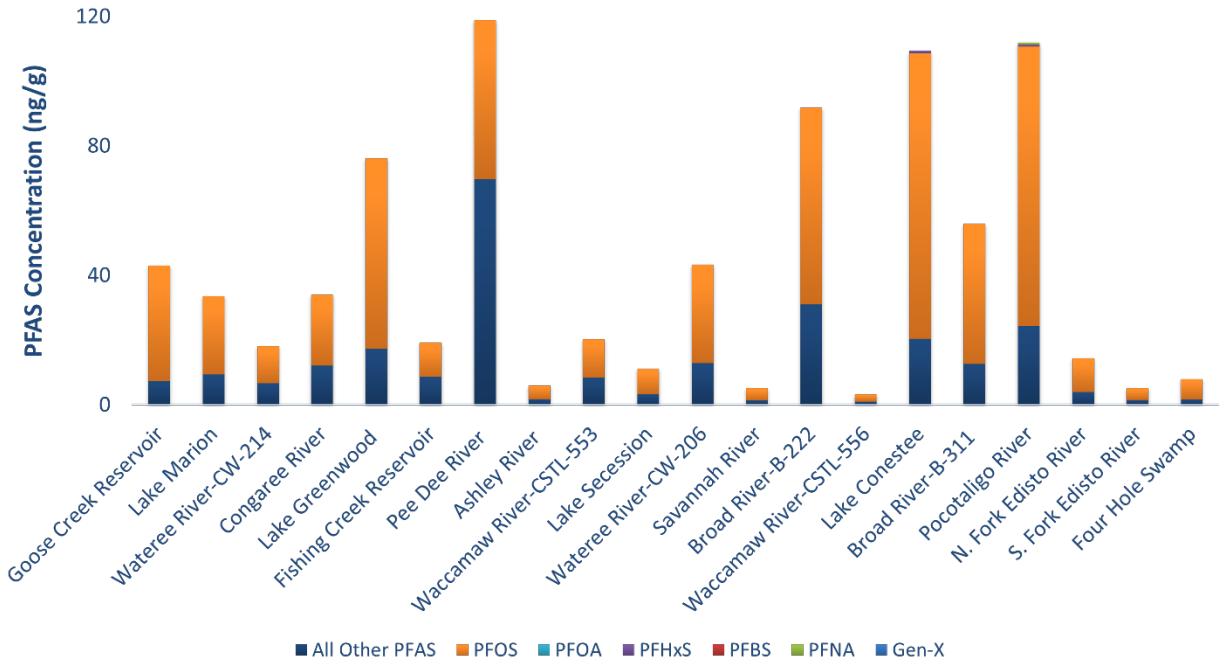


Figure 5. Largemouth bass filet PFAS results by location (ng/g). Largemouth bass were collected at all sites except Gills Creek. The six individual PFAS correspond to those EPA is currently proposing to regulate in drinking water. All Other PFAS is the sum of the remaining 19 PFAS analyzed as part of this project.

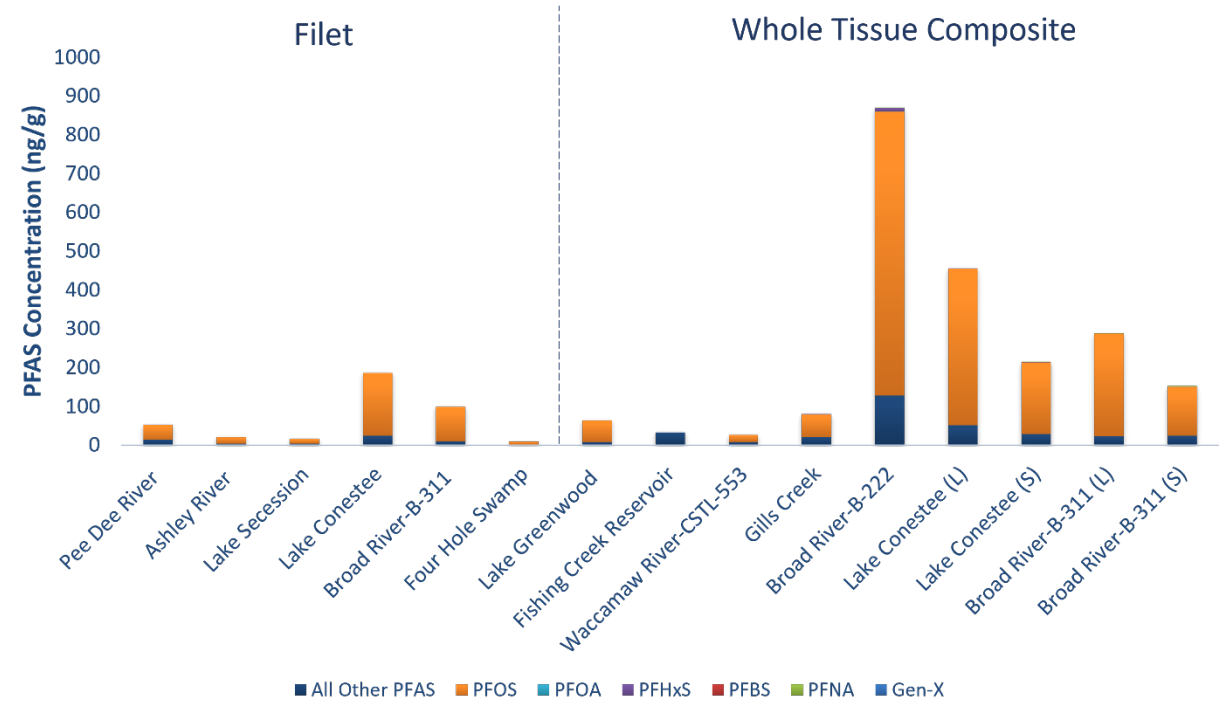


Figure 6. Bluegill filet (left) or whole tissue composite (right) PFAS results by location (ng/g). The six individual PFAS correspond to those EPA is currently proposing to regulate in drinking water. All Other PFAS is the sum of the remaining 19 PFAS analyzed as part of this project.

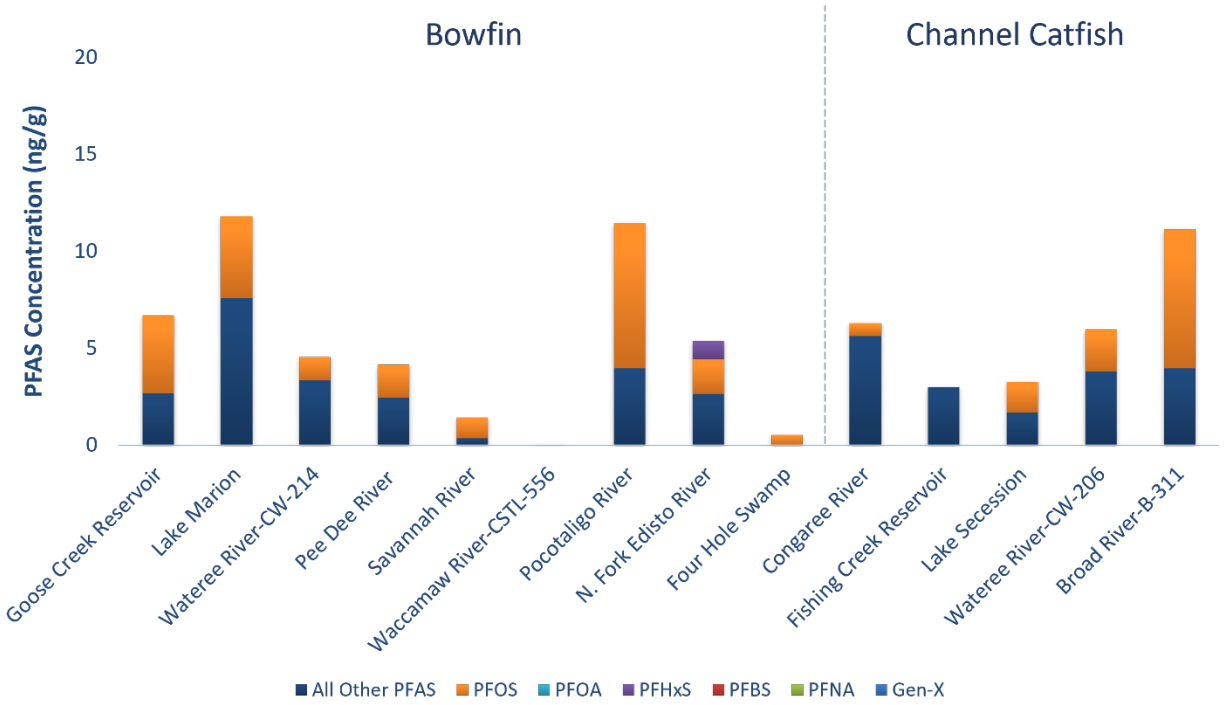


Figure 7. Demersal fish (bowfin, left; channel catfish, right) filet PFAS results by location (ng/g). The six individual PFAS correspond to those EPA is currently proposing to regulate in drinking water. All Other PFAS is the sum of the remaining 19 PFAS analyzed as part of this project.

Oyster

A total of 30 oyster soft tissue composite samples were collected from 24 sites. ΣPFAS concentrations in the oyster samples were generally lower compared to freshwater fish (Table 8). Total numbers of detected PFAS ranged from zero (all analytes below detect) to five on a per sample basis. Because concentrations were low with limited numbers of detects, conclusions on the presence of a predominant analyte are not possible (*e.g.,* PFOS in freshwater fish samples). However, a relatively high concentration of PFPeA was observed at six sites from the lower Edisto River basin south to Bull Creek near May River: 13-04, 15-02, 15-03A, 15-33, 16B-22, and 19-11. These six sites were resampled and confirmed the presence of PFPeA. PFPeA was not observed at any other oyster site. Average ΣPFAS for the 18 sites without detected PFPeA was 0.6 ng/g. For the six sites with detected PFPeA (12 samples), average ΣPFAS was 10.7 ng/g with PFPeA constituting 90 - 100% of the total.

Table 8. Oyster soft tissue composite results by site. ΣPFAS (ng/g) represents the sum of all 25 PFAS analyzed in each sample. No. of Detected Analytes is the number analytes present in each result above analytical detection limits. The table includes summary data related to the most prevalent (highest concentration) analyte: which PFAS (Analyte), corresponding concentration (Conc. ng/g), and fraction of ΣPFAS attributed to that analyte (% of Total). A dash (-) indicates all analytes in the sample were below respective analytical detection limits.

Site	ΣPFAS ng/g	No. of Detected Analytes	Most Prevalent Analyte		
			Analyte	Conc. ng/g	% of Total
Site-01-05	0.5	2	PFOS	0.3	62
Site-01-17	-	-	-	-	-
Site-03-01	1.6	5	PFOSAm	0.5	32
Site-04-03A	0.4	1	PFOS	0.4	100
Site-04-24	-	-	-	-	
Site-05-07	0.6	3	PFOA	0.2	34
Site-05-14	0.3	1	PFHxA	0.3	100
Site-06A-4B	2.1	2	PFOSAm	1.9	89
Site-07-06	0.2	1	PFOSAm	0.2	100
Site-08-29	0.2	1	PFOSAm	0.2	100
Site-09A-26	-	-	-	-	-
Site-09B-16	0.4	1	PFOSAm	0.4	100
Site-11-06	2.3	1	Gen-X	2.3	100
Site-12A-40	0.3	2	Gen-X	0.2	50
Site-12B-45	0.5	1	PFOSAm	0.5	100
Site-13-04 - 7/25	20.7	1	PFPeA	20.7	100
Site-13-04 - 9/7	13.8	2	PFPeA	13.5	98
Site-15-02 - 7/27	5.2	1	PFPeA	5.2	100
Site-15-02 - 9/7	9.2	2	PFPeA	9.0	98
Site-15-03A - 7/27	9.0	3	PFPeA	8.1	90
Site-15-03A - 9/7	7.6	3	PFPeA	7.0	93
Site-15-33 - 7/27	7.9	1	PFPeA	7.9	100
Site-15-33 - 9/7	6.9	1	PFPeA	6.9	100
Site-16B-22 - 7/28	7.6	1	PFPeA	7.6	100
Site-16B-22 - 9/8	25.8	2	PFPeA	25.6	99
Site-17-25	-	-	-	-	-
Site-18-17	0.6	1	Gen-X	0.6	100
Site-19-11 - 7/27	9.0	1	PFPeA	9.0	100
Site-19-11 - 9/6	6.1	1	PFPeA	6.1	100
Site-20-16	0.7	2	Gen-X	0.5	71

Blue Crab

Ten blue crab all soft tissue (offal) composite samples were collected from eight coastal sites. Sample composite size ranged from one to three individuals of varying sexes and maturities (Table 4). ΣPFAS averaged 21.2 ng/g (range = 1.3 – 69.0 ng/g) for the blue crab dataset (Figure 8). PFOS contributed 51% on average to ΣPFAS though the range was large on sample-by-sample basis (15 – 92%). PFOS concentrations ranged from 0.9 – 62.8 ng/g. Higher ΣPFAS and PFOS concentrations were observed in samples collected from the Lower Ashley River, Dawho River (10/13/2022), and Winyah Bay (10/18/2022) (Figure 8). Dawho River and Winyah Bay were resampled on 11/02/2022 and 11/16/2022, respectively, and demonstrated lower concentrations of both ΣPFAS (< 10 ng/g) and PFOS. Each sample at both sites included three individuals (Table 4). Upper Ashley River, Whale Branch, Rathall Creek, and Bulls Bay all demonstrated ΣPFAS concentrations of < 10 ng/g. PFOA was detected in five samples with all concentrations < 1.4 ng/g. PFNA was detected in four samples and PFHxS was detected in one sample. All concentrations were < 0.4 ng/g. Gen-X and PFBS were not detected in any blue crab sample (Figure 8).

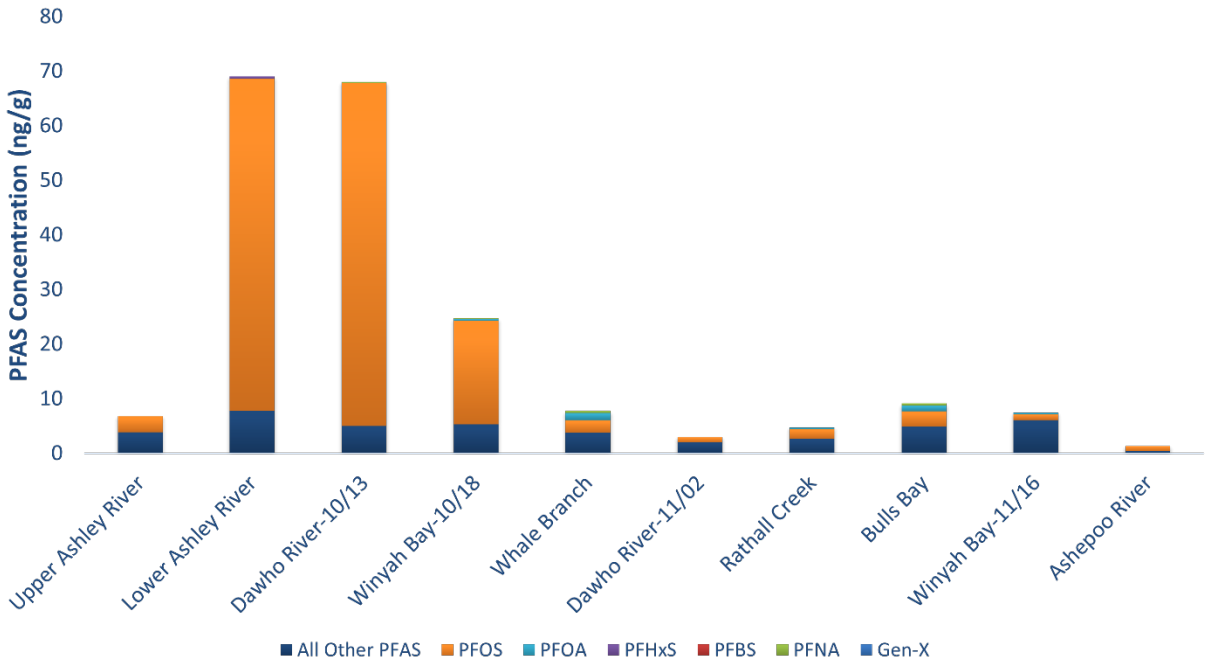


Figure 8. Blue crab all soft tissue (offal) PFAS results by location (ng/g). The six individual PFAS correspond to those EPA is currently proposing to regulate in drinking water. All Other PFAS is the sum of the remaining 19 PFAS analyzed as part of this project.

PFAS Class Characterization

The PFAS studied as part of this project may be grouped into six classes (Table 1). Surface water typically consisted of a mixture of short-chain perfluoroalkyl acids (PFAA) and long-chain PFAA. These two classes represented approximately 97% of ΣPFAS (short-chain PFAA = 57%, long-chain PFAA = 39%). PFOS and PFOA represented most of the long-chain PFAA signature in surface water with a more limited contribution from PFHxS. Other long-chain PFAAs were not detected or were limited in contribution to ΣPFAS. The short-chain PFAA pool in surface water was more diverse and included contributions of at least 1% of each of the six short-chain compounds to ΣPFAS (Table 1). PFBA, PFPeA, PFBS, and

perfluorohexanoic acid (PFHxA) each represented 11 – 17% of ΣPFAS. Gen-X was the only per- and polyfluoroether carboxylic acid (PFEA) included in this study and represented on average 2% of ΣPFAS, but as noted above, can be an important contributor to ΣPFAS at certain sites. Fluorotelomer sulfonic acids (FTS), perfluorooctane sulfonamides (FOSA), and perfluorooctane sulfonamidoacetic acids (FOSAA) were occasionally detected at low concentrations.

Across three tissue groups (freshwater fish filet, freshwater fish whole tissue composite, and blue crab soft tissue), long-chain PFAA contributed 89 to 97% of ΣPFAS. PFOS was the most prevalent long-chain PFAA as discussed above. PFOA was not detected in freshwater fish filet or whole tissue composite samples but represented on average 4% of blue crab soft tissue ΣPFAS though it was not detected in all samples. Perfluoroalkyl carboxylic acids with 11 – 14 carbons were routinely detected across all three tissue groups and represented in total 22 – 28% of ΣPFAS. This subset of long-chain PFAA includes perfluoroundecanoic acid (PFUnDA), perfluorododecanoic acid (PFDOA), perfluorotridecanoic acid (PFTrDA), and perfluorotetradecanoic acid (PFTDA). These compounds were seldom detected in surface water and, if present, at low concentrations. Short-chain PFAA represented < 1% of ΣPFAS in freshwater fish filet samples and 2% of ΣPFAS in whole tissue composites. This class comprised 5% of ΣPFAS in blue crab soft tissue samples with the majority attributed to PFPeA. Perfluorooctane sulfonamide (FOSA, PFOSAm), contributed an average of 5% the blue crab soft tissue, however, the average is skewed by PFOSAm presence in low ΣPFAS samples.

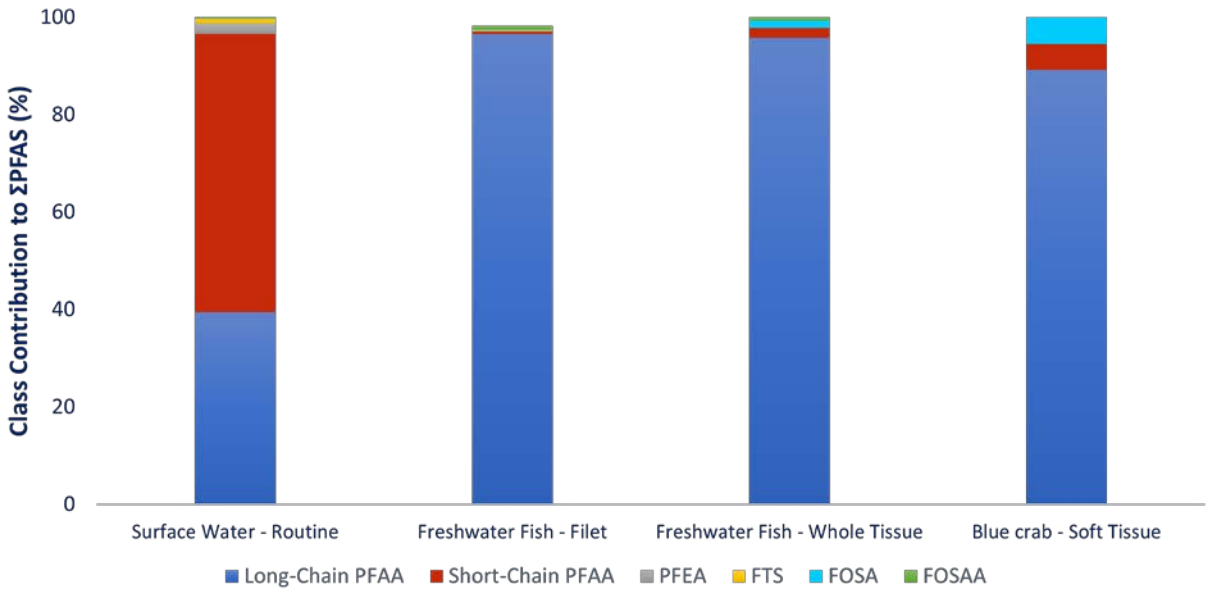


Figure 9. PFAS class contribution (%) to ΣPFAS by dataset. PFAS classes: long-chain and short-chain perfluoroalkyl acids (PFAA), per- and polyfluoroether carboxylic acids (PFEA, Gen-X only), fluorotelomer sulfonic acids (FTS), perfluorooctane sulfonamides (FOSA), and perfluorooctane sulfonamidoacetic acids (FOSAA).

Surface Water – Adaptive Management

As noted above, adaptive management sampling of surface water occurred during the second half of the project (January – June 2023) to provide additional insights into areas of interest identified from summer

and fall 2022 results (Figure 1). The following discussion highlights a selection of areas of interest. The scale of the adaptive management activity for a particular area was specific to the waterbody or watershed of interest. Maps identifying sampling site locations for each area of interest discussed below are presented in Appendix C.

Pocotaligo River Watershed

High ΣPFAS concentrations were observed in the first two quarters of sampling of two routine sites in the Pocotaligo River: PD-091 in Sumter and PD-043 near Manning. Notably, Gen-X concentrations ranging from 10.5 – 25.3 ng/L, PFOA ranging from 9.9 – 39.4 ng/L, and PFOS ranging from 6.8 – 68.3 ng/L were measured in the summer and fall samples at these sites. PD-043 in the lower reaches of the watershed also returned high summer concentrations of PFHxA (4180 ng/L), PFPeA (2700 ng/L), and PFBA (629 ng/L).

Three rounds of adaptive management sampling occurred in the Pocotaligo River watershed on 1/18/2023, 4/27/2023, and 5/24/2023. On 1/18/2023, upstream tributaries (Green Swamp [PD-719] and Cane Savannah Creek [PD-720]) were sampled along with routine Pocotaligo River sites (PD-091 and PD-043) and a mid-river site along 12 Bridges Road (PD-721). These results demonstrated relatively high Gen-X concentrations in Cane Savannah Creek and relatively high concentrations of PFOA, PFOS, and PFHxS in Green Swamp. ΣPFAS increased by a factor of 5.3 from PD-091 (70.4 ng/L) to 12 Bridges Road site (3734 ng/L). Specifically, notable increases were observed for Gen-X, PFBA, PFBS, PFHpA, and PFHxA. PFOA and PFOS each increased by a factor of 5 - 6, proportional to the increase in ΣPFAS. ΣPFAS concentrations decreased from 12 Bridges Road to PD-043 near the base of the river (218 ng/L).

Similar patterns and PFAS distributions were observed for the adaptive management sampling on 4/27/2023. A sample was also collected from Turkey Creek (PD-723) in northeast of the watershed as part of this sampling activity. Turkey Creek enters the Pocotaligo River between PD-091 and the 12 Bridges Road location. A Gen-X concentration of 746 ng/L was observed in Turkey Creek (83% of the ΣPFAS at this site). Further, PFOA and PFOS were 39.4 and 36.4 ng/L, respectively.

On 5/24/2023, five samples were collected in Turkey Creek to investigate the distributions of Gen-X in the stream. A similar Gen-X concentration (674 ng/L) was observed at 4/27/2023 sample at PD-723. Gen-X decreased in concentration from the lower reaches of the stream to the upstream area (674, 353, 246, 97.4, and 16.6 ng/L at PD-723, PD-725-728, respectively). Further, PFOA (average = 85 ng/L) and PFOS (average = 49 ng/L) were relatively high in lower Turkey Creek and decreased considerably at the most upstream location (PD-728). These observed upstream decreases in Gen-X and presence of high PFOA and PFOS concentrations downstream suggest an input or inputs of PFAS in the lower, more industrialized, reaches of the watershed.

The Pocotaligo River is a complex watershed as it relates to PFAS distributions. Upstream tributaries represent sources of PFAS to the river. Inputs local to the Pocotaligo River also contribute to PFAS observed at the PD-043 downstream sampling location based on changes in concentrations along the river. Turkey Creek may explain, in part, the Gen-X in the Pocotaligo River. However, relatively high Gen-X concentrations were observed upstream of Turkey Creek (Cane Savannah Creek and PD-091) indicating that there are multiple watershed inputs for this chemical.

Gen-X in the Saluda River Basin

The Congaree River is formed by the confluence of the Broad and Saluda rivers at Columbia. The river represents the most downstream major river component of the Saluda River Basin. Relatively high

concentrations of Gen-X (4.8 – 15.9 ng/L) were observed in summer and fall samples at two routine Congaree River sampling locations: S-964 in mid-river area between Columbia and Congaree National Park and C-007 at the base of the river upstream of its confluence with the Wateree River. Gen-X was not detected in summer and fall samples in the lower reaches of the Broad River near Columbia (B-337).

On 1/12/2023, sequential river samples were collected upstream of S-964 above and below wastewater treatment facilities discharging to the river in Columbia (S-955-957). The Congaree River was not fully mixed in this region and noticeable differences in field parameters (specific conductivity and temperature) were evident on the west side (Saluda River) and east side (Broad River). Gen-X concentrations on the east side were similar above and below the wastewater treatment plant outfalls (1.0 – 1.6 ng/L). The Gen-X concentration on the west side of the river was 10.2 ng/L, a factor of eight higher than on the east side.

Following the Congaree River sampling activity on 1/12/2023 (which was later supported with a replicated field activity on 4/20/2023), four additional adaptive management sampling activities were conducted to further investigate the potential entry point of Gen-X to the Saluda River. On 2/16/2023, three locations (S-1015-1017) were sampled above and below several regulated outfalls on the lower reaches of the Saluda River between Lake Murray and the Congaree River. Similar Gen-X concentrations ranging from 6.1 to 7.6 ng/L were measured in the three samples suggesting that Gen-X may originate above the Lake Murray dam.

On 3/22/2023, four samples were collected from three areas of the lower lake and forebay area of Lake Murray (CL-083 surface and at 20 m depth, S-1018, and S-1019). Gen-X in these samples ranged from 6.4 to 7.4 ng/L including a concentration of 6.7 ng/L at 20 m depth in the forebay (CL-083 20 m). The results suggest that lower Lake Murray is well-mixed as it relates to Gen-X. Further, five locations in the Saluda River between Lake Murray and Lake Greenwood were sampled on 5/5/2023. From downstream to upstream these sites were S-223, S-1023, S-047, S-295, and S-186. Gen-X concentrations were similar ranging from 6.1 – 8.1 ng/L.

An eight-sample profile was conducted on the Saluda River above Lake Greenwood on 6/7/2023. From downstream to upstream these sites were S-125, S-1024-1028, S-1014, and S-119. Gen-X concentrations in the lower six samples were similar ranging from 7.9 to 10.4 ng/L. The seventh sample at Cooley River Bridge Road demonstrated a Gen-X concentration of 34.2 ng/L. This is a routine sampling location (S-1014) where high Gen-X concentrations were observed previously. Gen-X in the final sample (S-119), collected ~5.5 river km upstream at Beech Springs Road, decreased to 1.2 ng/L.

These results suggest that there is a key source of Gen-X to the Saluda River Basin between Cooley River Bridge Road and Beech Springs Road. Gen-X was also detected in other Saluda Basin rivers, including the Reedy River and Rabon Creek, and likely contribute to some extent to the overall Gen-X input to the Saluda River basin.

PFOS in Lake Craig/Kelsey Creek near Croft State Park

Lake Craig (routine site CL-033) in Croft State Park near Spartanburg demonstrated some of the highest PFOS concentrations over the first half of the project. Lake Craig is formed as an impoundment of Kelsey Creek which runs through the center of Croft State Park. The watershed is predominantly forested and

was home to Camp Croft, a World War II training facility.[5] The upstream reach of Kelsey Creek includes a mix of residential and industrial land uses.

Five samples were collected as part of an adaptive management sampling activity on 3/21/2023. In addition to CL-033 in Lake Craig, samples were collected in Kelsey Creek above (B-865) and immediately below the lake (B-868), an unnamed tributary to Kelsey Creek draining the north-central area of the park (B-866), and in Thompson Creek (B-867), a tributary and lake arm of Lake Craig on the east side of the park. Very low PFOS was observed in Thompson Creek and the unnamed Kelsey Creek tributary (< 1.4 ng/L). PFOS in the Lake Craig and the upstream and downstream Kelsey Creek samples ranged from 62.3 to 82.6 ng/L.

An additional three-sample adaptive management activity exploring Kelsey Creek above the 3/21/2023 sites was conducted on 5/25/2023. This activity included Lake Craig (CL-033), an additional unnamed Kelsey Creek tributary draining former Camp Croft, current residential neighborhoods, and a golf course (B-870), and Kelsey Creek at Country Club Road below the industrial facilities (B-871). PFOS was relatively low in the unnamed Kesley Creek Tributary (6.5 ng/L) while Kelsey Creek at Country Club Road measured a PFOS concentration of 305 ng/L. The results of the adaptive management activities in this watershed suggest that the high concentrations of PFOS in Lake Craig originate from a source or sources to Kelsey Creek above Country Club Road.

Warrior Creek in the Enoree River Watershed

Warrior Creek (routine site B-150), a tributary to the Enoree River in the west-central area of the watershed, demonstrated high concentrations of PFOA, PFBS, and several other PFAS in summer and fall samples. Two adaptive management activities (1/12/2023 and 5/18/2023) were conducted in this area to investigate where in Warrior Creek these high PFAS signatures may originate and to observe a nearby watershed to Warrior Creek, Beaverdam Creek.

On 1/12/2023, concurrent measurements below agricultural fields in Warrior Creek (B-150) and Beaverdam Creek to the north (B-246), showed similar PFAS panels and concentrations among the detected analytes. Specifically, PFOA measured 19.8 ng/L in Warrior Creek and 16.2 ng/L in Beaverdam Creek while PFBS was 94.8 and 95.5 ng/L in these streams, respectively. PFOA and PFBS concentrations upstream of the agricultural fields in Warrior Creek (B-860) decreased by factors of 5.3 and 2.6, respectively.

These sites were sampled again on 5/18/2023 with an additional sample in Warrior Creek between B-150 and the upstream site sampled on 1/12/2023 (B-860). This additional site (B-869) was located within a cluster of agricultural fields. Once again, similar concentrations of PFOA and PFBS were observed at B-150 in Warrior Creek and in Beaverdam Creek. Concentrations of PFBS and PFOA decreased from downstream to upstream in Warrior Creek which indicates that PFAS inputs may occur between sites B-860 and B-150.

Big Generostee Creek near Anderson

Big Generostee Creek is a tributary of the upstream reaches of Lake Russell originating in Anderson. Routine site SV-316 demonstrated high ΣPFAS concentrations in 2022 attributed to several individual PFAS including PFOA, PFHxA, PFHpA, and PFPeA.

[5] Camp Crop Site History, US Army Corps of Engineers: https://www.campcroft.net/site-history

Adaptive management activities conducted on 2/8/2023 and 5/8/2023 centered on collecting two samples 2.9 stream km above SV-316: Big Generostee Creek (SV-837) and Fivemile Creek (SV-841) both at Lee Dobbins Road. Fivemile Creek drains to Big Generostee Creek immediately below the Lee Dobbins Road sampling location. The objective was to determine if high PFAS concentrations at SV-316 originate in Big Generostee Creek above Lee Dobbins Road or from Fivemile Creek. Similar results were achieved on both occasions. ΣPFAS concentrations in Big Generostee increased by factors of 18.6 and 6.6 from Lee Dobbins Road to SV-316 on 2/8/2023 and 5/8/2023, respectively. ΣPFAS concentrations in Fivemile Creek were considerably higher than Big Generostee Creek at Lee Dobbins Road suggesting PFAS in Fivemile Creek contribute to some extent to PFAS levels measured in Big Generostee at SV-316. However, ΣPFAS concentrations at SV-316 were consistently higher than in Fivemile Creek suggesting there may be a key source or sources of PFAS to Big Generostee Creek between Lee Dobbins Road and SV-316.

Chinquapin Creek near Batesburg-Leesville

Chinquapin Creek is an upstream tributary of the North Fork Edisto River near Batesburg-Leesville. Summer and fall sampling results at routine site E-091 demonstrated high ΣPFAS concentrations attributed to PFBA, PFHxA, and PFPeA, along with moderately high contributions of PFOA and PFOS. An adaptive management activity was conducted on 2/22/2023 which included a sampling location upstream of E-091 on Chinquapin Creek (E-609) and on nearby Duncan Creek (E-608) above a wastewater treatment plant outfall and golf course. ΣPFAS concentrations at the upstream Chinquapin Creek and Duncan Creek sites were relatively low at 10.1 and 1.7 ng/L, respectively. ΣPFAS increased to 61.5 ng/L at E-091 suggesting that there is a PFAS source to Chinquapin Creek between the upstream sampling location and E-091. Besides Duncan Creek, there are three additional small drainage area tributaries entering Chinquapin Creek between sampling locations: Horsepen Branch and Mare Branch to the east and Crumb Branch to the west. These tributaries are predominantly forested with interspersed agricultural fields.

Conclusions

The following conclusions are drawn from the results of this project:

- **PFAS are ubiquitous in the South Carolina aquatic environment.** While the overall magnitude (ΣPFAS or total PFAS) varies and distributions of individual PFAS compounds differ from waterbody to waterbody, PFAS were detected at nearly all surface water sites routinely sampled from July 2022 through June 2023. In general, PFAS concentrations were highest in summer and lowest in winter, likely related to reduced summertime stream flows and higher rates of wintertime precipitation.
- **PFAS in surface water is comprised of a mixture of short-chain and long-chain perfluoroalkyl acids (PFAA).** In these samples, short-chain and long-chain PFAA comprised 97% of ΣPFAS averaging 57 and 39%, respectively. Hexafluoropropylene oxide dimer acid (HFPO-DA or Gen-X) was the only per- and polyfluoroether carboxylic acid (PFEA) investigated as part of this study and represented on average 2% of ΣPFAS. However, at several locations, primarily in the Broad, Saluda, and Pee Dee river basins, Gen-X was an important constituent of ΣPFAS. Other PFAS classes were rarely detected.
- **The six PFAS EPA is currently proposing to regulate in drinking water are routinely detected in surface water across the state.** PFOS (long-chain PFAA) was the largest individual contributor to ΣPFAS representing on average 20% of the total at routine surface water sites. PFOA (long-chain PFAA) contributed on average 12% to ΣPFAS. For these sites, average PFOS was 11.2 ng/L and average PFOA was 8.9 ng/L. Both averages are higher than the current EPA proposed drinking water maximum contaminant level (MCL) of 4 ng/L for each compound. PFBS, a short-chain PFAA, comprised 11% (average = 6.4 ng/L) of ΣPFAS. Long-chain PFAA PFHxS averaged 6% (average = 4.1 ng/L) while PFNA represented 1% (average = 0.8 ng/L) of ΣPFAS. Gen-X represented 2% of ΣPFAS with an average concentration of 2.4 ng/L.
- **PFOS is the most prevalent PFAS in freshwater fish filet samples.** Long-chain PFAA comprised 97% of ΣPFAS in freshwater fish filet samples. PFOS represented on average 64% of ΣPFAS with an average 21.7 ng/L (range = below analytical detection limit to 162 ng/g) across all filet samples and species. Perfluoroalkyl carboxylic acids with 11 – 14 carbons were routinely detected in filet samples. This subset of long-chain PFAA included PFUnDA, PFDOA, PFTrDA, PFTDA. These compounds were seldom detected in surface water and, if so, were present in low concentrations. PFHxS and PFNA were detected rarely and at low concentrations (< 1 ng/g). PFOA and Gen-X were not detected in any filet sample.
- **PFAS concentrations in oyster tissue are generally low.** Except for a relatively high concentration of PFPeA at six locations from the lower Edisto River basin south to Bull Creek near May River, conclusions on the presence of a predominant PFAS analyte in this dataset were not possible.
- **PFOS is the most prevalent PFAS in blue crab soft tissue.** As with freshwater fish filet dataset, long-chain PFAA represented the majority of ΣPFAS in blue crab soft tissue samples. PFOS contributed most to the total averaging 51% of ΣPFAS and 15.5 ng/g. Long-chain perfluoroalkyl carboxylic acids with 11 – 14 carbons were also routinely detected in blue crab soft tissue samples. PFOA and PFNA were detected at low concentrations in approximately half of the blue crab samples. PFHxS was detected in one sample at low concentration while Gen-X was not detected in any sample.

Recommendations

The following are recommendations based on the results of this project:

- **Establish a statewide long-term surface water monitoring program for PFAS.** Results of this study have indicated seasonal trends in magnitudes of PFAS over an annual cycle. Multiple years of evidence (seasonal sampling) at a series of locations will resolve interannual variability attributed to both changes in hydrology and PFAS inputs from possible release pathways. The program should include sites in major rivers to establish basin-wide conditions as well as sites in areas of interest such as those discussed above.
- **Continue to gather PFAS data in freshwater fish to help develop species-specific consumption advisories.** The objective of this study was to provide an initial dataset from which next steps and future direction could be determined. The data collected as part of this study are insufficient to assist in developing fish consumption advisories. Given the relatively high PFOS concentrations observed in multiple freshwater fish species, it is recommended that the state incorporate PFAS testing into the Fish Consumption Advisory Program to produce a dataset that may be used to develop species-specific consumption advisories once federal standards are promulgated.
- **Develop an understanding of sources that release PFAS to the environment.** Based on the results of this study, the state should consider implementing a monitoring/testing framework for PFAS in regulated outfalls and investigate potential nonpoint source contributions to surface water. This potentially could include testing industrial effluent discharged to publicly owned treatment works, treated wastewater effluent from municipal, domestic, and industrial outfalls, and wastewater/sludge applied to agricultural fields. Further, where warranted, investigations could be conducted to provide insights into PFAS transport by overland flow and groundwater movement.
- **Find approaches to limit or reduce PFAS release to the environment.** This study has revealed that PFAS are ubiquitous in the South Carolina aquatic environment. Limiting the release of PFAS to the environment would provide broadscale environmental and human health benefits, enhance the quality of public resources, and reduce drinking water treatment costs.

Appendix A – Surface Water Sites

Site	Waterbody	River Basin	Latitude	Longitude
Routine Surface Water Sites				
B-040	Enoree River	Broad	34.6685	-82.0120
B-046	Broad River	Broad	34.5951	-81.4200
B-053	Enoree River	Broad	34.5090	-81.5985
B-150	Warrior Creek	Broad	34.6160	-81.9813
B-302	S Pacolet River	Broad	35.1079	-82.1289
B-320	Big Cedar Creek	Broad	34.1622	-81.1143
B-337	Broad River	Broad	34.0259	-81.0690
B-353	Broad River	Broad	35.0890	-81.5717
B-850	UT to Enoree River	Broad	34.8745	-82.2363
B-851	Big Browns Creek	Broad	34.7876	-81.6195
B-852	George Branch	Broad	34.8149	-81.4624
B-853	Slatestone Creek	Broad	34.1082	-81.0880
B-854	Buffalo Creek	Broad	34.6857	-81.6847
B-855	Fairforest Creek	Broad	34.6858	-81.6850
CL-033	Lake Craig	Broad	34.8667	-81.8347
CW-008	Fishing Creek	Catawba	34.7409	-80.9867
CW-019	Wateree River	Catawba	34.2457	-80.6531
CW-041	Catawba River	Catawba	34.8541	-80.8677
CW-057	Fishing Creek Reservoir	Catawba	34.6053	-80.8910
CW-206	Wateree River	Catawba	33.9470	-80.6285
CW-233	Fishing Creek	Catawba	34.6372	-80.9278
CW-238	Swift Creek	Catawba	34.1339	-80.5809
CW-249	Allison Creek	Catawba	35.0648	-81.1381
CW-250	Colonels Creek	Catawba	34.0054	-80.7332
E-050	Cow Castle Creek	Edisto	33.3442	-80.5942
E-091	Chinquapin Creek	Edisto	33.8254	-81.5222
E-094	Shaw Creek	Edisto	33.6190	-81.7031
E-102	N Fork Edisto River	Edisto	33.7096	-81.3153
E-104	N Fork Edisto River	Edisto	33.5766	-81.0385
E-109	Polk Swamp	Edisto	33.0892	-80.5214
E-111	Four Hole Swamp	Edisto	33.3646	-80.5614
E-112	Four Hole Swamp	Edisto	33.2692	-80.4376
E-114	S Fork Edisto River	Edisto	33.5555	-81.4837
E-116	Four Hole Swamp	Edisto	33.0875	-80.3807
RS-12099	Goodbys Swamp	Edisto	33.4441	-80.6187
MD-107	Kingston Lake	PeeDee	33.8383	-79.0458

Site	Waterbody	River Basin	Latitude	Longitude
MD-125	Intracoastal Waterway	PeeDee	33.8533	-78.6539
MD-127	Intracoastal Waterway	PeeDee	33.6872	-79.0045
MD-138	Waccamaw River	PeeDee	33.5622	-79.0881
MD-277	Parsonnage Creek	PeeDee	33.5529	-79.0340
PD-012	PeeDee River	PeeDee	34.7087	-79.8751
PD-015	PeeDee River	PeeDee	34.5253	-79.8333
PD-043	Pocotaligo River	PeeDee	33.7097	-80.0521
PD-078	Black Creek	PeeDee	34.2566	-79.6995
PD-091	Pocotaligo River	PeeDee	33.8757	-80.3520
PD-231	Jefferies Creek	PeeDee	34.1218	-79.5748
PD-330	Black Creek	PeeDee	34.3920	-80.0290
PD-353	Black River	PeeDee	33.9503	-80.1797
PD-361	Black Mingo Creek	PeeDee	33.5931	-79.4320
PD-373	Waccamaw River	PeeDee	33.8989	-78.8402
PD-717	Black River	PeeDee	34.1422	-80.2236
PD-718	Long Branch	PeeDee	33.9617	-80.4265
RS-07205	Polk Swamp	PeeDee	34.1865	-79.6678
CSTL-003	Salkehatchie River	Salkehatchie	33.2090	-81.3566
CSTL-014	Ireland Creek	Salkehatchie	32.9083	-80.6667
CSTL-076	Whippy Swamp	Salkehatchie	32.9096	-81.0097
CSTL-120	Little Salkehatchie River	Salkehatchie	32.8882	-80.8748
CSTL-125	Ashepoo River	Salkehatchie	32.8288	-80.6722
CSTL-550	Log Branch	Salkehatchie	33.0367	-81.3353
MD-001	Beaufort River	Salkehatchie	32.4456	-80.6632
MD-176	Chechesse Creek	Salkehatchie	32.3323	-80.8774
MD-252	Combahee River	Salkehatchie	32.5643	-80.5570
MD-282	Morgan River	Salkehatchie	32.4438	-80.6069
RL-21280	Lake Edgar Brown	Salkehatchie	33.2525	-81.3670
RO-18415	Whale Branch	Salkehatchie	32.5174	-80.6761
RS-11031	Black Creek	Salkehatchie	32.8641	-80.7690
RT-14082	Hazzard Creek	Salkehatchie	32.4093	-80.8758
RT-21253	Salt Creek	Salkehatchie	32.4468	-80.7193
C-005	Sixmile Creek	Saluda	33.9437	-81.0790
C-007	Congaree River	Saluda	33.7529	-80.6450
C-017	Gills Creek	Saluda	33.9481	-80.9891
C-070	Congaree Creek	Saluda	33.9373	-81.0323
C-075	Cedar Creek	Saluda	33.8399	-80.8604
RS-06151	Burdine Creek	Saluda	34.8627	-82.5654
S-015	Lake Conestee	Saluda	34.7704	-82.3507
S-096	Rabon Creek	Saluda	34.3821	-82.1025

Site	Waterbody	River Basin	Latitude	Longitude
S-1012	Mountain Creek	Saluda	34.5001	-82.3281
S-1013	Lake Katherine	Saluda	34.0077	-80.9612
S-1014	Saluda River	Saluda	34.5555	-82.4188
S-131	Lake Greenwood	Saluda	34.2791	-82.0587
S-311	Boyd Mill Pond	Saluda	34.4547	-82.2019
S-319	Reedy River	Saluda	34.8449	-82.4017
S-964	Congaree River	Saluda	33.8515	-80.9896
C-080	Halfway Swamp Creek	Santee	33.6255	-80.6600
CSTL-078	Cypress Swamp	Santee	33.0891	-80.2658
CSTL-102	Ashley River	Santee	32.9584	-80.2010
CSTL-123	East Branch Cooper River	Santee	33.0707	-79.8827
MD-043	Cooper River	Santee	32.9629	-79.9212
MD-049	Ashley River	Santee	32.8758	-80.0815
MD-248	Cooper River	Santee	32.8905	-79.9627
ST-032	Goose Creek Reservoir	Santee	32.9324	-80.0112
CL-069	Langley Pond	Savannah	33.5223	-81.8432
RS-18413	Pen Branch	Savannah	33.1826	-81.6676
SV-111	Three and Twenty Creek	Savannah	34.5998	-82.7723
SV-137	Twelve Mile Creek	Savannah	34.7429	-82.8021
SV-203	Little River	Savannah	34.8370	-82.9801
SV-239	Golden Creek	Savannah	34.8011	-82.7067
SV-250	Horse Creek	Savannah	33.4783	-81.9075
SV-316	Big Generostee Creek	Savannah	34.4532	-82.7318
SV-318	Long Cane Creek	Savannah	34.0004	-82.3522
SV-325	Upper Three Runs	Savannah	33.2390	-81.7437
SV-327	Steel Creek	Savannah	33.1459	-81.6288
SV-367	Savannah River	Savannah	33.0552	-81.5610
SV-371	Horn Creek	Savannah	33.6514	-82.0737
SV-693	Broadway Creek	Savannah	34.5471	-82.5403
SV-834	Six and Twenty Creek	Savannah	34.6783	-82.5934
SV-835	Shanklin Creek	Savannah	34.1732	-82.5196
Adaptive Management Surface Water Sites				
B-046-West	Broad River	Broad	34.5953	-81.4215
B-246	Beaverdam Creek	Broad	34.6462	-81.9955
B-857	Lake Blalock	Broad	35.0673	-81.8768
B-858	Pacolet River	Broad	34.9937	-81.8335
B-859	Pacolet River	Broad	34.9215	-81.7425
B-860	Warrior Creek	Broad	34.6112	-82.0369
B-861	Lawsons Fork Creek	Broad	35.0216	-82.0585
B-862	South Tyger River	Broad	34.9260	-82.1449

Site	Waterbody	River Basin	Latitude	Longitude
B-863	Middle Tyger River	Broad	34.9271	-82.1001
B-864	Tyger River	Broad	34.7554	-81.9273
B-865	Kelsey Creek	Broad	34.8943	-81.8664
B-866	UT to Kelsey Creek	Broad	34.8874	-81.8559
B-867	Thompson Creek	Broad	34.8851	-81.8328
B-868	Kelsey Creek	Broad	34.8646	-81.8330
B-869	Warrior Creek	Broad	34.6115	-82.0116
B-870	UT to Kelsey Creek - 2	Broad	34.8970	-81.8664
B-871	Kelsey Creek	Broad	34.9090	-81.8758
CW-714	Wateree River	Catawba	33.8139	-80.6130
CW-715	Fishing Creek	Catawba	34.9326	-81.1653
CW-716	South Fork Fishing Creek	Catawba	34.7845	-81.0460
E-608	Duncan Creek	Edisto	33.8722	-81.5466
E-609	Chinquapin Creek	Edisto	33.8626	-81.5601
E-610	North Fork Edisto River	Edisto	33.4801	-80.8738
E-611	North Fork Edisto River	Edisto	33.4021	-80.8700
PD-719	Green Swamp	PeeDee	33.8881	-80.3569
PD-720	Cane Savannah Creek	PeeDee	33.8789	-80.3661
PD-721	Pocotaligo River	PeeDee	33.8048	-80.2878
PD-722	Cane Savannah Creek	PeeDee	33.8782	-80.3915
PD-723	Turkey Creek	PeeDee	33.8745	-80.3344
PD-724	Sammy Swamp	PeeDee	33.7610	-80.2794
PD-725	Turkey Creek	PeeDee	33.8963	-80.3222
PD-726	Turkey Creek	PeeDee	33.9118	-80.3289
PD-727	Turkey Creek	PeeDee	33.9162	-80.3293
PD-728	Turkey Creek	PeeDee	33.9247	-80.3305
CSTL-614	Salkehatchie River	Salkehatchie	33.2081	-81.4652
CSTL-615	Halfmoon Branch	Salkehatchie	33.2800	-81.0512
CL-083	Lake Murray	Saluda	34.0496	-81.2303
CL-083-20m	Lake Murray	Saluda	34.0496	-81.2286
S-047	Saluda River	Saluda	34.1827	-81.7246
S-1015	Saluda River	Saluda	34.0465	-81.1907
S-1016	Saluda River	Saluda	34.0298	-81.1395
S-1017	Saluda River	Saluda	34.0136	-81.0852
S-1018	Lake Murray	Saluda	34.0179	-81.2403
S-1019	Lake Murray	Saluda	34.0969	-81.2341
S-1023	Saluda River	Saluda	34.1404	-81.6304
S-1024	Saluda River	Saluda	34.4095	-82.2465
S-1025	Saluda River	Saluda	34.4332	-82.2660
S-1026	Saluda River	Saluda	34.4633	-82.3074

Site	Waterbody	River Basin	Latitude	Longitude
S-1027	Saluda River	Saluda	34.4976	-82.3318
S-1028	Saluda River	Saluda	34.5263	-82.3746
S-119	Saluda River	Saluda	34.5972	-82.4284
S-125	Saluda River	Saluda	34.3922	-82.2239
S-186	Saluda River	Saluda	34.1684	-81.9094
S-223	Saluda River	Saluda	34.1018	-81.5685
S-295	Saluda River	Saluda	34.1742	-81.8637
S-955	Congaree River	Saluda	33.9648	-81.0364
S-956	Congaree River	Saluda	33.9412	-81.0234
S-957	Congaree River	Saluda	33.9345	-81.0176
CL-005	Lake Secession	Savannah	34.3124	-82.5792
SV-837	Big Generostee Creek	Savannah	34.4762	-82.7200
SV-841	Fivemile Creek	Savannah	34.4760	-82.7204

Appendix B – Tissue Sites

Freshwater Fish Sites

Waterbody	Basin	Latitude	Longitude
Goose Creek Reservoir	Santee	32.9376	-80.0266
Lake Marion	Santee	33.5868	-80.5326
Wateree River-CW-214	Catawba	34.2450	-80.6533
Congaree River	Saluda	33.9660	-81.0369
Lake Greenwood	Saluda	34.1964	-81.9434
Fishing Creek Reservoir	Catawba	34.6146	-80.8931
Pee Dee River	Pee Dee	34.5133	-79.8334
Ashley River	Santee	32.9468	-80.1653
Waccamaw River-CSTL-553	Pee Dee	33.8980	-78.8474
Lake Secession	Savannah	34.3147	-82.5805
Wateree River-CW-206	Catawba	33.9484	-80.6280
Gills Creek	Saluda	33.9546	-80.9821
Savannah River	Savannah	33.2177	-81.7693
Broad River-B-222	Broad	35.0315	-81.4965
Waccamaw River-CSTL-556	Pee Dee	33.8011	-79.0549
Lake Conestee/Conestee Nature Preserve	Saluda	34.7704	-82.3507
Broad River-B-311	Broad	34.0667	-81.0807
Pocotaligo River	Pee Dee	33.7094	-80.0528
North Fork Edisto River	Edisto	33.5768	-81.0386
South Fork Edisto River	Edisto	33.3143	-80.9654
Four Hole Swamp	Edisto	33.1980	-80.3283

Oyster Sites

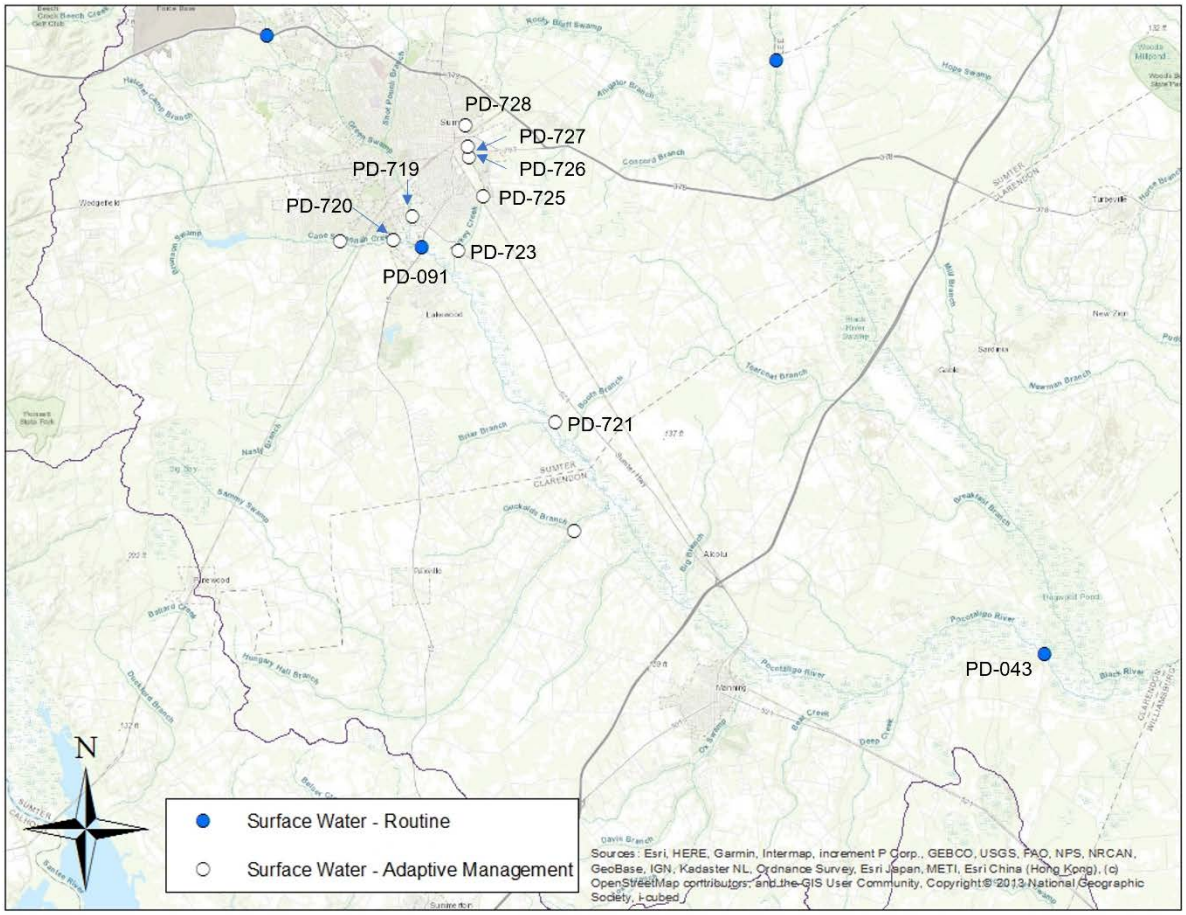
Site	Waterbody/Description	Latitude	Longitude
Site-01-05	Dunn Sound Creek	33.8597	-78.5802
Site-01-17	42nd Avenue – Cherry Grove	33.8351	-78.6276
Site-03-01	Withers Swash	33.6810	-78.8915
Site-04-03A	Main Creek	33.5535	-79.0296
Site-04-24	Oaks Creek	33.5311	-79.0513
Site-05-07	Jones Creek at Mud Bay	33.2709	-79.2009
Site-05-14	Mid Channel Island, Bly Creek	33.3471	-79.1839
Site-06A-4B	North Santee River – SW of Cane Island	33.1492	-79.2516
Site-07-06	Five Fathom Creek	33.0676	-79.4656
Site-08-29	Anderson Creek	32.9330	-79.6334
Site-09A-26	Hamlin Creek	32.8034	-79.7913
Site-09B-16	Confluence of Martin Creek and Nowell Creek	32.9005	-79.8905
Site-11-06	Abbapoola Creek	32.6652	-80.0114
Site-12A-40	Pine Creek	32.7130	-80.1390
Site-12B-45	Toogoodoo Creek	32.6787	-80.3208
Site-13-04	St. Pierre Creek at Peters Pt.	32.5388	-80.3446
Site-15-02	Mulligan Creek at Brickyard Creek	32.4823	-80.6924
Site-15-03A	Albergottie Creek	32.4490	-80.7098
Site-15-33	McCalley Creek	32.5131	-80.7273
Site-16B-22	Skull Creek near Pritchards Inlet	32.3069	-80.5433
Site-17-25	Hazzard Creek	32.4055	-80.8784
Site-18-17	Okatie River	32.3180	-80.9153
Site-19-11	Bull Creek at Savage Creek	32.1862	-80.8516
Site-20-16	Broad Creek	32.1955	-80.7205

Blue Crab Sites

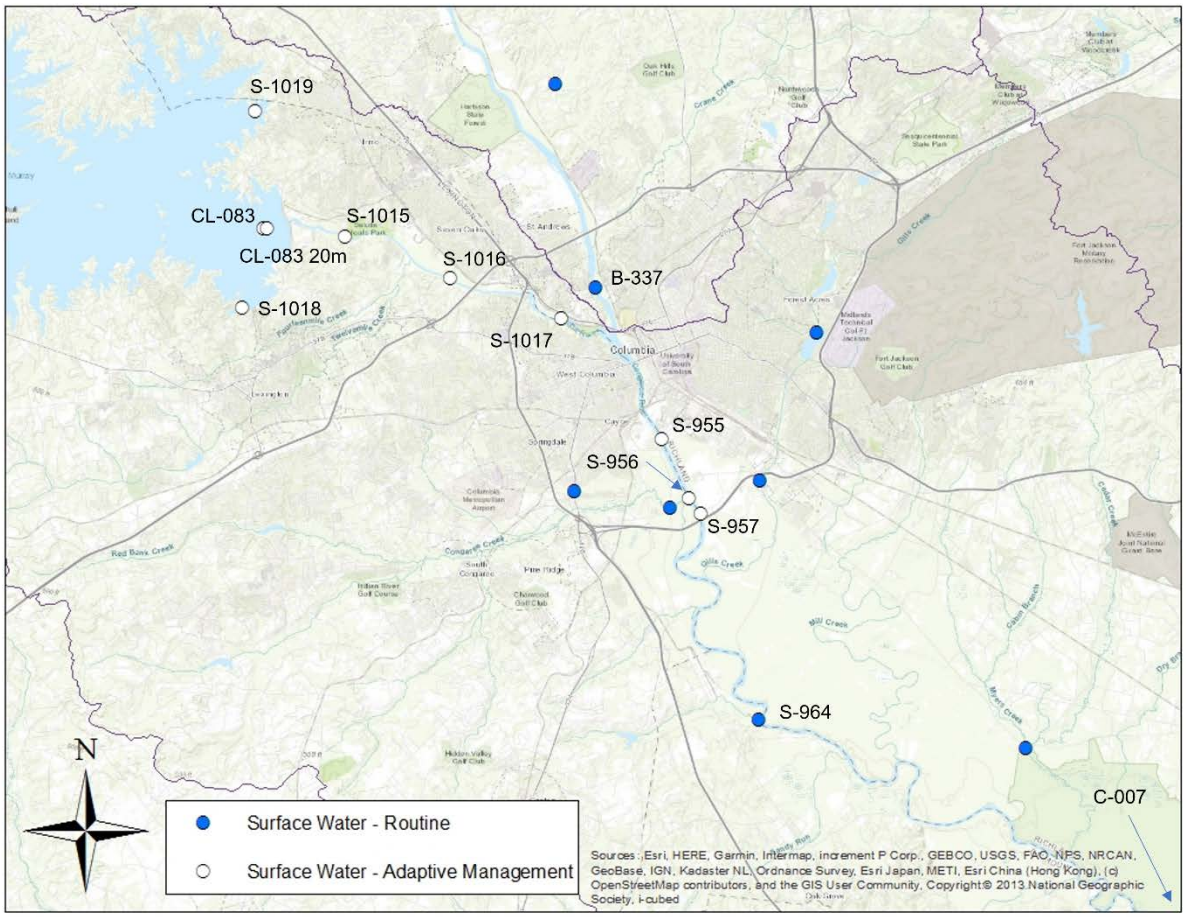
Waterbody	Latitude	Longitude
Upper Ashley River	32.8334	-79.9945
Lower Ashley River	32.8056	-79.9696
Dawho River	32.6350	-80.3273
Winyah Bay	33.2680	-79.2667
Whale Branch	32.4928	-80.8037
Rathall Creek	32.8575	-79.8756
Bulls Bay	33.0329	-79.5315
Ashepoo River	32.5135	-80.4080

Appendix C – Adaptive Management Study Maps

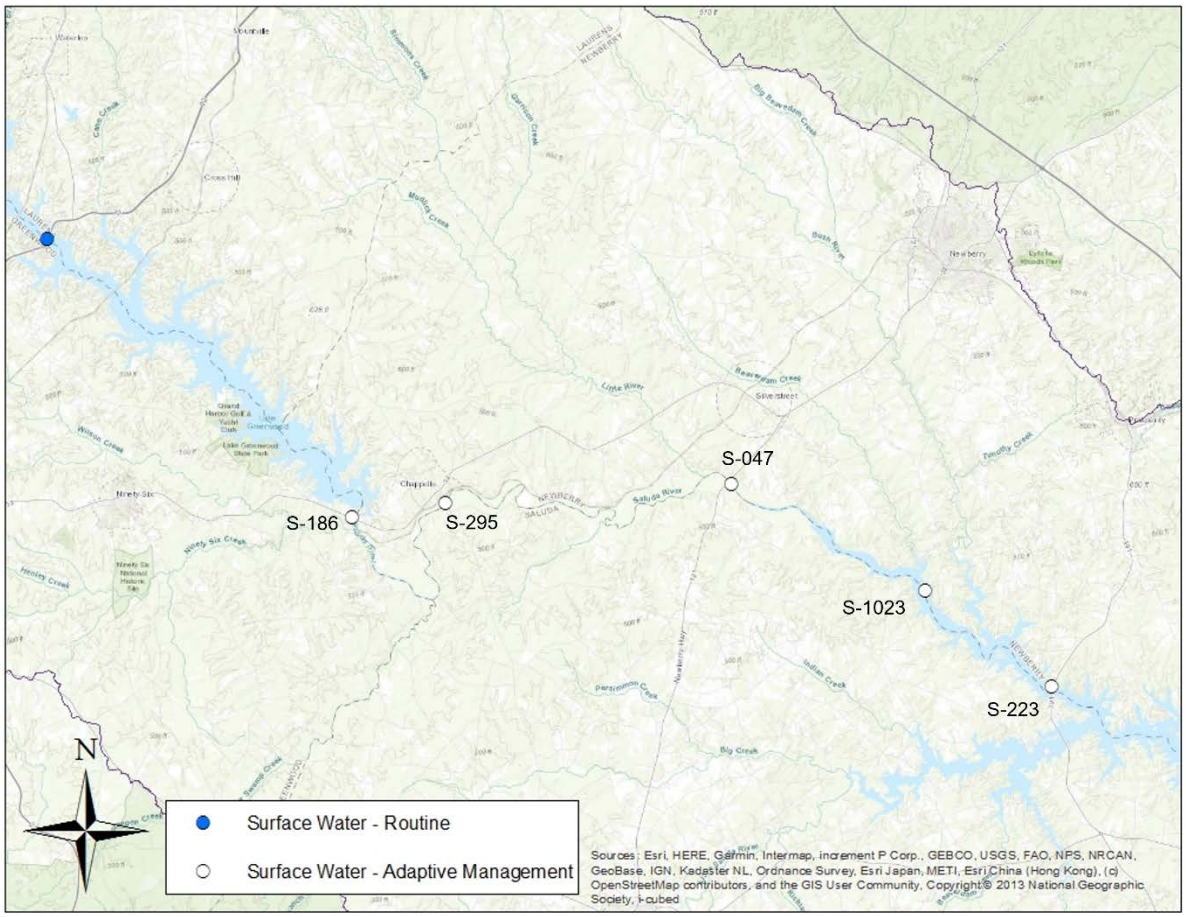
Pocotaligo River Watershed



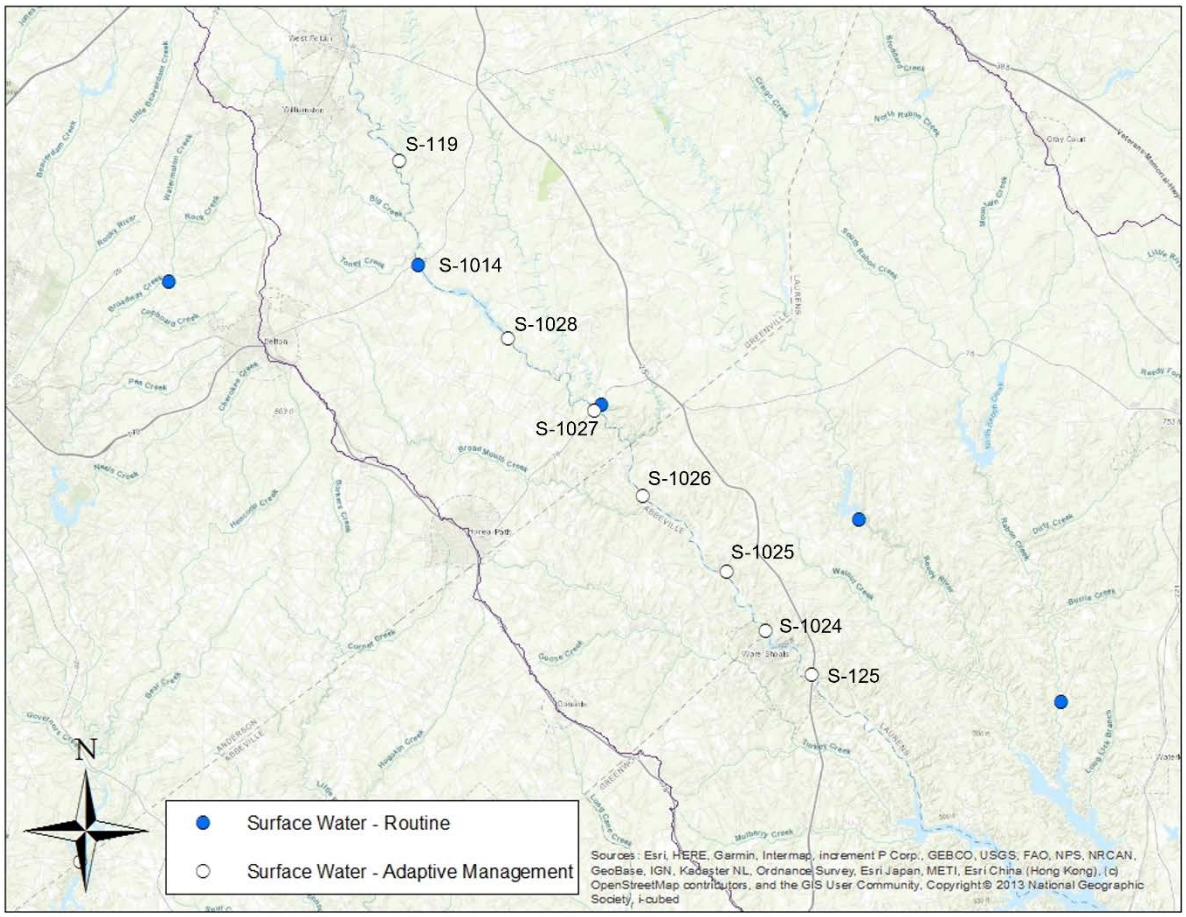
Saluda River Basin – Lake Murray, Lower Saluda River, and Congaree River



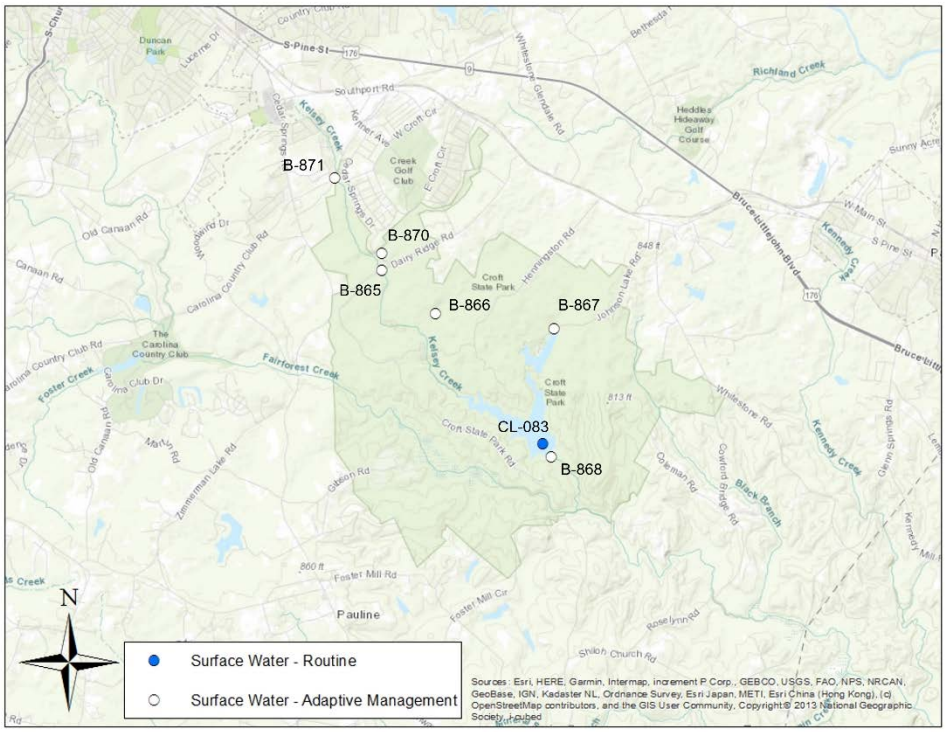
Saluda River Basin – Saluda River between Lake Greenwood and Lake Murray



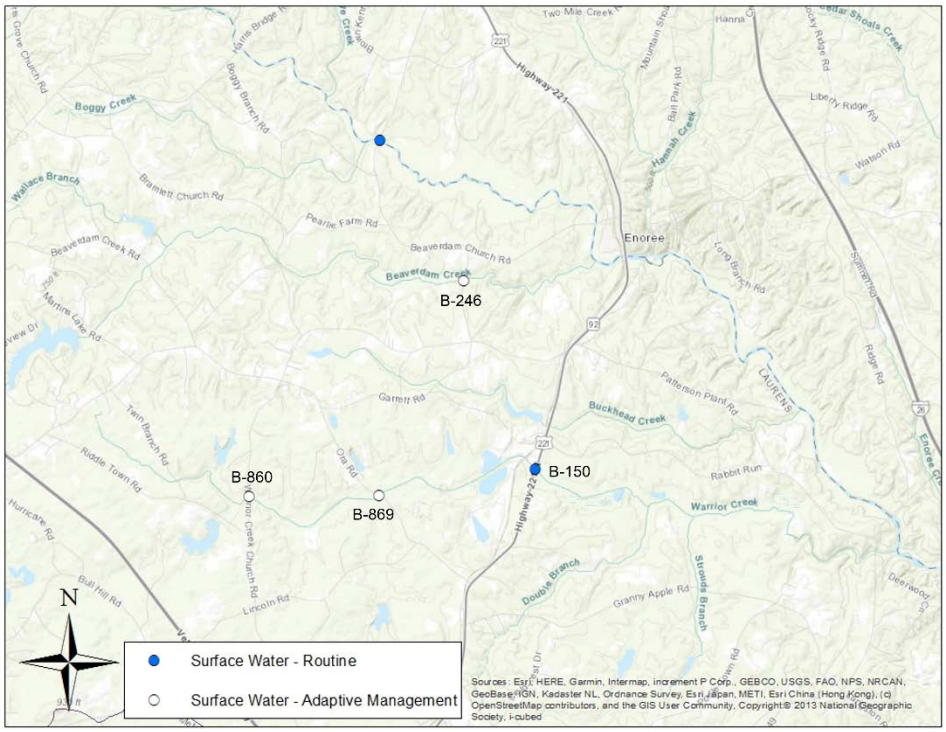
Saluda River Basin – Saluda River above Lake Greenwood



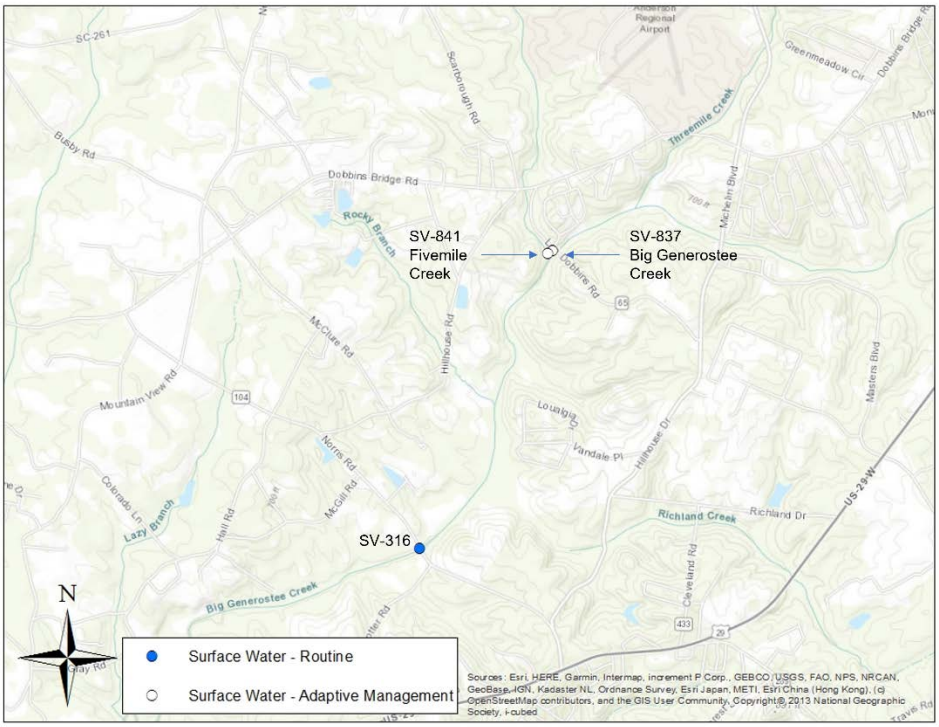
Lake Craig/Kelsey Creek near Croft State Park



Warrior Creek in the Enoree River Watershed



Big Generostee Creek near Anderson



Chinquapin Creek near Batesburg-Leesville