

**BASINWIDE WATER RESOURCES
MANAGEMENT PLAN**

**CYCLE 4 –
CAPE FEAR RIVER BASIN 2026**

North Carolina
Department of Environmental Quality
Division of Water Resources
Basin Planning Branch

DRAFT
Chapter 11
Northeast Cape Fear River Subbasin
HUC 03030007



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11 Northeast Cape Fear River Subbasin (HUC8 03030007)

11.1 General Description

The Northeast Cape Fear River subbasin is in the southeastern portion of the larger Cape Fear River Basin. This 8-digit hydrologic unit code (HUC) boundary (03030007) covers 1,741 square miles (mi²), or 1,114,240 acres, encompassing major portions of Duplin, Pender and New Hanover counties, as well as small fractions of Wayne, Onslow and Sampson counties. Major municipalities in the subbasin include Wilmington, Mt. Olive, Warsaw, Wallace and Rose Hill. Rural residential properties and communities are scattered throughout the subbasin.



The major river flowing through this subbasin is the Northeast Cape Fear River. This river flows through many of the previously listed counties as it travels from the headwaters near the Town of Mt. Olive in Wayne County to the Cape Fear River Estuary near the City of Wilmington in New Hanover County. While the Northeast Cape Fear River is the largest river system in this subbasin, many adjoining swamp-water tributaries feed this major river, including Goshen Swamp, Limestone Creek, Cypress Creek, Rockfish Creek, Angola Swamp, Long Creek and Harrison Creek. The drainage areas from these major rivers form the eight 10-digit HUC watersheds that comprise the Northeast Cape Fear River subbasin. These coastal plain creeks and swamps drain forested and wetland areas with extensive agriculture present.

In relation to the Level III Ecoregions scale, the Northeast Cape Fear River subbasin represents the transition zone from the Southeastern Plains to the Middle Atlantic Coastal Plain. These coastal areas are east of the “Fall Line” and contain many wetlands with tannin-stained slow-moving streams underlain by sedimentary rocks. On a finer scale, Level IV Ecoregions, this subbasin lies in the Rolling Coastal Plain, Swamps and Peatlands, Carolina Flatwoods, Mid-Atlantic Floodplains and Low Terraces. Included in these areas are the Holly Shelter Game Land in Pender County and Angola Bay Game Land just to the north on the Pender-Duplin County line (See Section 1.5 in Chapter 1 Regions of Ecological Significance).

There is at least one water quality monitoring station in the major tributaries in this subbasin which covers approximately 34% (378.1 miles) of freshwater miles and 100% (375.6 acres) of the saltwater acres being monitored across the subbasin (*Table 11-1*). Surface water quality monitoring stations consist of physical, chemical and/or biological monitoring data collection. Many of the impairments on the 2022 Integrated Report (IR) were found in urban areas but many were also found in more rural agricultural areas. The Northeast Cape Fear had 18.1% of the freshwater mile impairments in the Cape Fear River Basin. The location of permitted facilities and ambient and biological monitoring stations can be found in *Figure 11-1*. They are overlaid on a map of all classified waterbodies and their overall status as per the 2022 IR.

Water resource-related findings and issues identified in the Northeast Cape Fear River subbasin during the timeframe of this plan (2002 to 2020) include:

- Several impairments and/or water quality concerns consisting of stressed benthos, chloride, copper, fecal coliform bacteria and pH (Section 11.1).
- Population declines in six of the eight watersheds (Section 11.2).
- Significant numbers of animal feeding operations and deemed permitted poultry operations which have potential impacts to water quality (Section 11.3).
- Severe or Fair ratings were recorded for Muddy Creek (2003), Long Creek (2013), Goshen Swamp (2013) and Limestone Creek (2018), indicating benthos communities impacted by poor water quality and/or habitat (Section 11.4).
- Several waterbodies in the Northeast Cape Fear River subbasin are impaired due to arsenic and hexavalent chromium concentrations occurring above the Division of Public Health levels of concern in fish and shellfish tissue samples (Section 11.6).
- Elevated fecal coliform bacteria levels were detected in Panther (Creek) Branch (Section 11.8.1), Goshen Swamp (Section 11.8.1), Headwaters Northeast Cape Fear River (Section 11.8.2), Little Rockfish Creek (Section 11.8.5), Rockfish Creek (Section 11.8.5), Angola Swamp (Section 11.10.1) and Burgaw Creek (Section 11.10.1) during 2016 to 2020.
- The elevated and increasing fecal coliform bacteria and nutrient(s) (total phosphorus and/or nitrate+nitrite) concentrations detected at monitoring station(s) in Panther (Creek) Branch (Section 11.8.1.1), Goshen Swamp (Section 11.8.1.1), Northeast Cape Fear River (Section 11.8.2.1, 11.8.3.1 and 11.8.8.5), Little Rockfish Creek (Section 11.8.5.1), Rockfish Creek (Section 11.8.5.3) and Angola Swamp (Section 11.8.6.1) based on data collected from 2000 – 2019.
- Mt. Olive Pickle Company and Bay Valley Foods have chloride variances for their discharge into the headwaters of Northeast Cape Fear River [AU#: 18-74-19a] (Section 11.8.2.1) and Panther (Creek) Branch (Section 11.8.1.1 and 11.8.1.2).
- Based on calculated North Carolina Tropic Status Index scores for 2018, Cabin Lake was determined to have elevated biological productivity (**eutrophic conditions**) in May and September and exceptionally elevated biological productivity (**hypereutrophic conditions**) in June, July and August. Cabin Creek has exceptionally elevated biological productivity and recent sampling recorded exceedances of the 40 µg/L water quality standard for chlorophyll *a*, possibly due to excess nutrients (Section 11.8.3.4).
- A combined total of 30.7 freshwater miles in Stocking Head Creek [AU#: 18-74-24], Maxwell Creek [AU#: 18-74-24-1] and two unnamed tributaries to Stocking Head Creek [AU#: 18-74-24ut4 and 18-74-24ut5] are on the impaired waters list for excursions of the recreational standard for fecal coliform bacteria (Section 11.8.3.5).
- Ammonia concentrations displayed some of the highest annual mean values in Angola Creek compared to the other monitored waterways in the Northeast Cape Fear River subbasin (Section 11.8.6.1).

- The water quality in Burgaw Creek changed significantly after the removal of the Burgaw Wastewater Treatment Plant in 2012. While it appears overall water quality has improved, nutrient concentrations (total nitrogen and phosphorus) and fecal coliform bacteria concentrations are still concerning (Section 11.8.8.1).
- Several sanitary sewer overflow events that have impacted Smith Creek between 2010 and 2019 (Section 11.8.8.4).
- High annual mean fecal coliform bacteria concentrations were recorded in the 15.6-mile stretch of primary recreation waters (Class B) in the Northeast Cape Fear River (Section 11.8.8.5).
- The contribution of low dissolved oxygen from the Northeast Cape Fear River to the Cape Fear River could possibly contribute to lower dissolved oxygen levels found in the estuary (Section 11.10.2).
- Mallin, et al. (2004) concluded that additions of nitrogen and phosphorus into blackwater systems potentially increases biological oxygen demand by photosynthetic and heterotrophic activity that can subsequently reduce dissolved oxygen concentrations through increased biological oxygen demand (Section 11.10.3).
- A Soil and Water Assessment Tool was used in the Northeast Cape Fear River to assess the impact of point and nonpoint sources on total nitrogen, total phosphorus and dissolved oxygen (Section 11.10.3).

Figure 11-1: General Map of Monitoring Stations and Permitted Facilities in the Northeast Cape Fear River Subbasin.

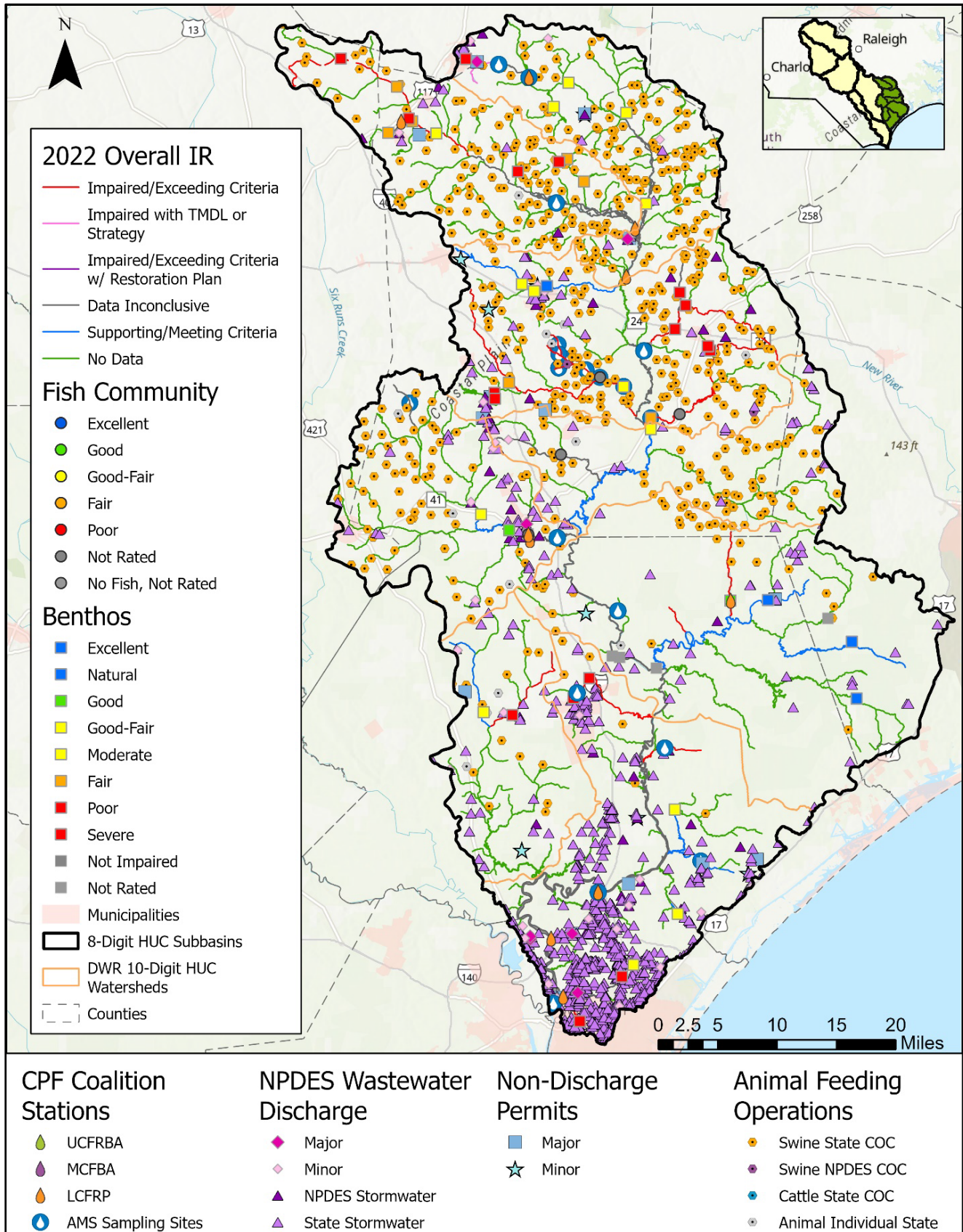


Table 11-1: Northeast Cape Fear River Subbasin 2022 Integrated Report Summary.

Assessment Unit ¹	Map Color	Freshwater Miles	Freshwater Acres	Saltwater Acres
Total	All Colors Combined	1,112.7	0.0	375.6
Total Monitored	Combined Blue, Gray, Red, Pink	378.1	0.0	375.6
Not Monitored	Green	734.6	0.0	0.0
Meeting Criteria (Category 1)	Blue	102.2	0.0	0.0
Data Inconclusive (Category 3)	Gray	159.1	0.0	375.6
Exceeding Criteria 303(D) (Category 5)	Red	113.4	0.0	0.0
Exceeding Criteria with TMDL (Category 4)	Pink	3.4	0.0	0.0
Exceeding Criteria (Combined Category 4 and 5)	Combined Red and Pink	116.8	0.0	0.0
% Exceeding of Monitored Exceeding (Combined Category 4 and 5)	Combined Red and Pink / Total	30.9%	0.0%	0.0%

¹ All waterbodies in North Carolina are impaired for Fish Tissue Mercury and not included in Category 4 and 5 impairments on this table.

Based on the data collected in the monitored waterways, 116.8 freshwater miles in this subbasin have at least one water quality impairment for excursions of different water quality standards based on the 2022 IR (*Table 11-1*). Benthos and fecal coliform impairments are the most prevalent across this subbasin (*Table 11-2*). The six benthos impairments (totaling 68.8 miles) are in sections of Goshen Swamp, Limestone Creek, Muddy Creek, Burgaw Creek, Long Creek and Burnt Mill Creek. The four fecal coliform impairments (totaling 30.8 miles) are based on a 5-in-30 sampling methodology and were identified in Stocking Head Creek, Maxwell Creek and two unnamed tributaries to Stocking Head Creek. There is a single copper impairment identified along the entire length of Burgaw Creek; two pH impairments (totaling 7.4 miles) in Mill Pond and Lillington Creek; and one chloride impairment in the upper reaches of the Northeast Cape Fear River.

All waterbodies statewide are impaired for mercury in fish tissue and a Total Maximum Daily Load (TMDL) in place (NCDEQ, 2012). The impairment for fish tissue mercury is not included in tables or maps. Excess nutrients (nitrogen and phosphorus) and fecal coliform bacteria from both point (industrial and municipal wastewater systems) and nonpoint sources (land use and land cover, stormwater management systems and animal feeding operations) are also concerns that need to be addressed throughout this subbasin and will be discussed throughout this chapter.

Table 11-2: Northeast Cape Fear River Subbasin 2022 Impairments by Parameter (Category 4 and 5).

PARAMETER (Category 4 and 5 Combined) ^{1,2}	FW Miles ³	FW Acres ³	SW Acres ³
Benthos (Nar, AL, FW)	68.8	0.0	0.0
Chloride (230 mg/l, AL, FW)	3.4	0.0	0.0
Copper (7 µg/l, AL, FW)	9.5	0.0	0.0
Fecal Coliform (GM 200/400 5 in 30, REC, FW)	30.8	0.0	0.0
pH (4.3 su, AL, Sw)	7.4	0.0	0.0

¹ Waterbody Uses: AL – Aquatic Life, REC – Recreation.

² Waterbody Type: FW – Freshwater, Sw - Swamp Waters.

³ Other: GM – Geometric Mean, Nar – Narrative.

There are three class B waterways in the Northeast Cape Fear River subbasin totaling 21.1 freshwater miles (*Table 11-3*). Class B waters have primary contact recreation as best uses, i.e., swimming, diving, water skiing and similar uses involving human body contact in an organized manner or on a frequent basis. These include sections of Cabin Creek, Duff Creek (Lake Tut) and Northeast Cape Fear River from N.C. Hwy. 210 to Prince George Creek. There is one class SC water classification on the Northeast Cape Fear River from the mouth of Ness Creek to the Cape Fear River. There is also a High Quality Water classified waterway along the Northeast Cape Fear River from Muddy Creek to Rockfish Creek. There are Primary Nursery Areas in the Northeast Cape Fear River and Tonys Creek as described in 15A NCAC 03R .0103. All waterways in this subbasin are at least Class C waterways, which have best uses as secondary contact recreation, aquatic life propagation/protection and agriculture. Neck Savanna in Pender County is the only waterway classified as a Unique Wetland in the Northeast Cape Fear River subbasin. All the surface waters that are monitored in this subbasin have the supplemental swamp water classification. This classification is due to the natural characteristics of swamps such as low dissolved oxygen and low pH. See Section 11.7.8 for more details on dissolved oxygen in the Northeast Cape Fear River subbasin and adjoining watersheds.

Table 11-3: Northeast Cape Fear River Subbasin Surface Water Classifications

Classification*	Freshwater Miles	Freshwater Acres	Saltwater Acres
C	1,112.7	0.0	0.0
B	21.1	0.0	0.0
SC	0.0	0.0	375.6
Sw	1,102.7	0.0	375.6
HQW	19.5	0.0	0.0

*Waterbody Classification C - Aquatic life propagation and secondary recreation, B - Primary contact recreation, SC - Tidal salt waters, Sw - Swamp Waters

11.2 Population and Land Use

The Northeast Cape Fear River subbasin drainage area is 1,741 square miles across eight watersheds (*Table 11-4*). These watershed drainage areas range from 141 to 377 square miles. During 2010 to 2020, a majority of the eight 10-digit hydrologic unit code (HUC) watersheds decreased in population except for the Cypress Creek – Northeast Cape Fear River (NECFR) and Harrisons Creek – NECFR watersheds, which increased in population. The losses ranged from 431 to 3,155 people. The increases range from 57 to 7,688. The largest population change was identified in the Harrisons Creek-NECFR watershed, which contains Wilmington. Wilmington, in northern New Hanover County and Mt. Olive, in southern Wayne County, are two of the largest municipalities located in this watershed. Based on the 2020 Census data, the population in the Northeast Cape Fear River subbasin is estimated to be 164,048 (*Table 11-4*).

Table 11-4: Estimated Population of the Watershed Boundary Scale (HUC 10)

HUC10 Watershed Name	HUC10	Land Area (mi ²)	Population 2010	Population 2020	Population Density 2020 (pop/mi ²)	2010 - 2020 Pop. Change
Goshen Swamp	0303000701	185	11,055	8,444	46	-2,611
Headwaters NECFR	0303000702	162	15,703	12,548	77	-3,155
Limestone Creek-NECFR	0303000703	257	17,772	15,727	61	-2,045
Cypress Creek-NECFR	0303000704	154	11,427	11,484	75	+57
Rockfish Creek	0303000705	178	12,682	10,830	61	-1,852
Angola Swamp-NECFR	0303000706	377	5,932	5,501	15	-431
Long Creek	0303000707	141	6,985	6,179	44	-806
Harrisons Creek-NECFR	0303000708	287	85,647	93,335	325	+7,688
Northeast Cape Fear River Subbasin Total		1,741	167,203	164,048	94	-3,155

Table data is from NC One Map US Census Block Data for 2010 and Esri Living Atlas for 2020 USA Census Redistricting Blocks processed for Cape Fear River Basin HUC10s.

As of 2019, the land cover across the subbasin was approximately 638 square miles of wetlands (37%), 422 square miles of agricultural lands (24%) and 436 square miles of forest land (25%). The remaining land cover was 107 square miles of grassland/shrub (6%), 123 square miles of developed land (7%), 12 square miles of open water (0.7%) and two square miles of barren land (0.1%) (*Table 11-5*). This land cover provides a perspective for which to view the water quality in this subbasin. Agricultural lands, forest land, wetlands and developed land all function within the environment to influence water quality. The complex interactions of water with these different landscapes are observable in the elevated nutrient and fecal coliform bacteria concentrations detected in some waterways in this subbasin.

The Cape Fear River Basin has many diverse wetland habitats with close to 90% located in the lower half of the basin in the Coastal Plain ecoregion of the Black River, lower Cape Fear River and Northeast Cape Fear River subbasins. The Northeast Cape Fear River subbasin accounts for 37% of the wetland cover.

Common freshwater wetland types in the Cape Fear River Basin include riverine swamp forests, bottomland hardwoods, pocosins, Carolina bays and pine flatwoods. Riverine swamps and bottomland hardwood forests buffer many of the rivers and creeks in the basin. Riverine swamps are more common in the Coastal Plain, including the Northeast Cape Fear River and its Goshen Swamp tributary. The most expansive areas of swamp forest occur at the confluence of the Cape Fear and Black rivers and along the lower part of the Northeast Cape Fear River. Pocosin wetlands have an important presence in the Cape Fear River Basin and are most common in the Northeast Cape Fear River subbasin, where more than a third of the basin’s wetlands are found. The two largest tracts of pocosins are located at the Holly Shelter Game Land in Pender County and Angola Bay Game Land just to the north on the Pender-Duplin county line. More information on regions of ecological significance, land cover and wetlands across the entire Cape Fear River Basin can be found in Chapter 1.

Table 11-5: Land Cover of Northeast Cape Fear River Subbasin.

Land Cover¹	2001	2011	2019	% Change 2001-2019	Mi² Change 2001-2019	Total Mi² 2019
Agriculture	24.09%	24.14%	24.25%	0.67%	2.81	422.25
Barren Land²	0.14%	0.13%	0.13%	-4.43%	-0.10	2.26
Developed	6.49%	6.89%	7.06%	8.72%	9.86	122.96
Forest	25.50%	25.38%	25.02%	-1.91%	-8.47	435.67
Grassland/Shrub	6.34%	6.02%	6.14%	-3.27%	-3.61	106.85
Open Water	0.66%	0.81%	0.70%	6.16%	0.71	12.26
Wetlands	36.77%	36.63%	36.71%	-0.19%	-1.19	639.23
Total Mi²						1,741.48

¹ Data was downloaded from the Multi-Resolution Land Characteristics NLCD website and processed for each Cape Fear River Basin HUC8 in 2022.

² Barren Land is a catch-all category for tilled land, new development, cutover, bare rock areas.

The watersheds of the Northeast Cape Fear River subbasin exhibit a diversity of uses, including agricultural, forested landscapes and wetlands (*Table 11-6, Figure 11-2*). The Goshen Swamp, Headwater Northeast Cape Fear River, Limestone Creek-Northeast Cape Fear River and Rockfish Creek watersheds all have greater than 30% of land cover in agriculture. These four watersheds also contain some of the lowest percentages of wetlands with between 21 and 24% of the land cover containing wetlands. The watersheds with an abundance of wetlands include the Angola Swamp – Northeast Cape Fear River and Harrisons Creek – Northeast Cape Fear River watersheds with greater than 47% of the land cover as wetlands. The Harrisons Creek – Northeast Cape Fear River watershed also has the highest percentage of developed land at greater than 15%. Cypress Creek – Northeast Cape Fear River and Long Creek are both dominated by forest land at greater than 30%. Notably, these two watersheds also contain the highest percentages of grassland/shrub.

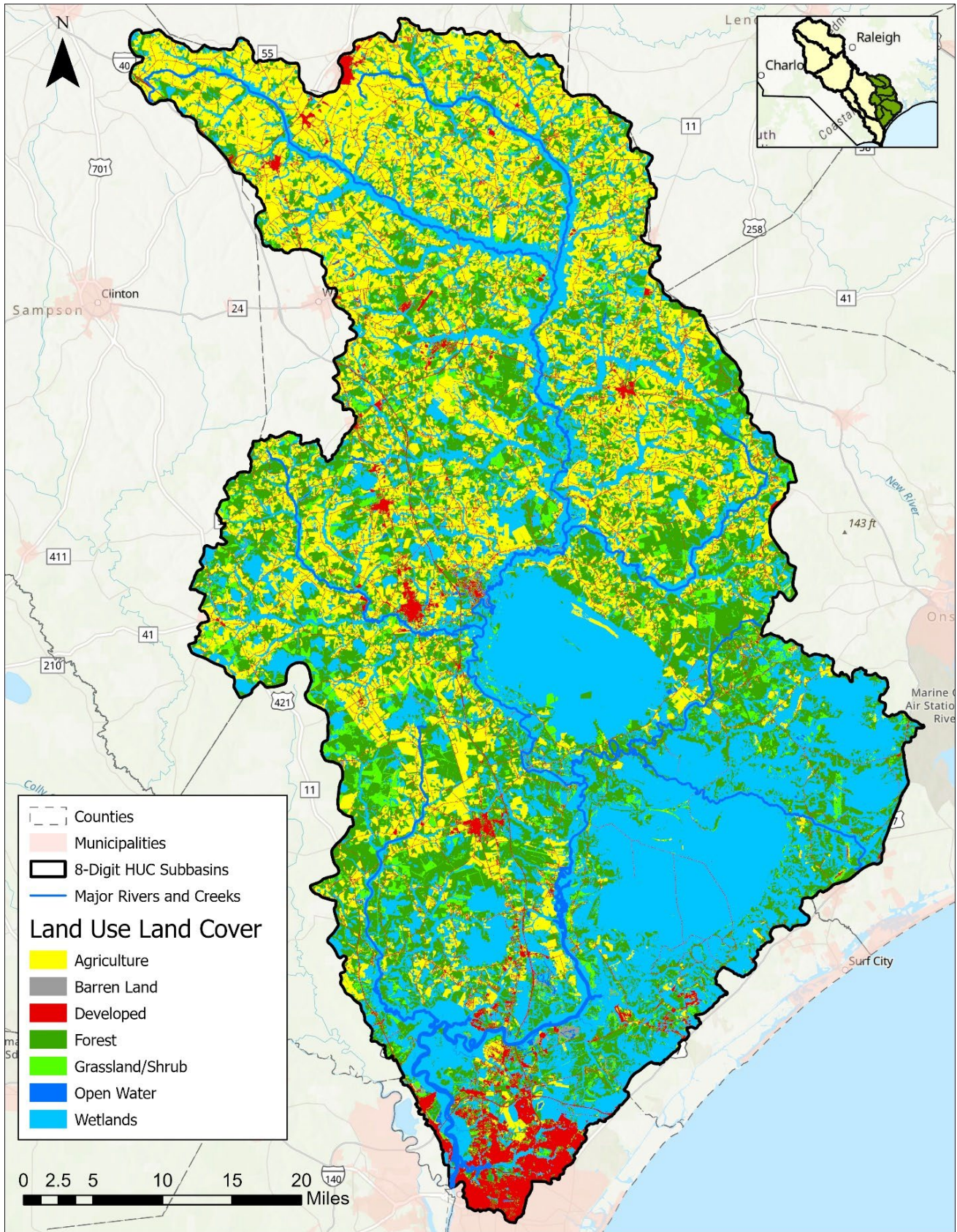
Table 11-6: Land Cover in the HUC10 Watersheds of the Northeast Cape Fear River Subbasin in 2019.

Watershed ¹	Land Area (mi ²)	Agriculture	Barren Land ²	Developed	Forest	Grassland/ Shrub	Open Water	Wetlands
Goshen Swamp	185	51.23%	0.01%	6.37%	16.98%	3.97%	0.50%	20.93%
Headwaters NECFR	162	46.54%	0.01%	7.33%	19.92%	4.42%	0.28%	21.50%
Limestone Creek-NECFR	257	33.85%	0.01%	7.11%	28.14%	7.45%	0.38%	23.07%
Cypress Creek-NECFR	154	26.31%	0.03%	6.65%	31.32%	7.43%	0.53%	27.73%
Rockfish Creek	178	31.73%	0.02%	6.92%	28.83%	9.36%	0.33%	22.82%
Angola Swamp-NECFR	377	5.65%	0.05%	2.21%	21.93%	4.44%	0.35%	65.36%
Long Creek	141	17.25%	0.07%	4.06%	38.77%	9.93%	0.46%	29.47%
Harrisons Creek-NECFR	287	7.79%	0.62%	15.46%	21.87%	5.01%	2.28%	46.97%

¹Data was downloaded from the Multi-Resolution Land Characteristics NLCD website and processed for each Cape Fear River Basin HUC8 in 2022.

² Barren Land is a catch-all category for tilled land, new development, cutover, bare rock areas.

Figure 11-2: Land Cover in the Northeast Cape Fear River Subbasin.



11.3 Permits

As of May 2022, there were 37 National Pollutant Discharge Elimination System (NPDES) wastewater, 26 non-discharge and land application, 79 NPDES stormwater, 1,825 state stormwater and 558 animal feeding operation (AFO) permits issued in the Northeast Cape Fear River subbasin (*Table 11-7*). *Figure 11-3* shows the location of the permitted facilities in the Northeast Cape Fear River subbasin.

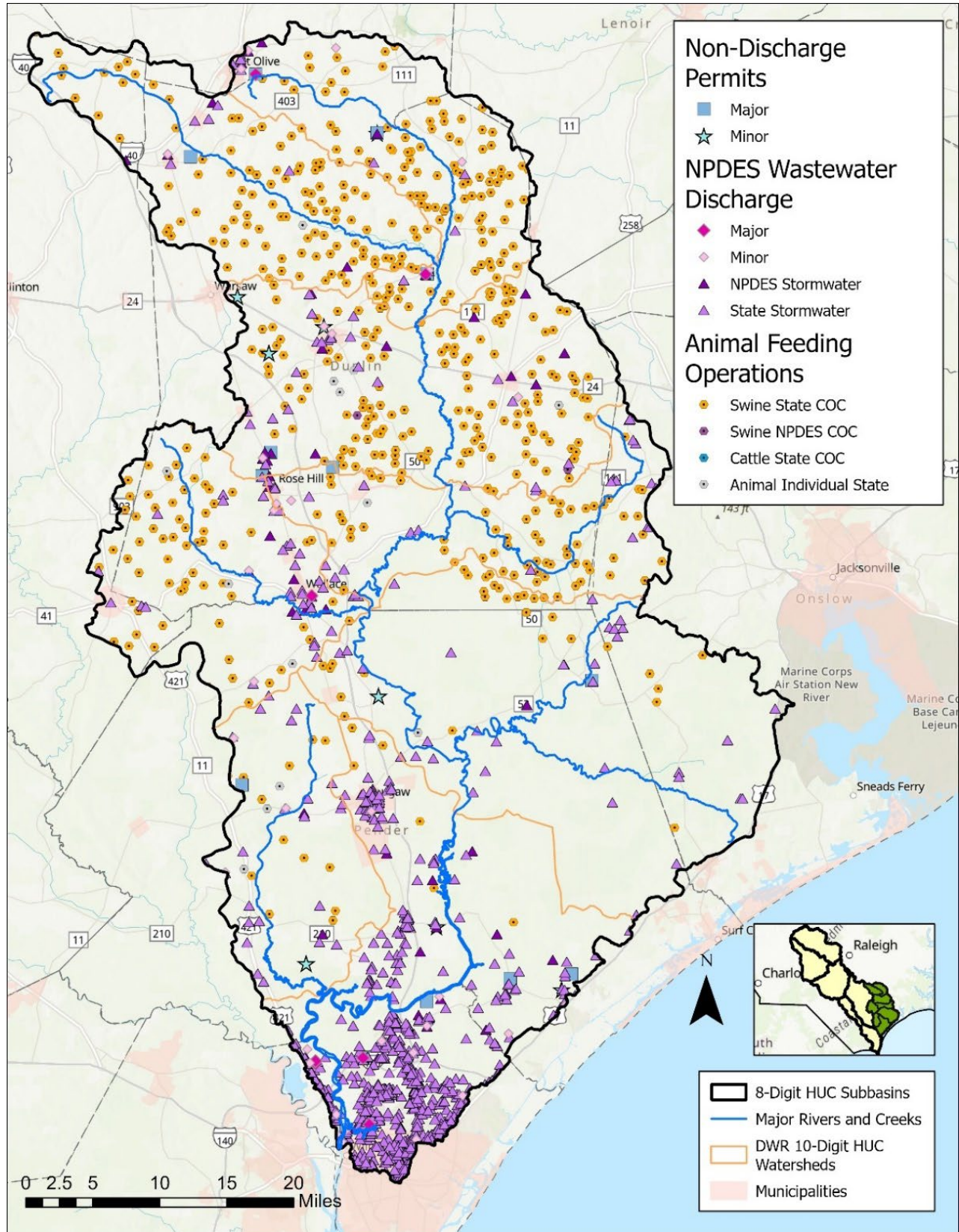
The Northeast Cape Fear River subbasin accounts for just 7% the total permitted as-built discharge (425.47 MGD) in the Cape Fear River Basin. There are 7 major NPDES permits for municipal and industrial wastewater treatment plants (WWTPs) and 30 minor NPDES permits in the subbasin with a total permitted as-built flow of 30.5 MGD (*Table 11-8*). Facilities designated as major are permitted to discharge more than one million gallons per day (1 MGD). Three of the major facilities discharge directly to the Northeast Cape Fear River, two discharge to the mainstem Cape Fear River, one discharges to both the mainstem and Northeast Cape Fear rivers and one discharges to Rockfish Creek.

The Northeast Cape Fear River subbasin also accounts for 17% of the total permitted field acreage (21,771 acres) for non-discharge and residual land application permits in the Cape Fear River Basin. Permitted fields are primarily used for land application of residual solids.

Table 11-7: Permitted Facilities and Associated Information in the Northeast Cape Fear River Subbasin.

Number of Permits ¹		Permit Information ¹	
NPDES Wastewater Discharge²			
Major	Minor	Permitted As-Built (MGD)	
7	30	30.45	
Non-Discharge and Land Application³			
Major	Minor	Field Number	Field Acres
16	10	228	3,720.7
Stormwater			
State	NPDES	NPDES Outfalls	
1,825	79	124	
Animal Feeding Operations			
Number of Permits		Allowable Headcount	Allowable Weight (lb)
558		2,447,261	315,906,806
¹ Active and expired permitted facilities and associated permit data were queried from the DWR Basinwide Information Management System (BIMS) in May 2022. Expired permits remain in effect until a renewed permit is issued by DWR. ² Permitted NPDES discharge facility numbers are based on the number of facilities and as-built totals that discharge to the Cape Fear River Basin ³ Some permitted fields are associated with facilities located outside of the Cape Fear River Basin.			

Figure 11-3: NPDES Wastewater, NPDES Non-Discharge, NPDES Stormwater and Animal Operations Permits in the Northeast Cape Fear River Subbasin.



Several NPDES and many state stormwater permits are concentrated near Wilmington in the lower part of the subbasin. Wilmington is the only NPDES Municipal Separate Storm Sewer System (MS4) program in the subbasin. NPDES MS4 permits are required for every owner/operator of facilities in areas that the US Census Bureau designates as an Urbanized Area. More information about the permitting programs, state stormwater facilities and Urbanized Areas can be found in Chapter 3. A complete list of permits can be found in the Chapter 3 Appendix.

Permitted AFOs have a significant presence in the Northeast Cape Fear River subbasin. The Northeast Cape Fear River subbasin ranked first with the highest number of permitted AFOs in the basin (and statewide) with 558 permitted operations. As of May 2022, the permitted AFOs are primarily swine with 541 Swine State Certificates of Coverage (COC), three Swine NPDES COCs and 14 Animal Individual State COCs. This subbasin also accounts for 42% of the total permitted live weight in the basin with 315.9 million pounds, the second highest permitted live weight in the basin and the state. There are 887 lagoons associated with AFO facilities in the subbasin, the second highest in the basin and the state. These lagoons account for over 20% of all lagoons and waste ponds (4,046 statewide) in North Carolina. Overall basin maps and summary tables are available in Chapter 1, section 1.5.1, Chapter 1 appendix and permit maps and tables in Chapter 3, section 3.6.

In addition to permitted animal operations, the US Department of Agriculture (USDA) 2022 [Census of Agriculture](#) data indicates that there are numerous poultry and swine operations located in the counties located entirely or partially within the Northeast Cape Fear River subbasin. Many of these operations are considered deemed permitted under North Carolina Administrative Code (NCAC) [15A NCAC 02T .1303](#). Deemed permitted is defined as “a facility that is considered to have a needed permit and to be in compliance with the permitting requirements of [General Statute 143-215.1\(a\)](#) even though it has not received an individual permit for its construction or operation.” The Census of Agriculture can be used to help evaluate which counties have the highest agricultural activity. It can also be used to evaluate historic agricultural trends to formulate policies, develop programs and identify and allocate local and national funds for agricultural programs.

To understand animal agriculture in the subbasin, Duplin and Pender counties were queried for poultry and swine numbers. Both counties reported an increase in poultry inventory and production numbers between 2007 and 2022 ([Table 11-8](#)). Combined, inventory increased by 119% (from 11 million to 24.1 million) and production contracts increased by 108% (from 50.8 million to 105.4 million) ([Table 11-8](#)). Of the two counties queried for this subbasin, Duplin County contains 91% of both the 2022 inventory and production contract numbers. When reviewing the Census of Agriculture for all counties in the basin, [Duplin County had the highest poultry numbers for both inventory and production contracts in 2022 \(Figure 11-4, Figure 11-5\) followed by Sampson and Randolph counties](#). Duplin County accounts for 29% (22 million) of the Cape Fear River Basin chicken inventory (76 million) and 10.5% of the statewide chicken inventory (209.6 million).

[Duplin County also had the highest inventory of swine/hogs \(1.89 million\) followed by Sampson County \(1.85 million\) \(Figure 11-6\)](#). Duplin County produces 38% (1.89 million) of the Cape Fear River Basin’s swine inventory (4.9 million) and 23.8% of the statewide inventory (7.9 million). DWR has minimal information on the location of deemed permitted facilities or the location of where manure is transported and land

applied. More information about counties queried for the Census of Agriculture can be found in Chapter 1 and the Chapter 1 Appendix.

Table 11-8: USDA Census Data for Chicken/Poultry and Swine in Northeast Cape Fear River Subbasin Counties.

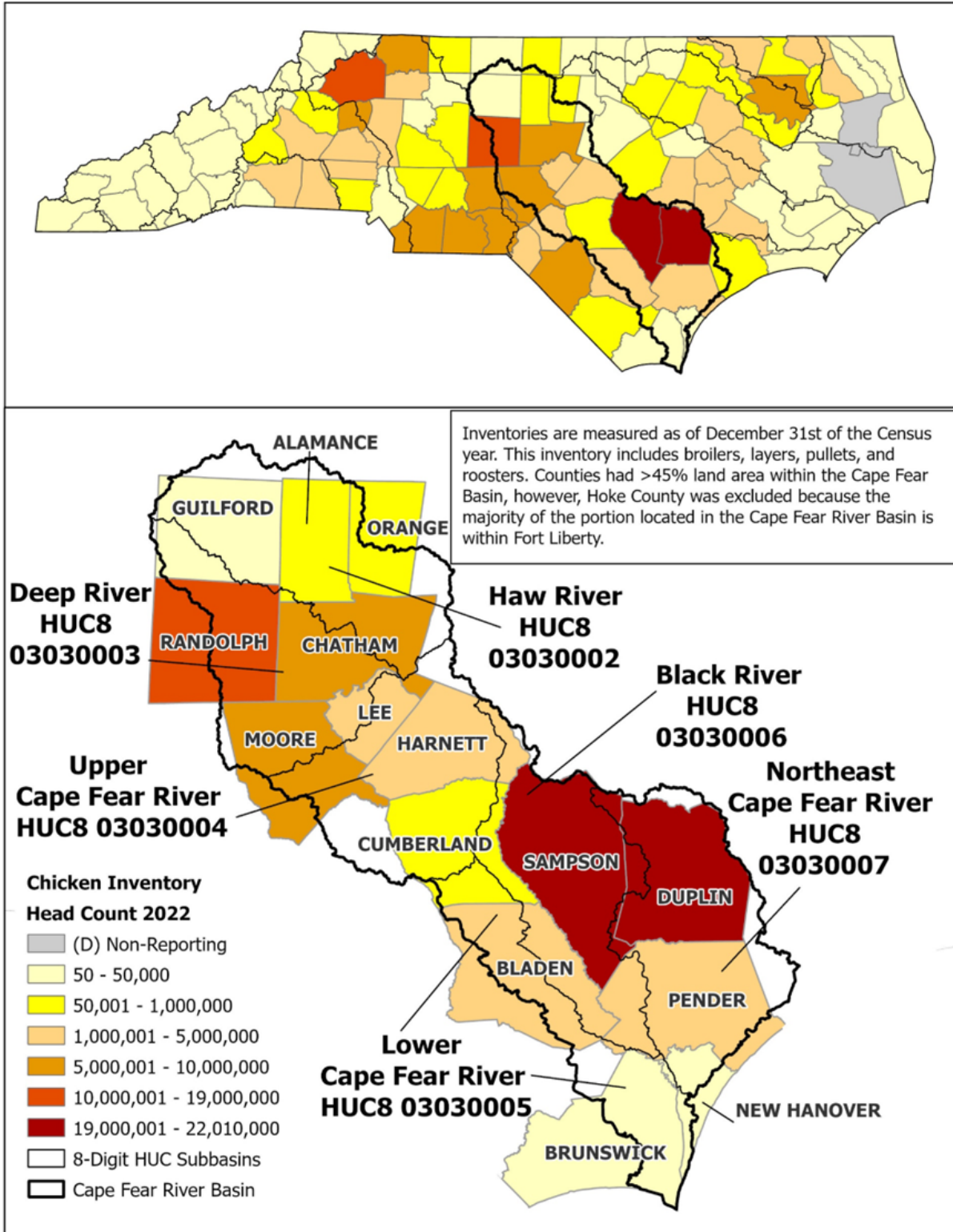
USDA Data	Duplin ³	Pender ³	Total
Poultry 2007			
Inventory ¹	10,257,442	782,097	11,039,539
Contract ²	46,840,736	3,925,250	50,765,986
Poultry 2012			
Inventory ¹	12,325,690	2,240,861	14,566,551
Contract ²	58,126,617	9,594,234	67,720,851
Poultry 2017			
Inventory ¹	16,592,763	1,572,756	18,165,519
Contract ²	69,770,960	7,840,573	77,611,533
Poultry 2022			
Inventory ¹	22,008,081	2,108,056	24,116,137
Contract ²	95,986,288	9,442,408	105,428,696
Swine (Hogs) 2007			
Inventory ¹	2,285,224	254,180	2,539,404
Contract ²	7,337,237	1,043,516	8,380,753
Swine (Hogs) 2012			
Inventory ¹	1,733,026	203,873	1,936,899
Contract ²	4,986,039	578,214	5,564,253
Swine (Hogs) 2017			
Inventory ¹	1,957,364	269,727	2,227,091
Contract ²	5,380,492	1,220,283	6,600,775
Swine (Hogs) 2022			
Inventory ¹	1,884,573	254,535	2,139,108
Contract ²	6,477,337	796,200	7,273,537

¹ USDA Inventory numbers represent a point in time (end of December) when the census data were collected. Poultry includes broilers, layers, pullets and roosters.

² USDA Production Contract numbers are “totals for the portion of agriculture production raised and delivered under production contract” (USDA, 2017). Chicken production accounts for data items associated with broilers, layers and pullets for 2012 to 2022 and broilers and pullets for 2007. Production Contract and Inventory represent different data items and cannot be combined or added.

³ Counties included in this table have >45% land area within the Cape Fear River Basin.

Figure 11-4: USDA Census of Agriculture Chicken/Poultry Inventory (USDA, 2022)



p

Figure 11-5: USDA Census of Agriculture Chicken/Poultry Production (USDA, 2022)

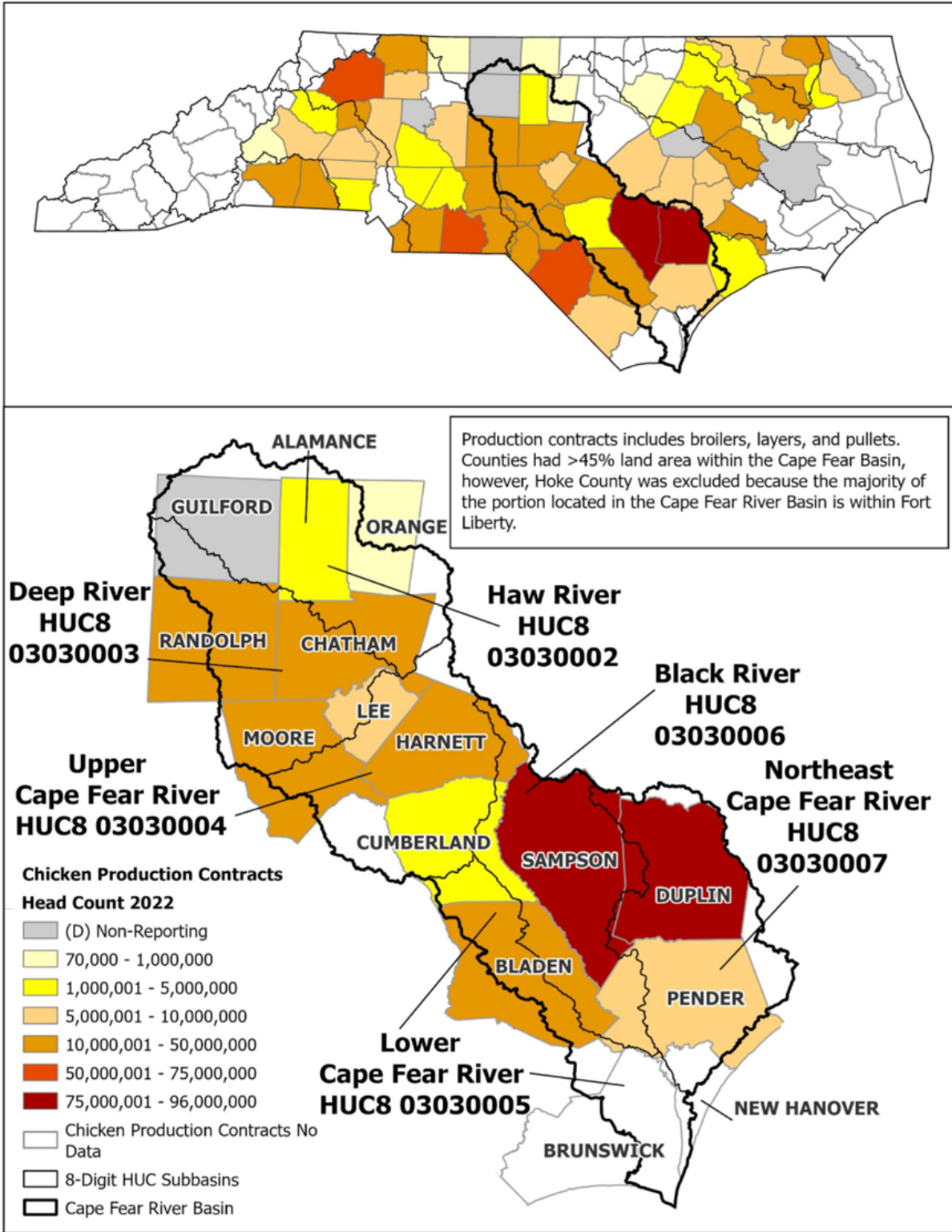
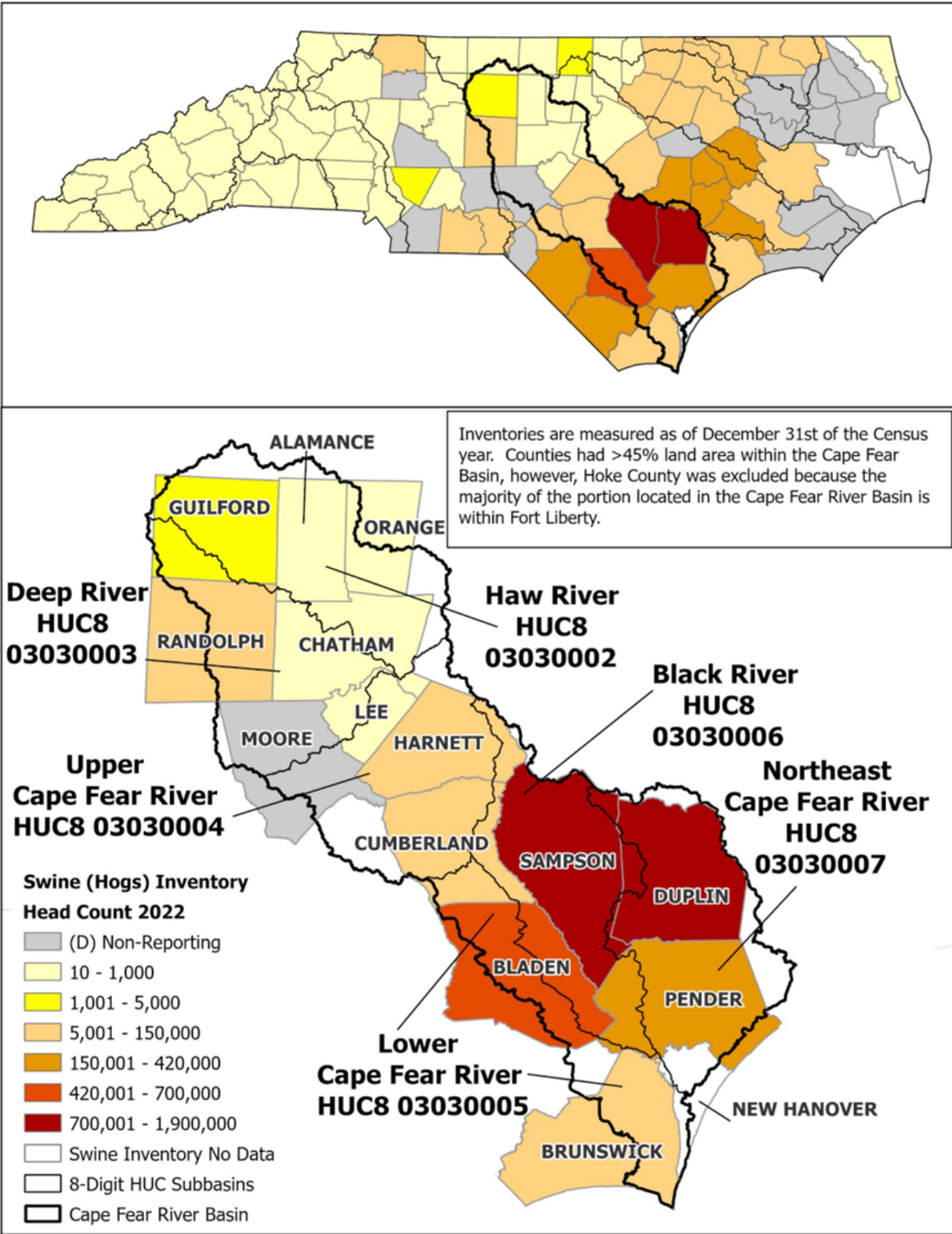


Figure 11-6: USDA Census of Agriculture Swine (Hog) Inventory (USDA, 2022)



The United State Geological Survey (USGS), with financial support from an EPA Section 319 grant, conducted a study and produced a report titled *Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Animal Feeding Operations*. This study compared 54 agricultural watersheds, with drainage areas less than 20 square miles, that either received drainage from areas with swine AFOs or streams receiving primarily inorganic fertilizer inputs (Harden, 2015). The study provided needed information “from a large number of sites over a broader geographic area to better understand relations between swine CAFOs [concentrated animal feeding operations] and stream water quality in eastern North Carolina” (Harden, 2015). Included in this study were the Black River, Northeast Cape Fear River and Lower Cape Fear River subbasins. The full report is available online at <https://pubs.usgs.gov/sir/2015/5080/pdf/sir2015-5080.pdf>. This study identified waterways with “measurable concentrated animal feeding operations manure effects” (Harden, 2015). As this chapter focuses on the Northeast Cape Fear River subbasin, we will briefly highlight the waterways that were identified by the USGS report within this subbasin by stream name, stream index and associated USGS site number *Table 11-9*.

Table 11-9: United State Geological Survey Stations with Measurable Concentrated Animal Feeding Operations Manure Effects.

Stream name	Stream Index	USGS Site Name	Watershed
Young Swamp	18-74-19-1	SW-11	Goshen Swamp
Big Branch	18-74-19-9-1	SW-12	Goshen Swamp
King Branch	18-74-19-13-1	SW-13	Goshen Swamp
Bear Swamp	18-74-19-9	SP-12	Goshen Swamp
Nahunga Creek	18-74-19-13	SP-13	Goshen Swamp
Poley Branch	18-74-8-4	SP-14	Headwaters Northeast Cape Fear River
Stephens Swamp	18-74-25-2	SP-16	Limestone Creek
Doctors Creek	18-74-29-3	SP-18	Rockfish Creek

“SW – 00” – Swine site and number

“SP – 00” – Swine and poultry site and number

Note: Big Branch confluent with Bear Swamp. King Branch confluent with Nahunga Creek.

The USGS study conclusions state: “On the basis of the results of this study, it is apparent that land-applications of waste manure at swine CAFOs influenced ion and nutrient chemistry in many of the North Carolina Coastal Plain streams that were studied. In particular, sodium+potassium concentrations coupled with $\delta^{15}\text{N}$ values of nitrate+nitrite were useful water-quality indicators for distinguishing sites with measurable CAFO manure effects.” (Harden, 2015). “On the basis of the comparisons of sodium+potassium concentrations, nitrate+nitrite concentrations, and the $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ of nitrate+nitrite values, 10 of the 36 CAFO sites (28%) had results similar to background conditions, and 21 of the sites (58%) had results with measurable CAFO manure effects. Note that the identification of those SW [swine] or SP [swine and poultry] watersheds as being similar to background conditions does not necessarily imply that CAFOs in those watersheds have no local influence on water quality, only that no distinction was noted at the watershed sampling location for the constituents that were examined.” (Harden, 2015). “Five of the SW and SP sites (14%) had limited or indeterminate results for determining whether they were similar to background or manure influenced” (Harden, 2015). “Interestingly, some individual SW and SP sites did not appear to be affected by animal-waste manures” (Harden, 2015). The

study also states: “it would be beneficial to base future similar analyses on a larger number of samples that more fully reflect hydrologic and seasonal variability in water-quality conditions among sites of interest” (Harden, 2015). Brown et al. (2020) investigated the spatial nutrient variability and seasonal variability of nutrients in the Black, Northeast Cape Fear and Lower Cape Fear rivers using $\delta^{15}\text{N}$ isotopes. This study is also available online at <https://pubmed.ncbi.nlm.nih.gov/32666139/>.

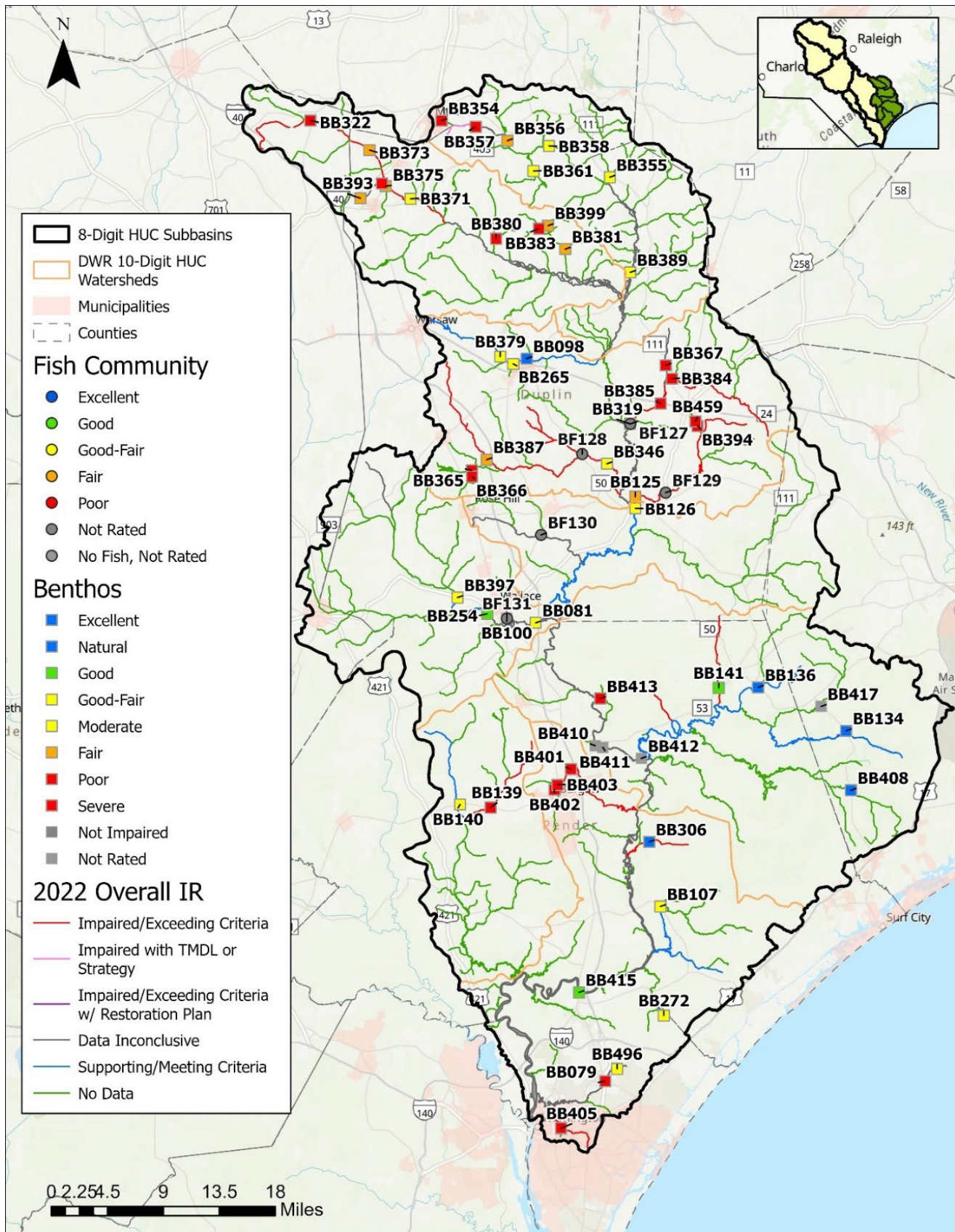
DWR permits animal feeding operations with liquid waste management systems under non-discharge permits. The Division has little to no information on deemed permitted facilities. To better understand how these facilities are impacting our water resources, more information (i.e., water quality data, source identification) is needed throughout the basin. Data collected could be used by an interagency workgroup consisting of water resource professionals, the agricultural community, researchers (academia), database managers and interested community members to review the existing regulatory framework, identify which BMPs are most effective at reducing the amount of sediment, bacteria and nutrients leaving a site and how best to manage and track waste generated on the farm.

11.4 Biological Health

Biological aquatic communities are highly sensitive to changes in both water quality and quantity and are indicators of both long- and short-term environmental conditions. Benthos and fish community survey information are collected on species richness (i.e., diversity), abundance and composition, as well as site specific conditions, such as stream habitat, physical water quality parameters, stream width and flow regime. Survey results, and the presence of pollution tolerant and/or intolerant benthos species, are used to calculate an IBI, or an Index of Biotic Integrity score. Fish community IBIs evaluate the effects of all classes of factors that influence the fish community (i.e., water quality, energy source, habitat quality, flow regime and biotic interactions). Therefore, not all changes in the fish community are related to water quality. Fish community scores are a measure of the ecological health of the waterbody and may not directly correlate to water quality as benthic scores do. IBI scores are assigned a descriptive rating, or bioclassification: Excellent, Good, Good-Fair, Fair, Poor, Not Rated or Not Impaired. An “EPT” Biotic Index (BI) can also be used to assign ratings by using pollution sensitive species of mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Trichoptera*). Benthic biocriteria, bioclassification assignment and [sampling methodology](#) can vary with region and stream conditions.

In the Northeast Cape Fear River subbasin, three assessment methodologies were used: Swamp (primarily), EPT and Full Scale. Fish community IBIs have not been developed for the Coastal Plain ecoregion where most of the Northeast Cape Fear River subbasin is located; therefore, the fish community results cannot be rated. See the [Benthic Standard Operating Procedures \(SOP\)](#) available through DWR Water Sciences Section (WSS) for more information on biological monitoring and bioclassification ratings and Chapter 2 for more information on basinwide biology sampling. The [Biological Assessment Branch](#) monitors each basin on a rotating five-year cycle. Basin monitoring locations are often re-visited during each cycle. Additional locations, called special study sites, may be monitored once or multiple times and are assessed during the monitoring cycle year and/or between cycle years. The basin monitoring cycle years covered in this plan were completed in 2008, 2013 and 2018. Biological monitoring is occurring in 2023 as well but will not be included in this plan. The results of the previous monitoring cycle, completed in 2003, were evaluated as a point of comparison. All monitoring stations in the Northeast Cape Fear River subbasin are displayed with their current ratings in [Figure 11-7](#).

Figure 11-7: Biological Community Monitoring Stations for Benthos and Fish in the Northeast Cape Fear River Subbasin.

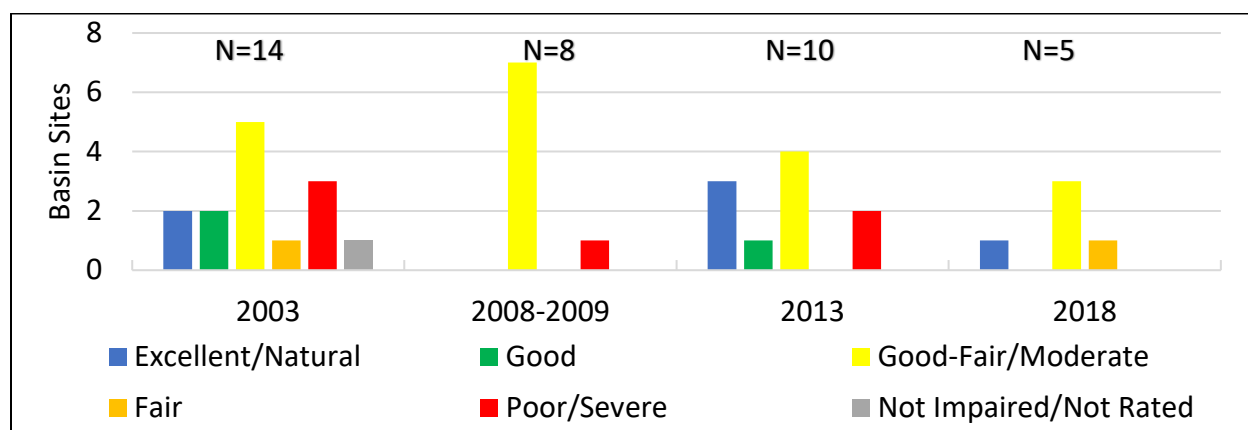


11.4.1 Benthic Macroinvertebrates

The Northeast Cape Fear River subbasin benthos monitoring results for the four cycle years are displayed in *Figure 11-8*. Basin station monitoring results for 2009 were also combined with 2008 as some stations were sampled (or resampled) in 2009 due to the drought in 2008. The most recent round of sampling occurred in 2018. Additionally, more stations were sampled during the first three cycle years than in the last cycle year. A total of five benthos stations were sampled in this subbasin in 2018. These stations were previously sampled during the prior rounds of sampling, providing a recent metric to determine which stations have improved, declined, or remained at a repeatable rating. Eleven stations were sampled in either 2013 or 2018 with comparable sites sampled in 2003, 2008, or 2009. The results from these 11 sites showed improvement at two sites, decline at two sites and seven sites remained unchanged. A Moderate rating was the most common during all four sample cycles. Severe or Fair ratings were recorded for Muddy Creek (2003), Long Creek (2013), Goshen Swamp (2013) and Limestone Creek (2018), indicating benthos communities impacted by poor water quality and/or habitat. Holly Shelter Creek (2013) and Lillington Creek (2018) received the Natural rating, indicating good swamp habitat, biotic index and taxa richness. All benthos and fish community station results from 2002 to 2021 are available in the Chapter 2 Appendix.

In addition to benthos and fish community monitoring, DWR investigates fish kills that occur across North Carolina. Between 2010 and 2020, two fish kill events were recorded in the Northeast Cape Fear River. One event occurred in an unnamed tributary to the Northeast Cape Fear River in the aftermath of Hurricane Irene in 2011 resulting in an estimated mortality of 500 fish, possibly due to low dissolved oxygen. Another event occurred in the mainstem Northeast Cape Fear River in the wake of Hurricane Florence in 2018 resulting in an estimated mortality of 5,000 fish. The 2018 event included American eel that were lethargic at the edge of the water. It was noted that the fish kill likely occurred throughout the river, yet fish aggregated in the investigation area due to calm waters. Anoxic (lacking oxygen) conditions occurred for miles upstream and downstream of the investigation location.

Figure 11-8: Northeast Cape Fear River Subbasin Benthos Bioclassification Ratings 2003, 2008-2009, 2013 and 2018 for Basin Sites.



There is some variability in the basin monitoring sites chosen for monitoring cycle years 2003, 2008-2009, 2013, 2018. Graph data contains one station result per cycle year for 2003, 2013, 2018 and one station result for combined years 2008-2009. Where applicable, the most recent result for stations sampled >1 time per year(s) OR the most common result for stations sampled >2 times per year(s) was used.

11.5 Shellfish Growing Areas

The Department of Environmental Quality’s [Division of Marine Fisheries](#) is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting for human consumption. Shellfish growing areas are classified as Approved, Conditionally Approved, Restricted or Prohibited. Approved areas are consistently open, while Prohibited areas are permanently closed. Conditionally Approved areas can be open to harvest under certain conditions, such as dry weather when stormwater runoff is not having an impact on surrounding water quality. Restricted waters can be used for harvest at certain times as long as the shellfish are subjected to further cleansing before they are made available for consumption. In the Northeast Cape Fear River subbasin the shellfish growing area (B10) is classified as “Prohibited” for shellfish harvesting.

11.6 Fish Consumption Advisories

Fish consumption advisories are based on human health advisory decisions from the North Carolina Department of Health and Human Services (NCDHHS) Division of Public Health (DPH). Any waterbody with a fish tissue advisory and site-specific fish tissue data is considered to be Exceeding Criteria and included on the 303(d) list of impaired waters. All waterbodies in North Carolina also have fish tissue advisories due to mercury exceeding the DPH level of concern. See the NCDHHS [website](#) for the most up-to-date fish consumption advisories and the list of fish species and consumption recommendations associated with each advisory.

Several waterbodies in the Northeast Cape Fear River subbasin are impaired due to arsenic and hexavalent chromium concentrations occurring above the NCDHHS levels of concern in fish and shellfish tissue samples ([Table 11-10](#)). Arsenic and hexavalent chromium fish tissue advisories were issued for the first time in 2017 by NCDHHS and added to the 2020 IR. Arsenic and hexavalent chromium fish tissue advisories issued in 2021 will be on the 2024 IR ([Table 11-10](#)). See Chapter 9 for more information on arsenic and hexavalent chromium fish tissue advisories.

On June 13, 2023, NCDHHS issued a fish consumption advisory for perfluorooctane sulfonic acid (PFOS) in a portion of the Cape Fear River ([NCDHHS press release](#)). PFOS is one of the most widely used and studied chemicals in the group of chemicals known as per- and polyfluoroalkyl substances, or PFAS. This most recent 2023 advisory will also be added to the 2026 IR and will ultimately impair portions of the Cape Fear River mainstem. See Chapter 12 for more information on addressing PFAS in the Cape Fear River Basin.

Table 11-10: NC Fish Consumption Advisories as of January 2023 in the Northeast Cape Fear River Subbasin. See NC DHHS Website for the Most up-to-date List of Advisories (NC DHHS, 2021).

River	Counties	Location Of Advisory*	Pollutant	Species
All waters in the Cape Fear River Basin	All Counties in NC	Statewide	Mercury	Many Species See Website & Flyer
Burnt Mill Creek	New Hanover	*Near Archie Blue Community Park, Upstream of the confluence with Smith Creek	Arsenic, Hexavalent Chromium	bowfin, bluegill, flathead catfish

River	Counties	Location Of Advisory*	Pollutant	Species
Northeast Cape Fear River	New Hanover, Pender	*Near Riverside Park community building, upstream of U-40 bridge, at Castle Hayne Boat Ramp	Arsenic, Hexavalent Chromium	bowfin, bluegill

NC DHHS Website: <https://epi.dph.ncdhhs.gov/oe/fish/advisories.html#top>

See the website for a list of fish and consumption limitations and recommendations. Consumption advisories are different for each pollutant and for different consumers like children under 15, women of childbearing age, pregnant women, nursing women and all others.

What fish are safe to eat flyer – NC DPH <https://epi.dph.ncdhhs.gov/oe/mercury/safefish.pdf>

*Fish Tissue Advisory issued in 2021 will be listed on the 2024 IR ,^Fish Tissue Advisory issued in 2017 is listed on 2022IR, +Fish Tissue Advisory issued in 2023 will be listed on the 2026 IR

11.7 Ambient Water Quality

Monthly chemical and physical samples are taken by DWR through the Ambient Monitoring System (AMS) stations as well as by coalitions of NPDES permit holders that are active in the Cape Fear River Basin. The Lower Cape Fear River Program (LCFRP) collects ambient samples in the Northeast Cape Fear River subbasin. Many of the ambient stations are associated with waterbody locations where potential pollution could occur from known land use activities in the subbasin. There are also portions of the subbasin where no water quality data are collected; therefore, water quality in those areas cannot be evaluated. Parameters collected depend on the waterbody classification but typically include conductivity, dissolved oxygen, pH, temperature, turbidity, nutrients and fecal coliform bacteria. Each classification has an associated set of standards the parameters must meet to be considered supporting the waterbody’s designated uses. Stressors are either chemical parameters or physical conditions that at certain levels prevent waterbodies from meeting the standards for their designated use.

The method used to identify an impaired waterbody for the IR is typically based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over 5 years. The IR methodology also addresses less common situations such as small datasets (<10 samples) as can happen with lake and reservoir sampling. See Chapter 2 for information on the IR methodology and the ambient monitoring programs, including the Random Ambient Monitoring System (RAMS). It is important to note that fecal coliform results not collected using a 5-in-30 methodology are used for screening purposes only. There are currently 11 AMS and ten LCFRP stations monitored in the Northeast Cape Fear River subbasin with two stations co-located for the AMS and LCFRP (B9090000 and B9580000) (*Table 11-11; Figure 11-9*). Three short-term surface water quality stations were established for a two-year period. One in 2009-2010, one in 2015-2016 and another in 2019-2020 as part of the Random Ambient Monitoring System (RAMS). An additional ten stations were part of the Stocking Head Creek special study. A complete list of all ambient monitoring stations from 2000 to 2020 is available in Chapter 2 Appendix.

While the LCFRP primarily collects instream monitoring information in waterways with point source dischargers, they also maintain several voluntary instream monitoring stations in the Northeast Cape Fear River subbasin not directly associated with a facility/discharger to understand the impacts of nonpoint sources in the Cape Fear River Basin. The LCFRP samples monthly in this subbasin. DWR recognizes the importance of this work and encourages continued monitoring of these stations.

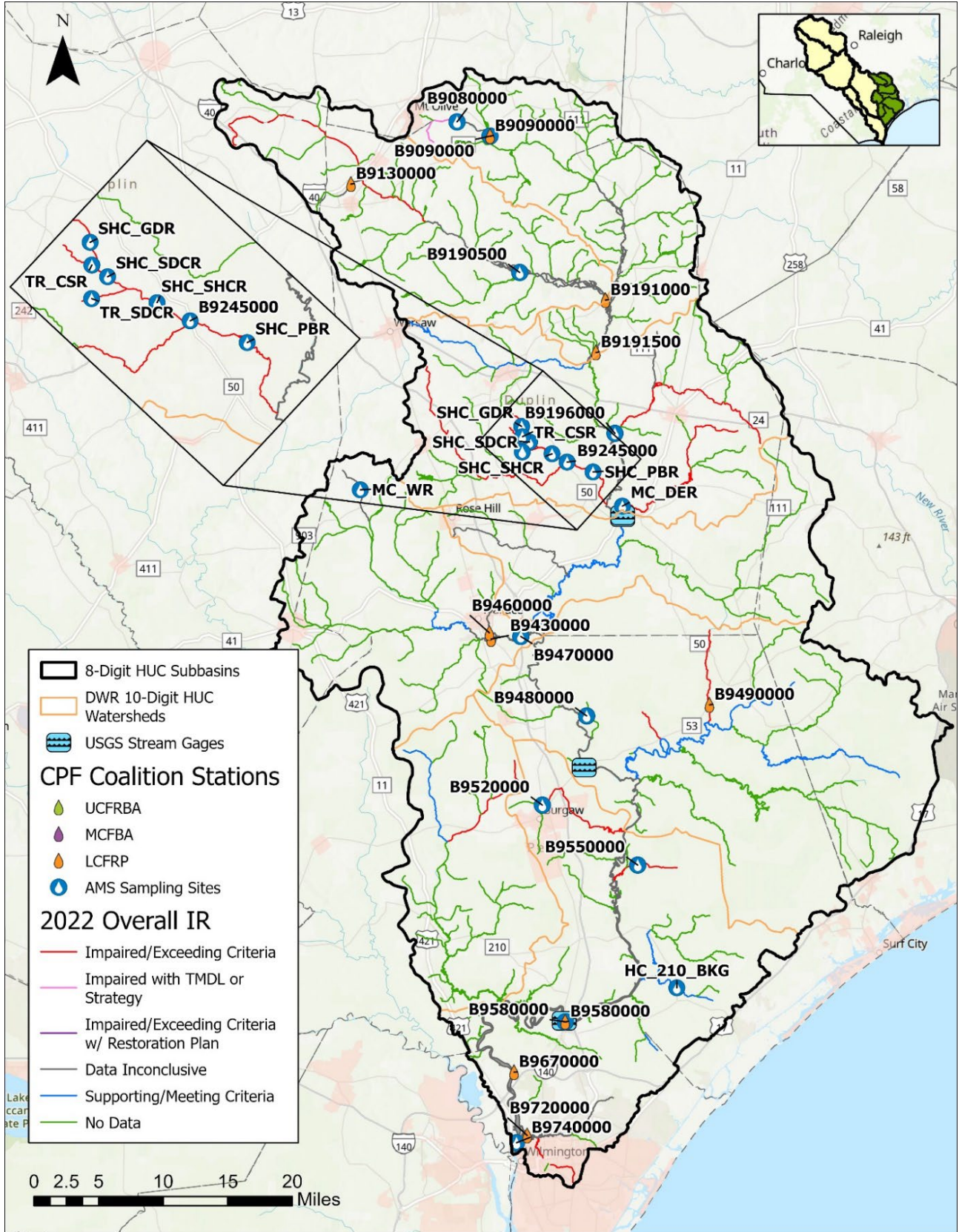
An overall comparison of the Northeast Cape Fear River HUC10 watershed scale ambient water quality results from 2016 to 2020 is shown in *Table 11-12*. Mean results for pH, DO, conductivity, nutrients, turbidity and fecal coliform were determined for stations that had a minimum of five years and 40 average day records. *Table 11-12* also shows the HUC8 mean levels for these parameters from 2016 to 2020 in the Northeast Cape Fear River subbasin, and for comparison purposes, the highest HUC8 mean levels basinwide for conductivity, nutrients, turbidity, TSS and fecal coliform.

Table 11-11: Ambient Monitoring System, Lower Cape Fear River Partnership Coalition and Special Study Stations Sampled between 2002 and 2020 in the Northeast Cape Fear River Subbasin.

Station ID	Station Location	Ecoregion	Stream AU#	Stream Classification
Ambient Surface Water Quality Monitoring Stations				
B9090000	Northeast Cape Fear River at NC 403 near Williams	Southeastern Plains	18-74-(1)b	C; Sw
B9080000	Northeast Cape Fear River at Sr 1937 near Mt Olive	Southeastern Plains	18-74-(1)a	C; Sw
B9130000	Panther Creek near Faison	Southeastern Plains	18-74-19-3b	C; Sw
B9190500	Goshen Swamp at Sr 1004 near Westbrook Crossroad	Southeastern Plains	18-74-19b	C; Sw
B9191000	Goshen Swamp at Nc 11 and NC 903 near Kornegay	Southeastern Plains	18-74-19b	C; Sw
B9191500	Northeast Cape Fear River at Sr 1700 near Sarecta	Southeastern Plains	18-74-(1)c1b	C; Sw
B9196000	Northeast Cape Fear River at Sr 1961 at Hallsville	Middle Atlantic Coastal Plain	18-74-(1)c3	C; Sw
B9245000	Stocking Head Creek at Sr 50	Middle Atlantic Coastal Plain	18-74-24	C; Sw
B9430000	Rockfish Creek at US 117 near Wallace	Middle Atlantic Coastal Plain	18-74-29c	C; Sw
B9460000	Little Rockfish Creek at NC 11 near Wallace	Middle Atlantic Coastal Plain	18-74-29-6	C; Sw
B9470000	Rockfish Creek at I 40 At Wallace	Middle Atlantic Coastal Plain	18-74-29d	C; Sw
B9480000	Northeast Cape Fear River at Sr 1318 near Watha	Middle Atlantic Coastal Plain	18-74-(29.5)	C; Sw
B9490000	Angola Creek at Nc 53 near Maple Hill	Middle Atlantic Coastal Plain	18-74-33-3	C; Sw
B9520000	Burgaw Creek at Us 117 at Burgaw	Middle Atlantic Coastal Plain	18-74-39b	C; Sw
B9550000	Lillington Creek at Sr 1520 near Stag Park	Middle Atlantic Coastal Plain	18-74-42	C; Sw
B9580000	Northeast Cape Fear River at Us 117 at Castle Hayne	Middle Atlantic Coastal Plain	18-74-(47.5)	B; Sw
B9670000	Northeast Cape Fear River near Wrightsboro	Middle Atlantic Coastal Plain	18-74-(52.5)	C; Sw

Station ID	Station Location	Ecoregion	Stream AU#	Stream Classification
B9720000	Smith Creek at Us 117 And NC 133 at Wilmington	Middle Atlantic Coastal Plain	18-74-63	C; Sw
B9740000	Northeast Cape Fear River at NC 133 at Wilmington	Middle Atlantic Coastal Plain	18-74-(61)	SC; Sw
Special Study Stations				
HC_210_BKG	Harrisons Creek at NC 210	Middle Atlantic Coastal Plain	18-74-49	C; Sw
MC_DER	Muddy Creek at Durwood Evans Rd	Middle Atlantic Coastal Plain	18-74-25	C; Sw
MC_WR	Murpheys Creek at Waycross Rd	Southeastern Plains	18-74-29-0.5	C; Sw
SHC_GDR	Stocking Head Creek at Graham Dobson Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw
SHC_PBR	Stocking Head Creek at Pasture Branch Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw
SHC_SDCR	Stocking Head Creek at S Dobson Chapel Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw
SHC_SHCR	Stocking Head Creek at Stocking Head Creek Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw
TR_CSR	UT to Stocking Head Creek at Cool Springs Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw
TR_SDCR	UT to Stocking Head Creek at S Dobson Chapel Rd	Middle Atlantic Coastal Plain	18-74-24	C; Sw

Figure 11-9: Ambient Monitoring System, Lower Cape Fear River Partnership Coalition, Special Study and Surface Water Quality Monitoring Stations in the Northeast Cape Fear River Subbasin.



An overall HUC8 scale comparison of the Cape Fear River Basin's six subbasins is available in Chapter 3. All of the HUC10 scale parameter means and the number of stations used in the analysis are available in the Chapter 2 Appendix. At the HUC8 scale, the Northeast Cape Fear subbasin (HUC8 03030007) had the highest mean five-year results for conductivity, fecal coliform, total phosphorus (TP), ammonia (NH₃) and organic nitrogen, total Kjeldahl nitrogen (TKN) minus ammonia while the Haw River subbasin (HUC8 03030002) had the highest mean five-year results for turbidity, TSS, total nitrogen (TN) and inorganic nitrogen/nitrate+nitrite (NO_x). The highest basinwide HUC10 values included in the *Table 11-12* are described in-depth in the watershed chapters spanning chapters 6 through 11 of this report.

At the watershed scale for five-year (2016-2020) means, Harrison Creek-Northeast Cape Fear River had the highest conductivity value (1,413 μ S/cm) likely due to saltwater influence from the estuary as measured at two stations B9670000 and B9720000. This watershed also had the highest turbidity possibly due to runoff from the developed landscape around Wilmington. Goshen Swamp and the Headwaters Northeast Cape Fear River watersheds in the upper part of the subbasin had notably high conductivity levels because of two industrial dischargers with high chloride concentrations in their discharge. Both facilities have approved variances from the water quality standards to discharge their chlorinated effluent into these two watersheds. Goshen Swamp had the second highest conductivity with 621 μ S/cm and Headwaters Northeast Cape Fear had the third highest conductivity with 478 μ S/cm (*Table 11-12*).

Angola Swamp-Northeast Cape Fear River watershed had the highest total Kjeldahl nitrogen concentrations most likely due to forested wetlands; however, unusual pulses of elevated ammonia concentrations have contributed to the elevated total Kjeldahl nitrogen values. Basinwide, the Angola Swamp Northeast Cape Fear River watershed had the second highest total Kjeldahl nitrogen concentrations (1.13 mg/L). The Headwaters Northeast Cape Fear River watershed typically had the highest ammonia concentrations. These elevated concentrations are most likely due to the multiple effluent limit violations from a point source discharger and possibly from nonpoint sources. Basinwide, the Headwaters Northeast Cape Fear River watershed typically had the third highest ammonia concentrations (0.11 mg/L) and Rockfish Creek was nearly as high (0.108 mg/L).

The Rockfish Creek watershed had the highest nitrate+nitrite (NO_x) and total nitrogen concentrations most likely due to point source discharger Wallace Chicken Processing Plant, as well as possibly other point and nonpoint sources. The Rockfish Creek watershed also had the highest total phosphorus concentrations possibly from a combination of point and nonpoint sources of pollution. Basinwide, the Rockfish Creek watershed typically had the highest total phosphorus concentrations in the basin with a mean value of 0.38 mg/L. This watershed also had notably high total Kjeldahl nitrogen levels with a typical value of 1.05 mg/L. Goshen Swamp, Headwaters Northeast Cape Fear River and Angola Swamp-Northeast Cape Fear River watersheds also had notably high total phosphorus concentrations.

Goshen Swamp had the highest fecal coliform bacteria concentrations possibly due to agriculture, animal feeding operations and aging/failing septic systems (*Table 11-12*). Goshen Swamp's fecal coliform levels--2,478 colonies/100 mL--were the highest in the basin. Basinwide, the Headwaters Northeast Cape Fear River and Rockfish Creek watersheds had the second and third highest fecal coliform bacteria levels with mean values of 1,418 colonies/100 mL and 1,284 colonies/100 mL, respectively (*Table 11-12*).

Table 11-12: Northeast Cape Fear River (NECFR) Subbasin HUC 10 Watersheds Ambient Water Quality Means for 2016-2020.

Watershed HUC 10	Watershed Name	Number of Stations [^]	pH	DO (mg/L)	Conductivity (µS/cm)	NH3 (mg/L)	TKN (mg/L)	NOx (mg/L)	TN (mg/L)	TP (mg/L)	Turbidity (NTU)	TSS (mg/L)	Fecal Coliform (CFU/100 mL)
Highest HUC 8 in Cape Fear River Basin		\bar{x}			711	0.09	0.92	1.34	2.10	0.21	20.19	22.90	1,093
Highest HUC 10 in Cape Fear River Basin		\bar{x}			1,413	0.27	1.44	2.62	3.48	0.38	26.63	26.64	2,478
03030007*	HUC8 Northeast Cape Fear River (NECFR) Watershed	17	6.47	6.96	711	0.09	0.92	0.61	1.54	0.21	6.45		1,093
0303000701	Goshen Swamp	3	6.72	7.28	621	0.07	0.86	0.55	1.41	0.20	3.75		2,478
0303000702	Headwaters NECFR	2	6.63	7.38	478	0.11	0.88	1.05	1.92	0.19	4.60		1,418
0303000703	Limestone Creek-NECFR	1	6.61	7.71	162	0.04	0.85	0.60	1.44	0.15	5.59		269
0303000704	Cypress Creek – NECFR	0											
0303000705	Rockfish Creek	3	6.81	8.00	159	0.108	1.05	1.09	2.14	0.38	6.58		1,284
0303000706	Angola Swamp-NECFR	2	5.98	6.76	115	0.10	1.13	0.38	1.52	0.26	6.56		759
0303000708	Harrisons Creek-NECFR*	6	6.23	6.04	1,413	0.07	0.85	0.27	1.12	0.14	8.08		446
EPA Nutrient Criteria – Coastal ⁺									0.72	0.032			
Minimally Impacted Streams ^{**}						<0.05	<0.5	<0.3	<0.8	<0.05			

+ USGS Circular #1350 – The Quality of Our Nation’s Water – Nutrients in the Nation’s Streams and Groundwater, 1992-2004. Neil Dubrovsky et al., 2010.

[^]Ambient stations with a minimum of data collected for 5 years from 2016 to 2020 and 40 average day records were included in the analysis.

*HUC10 Harrison Creek-Northeast CPF (0303000708) includes one Estuary station and five River/Stream stations, all other stations in the HUC8 Northeast Cape Fear River subbasin (03030007) are River/Stream stations.

** DWQ ESS- ISU Special Study. March 14, 2005, Lower Cape Fear River/Estuary TMDL Study.

Orange highlighted values represent the highest mean instream concentration or lowest DO concentration in comparison to the other HUC 10 watersheds.

Green highlighted row represents the overall HUC 8 watershed mean for each constituent for comparison purposes.

Emerging compounds (EC) are lesser known compounds that are increasingly being detected in soil, groundwater and surface water. They come from a wide range of sources, including industrial chemicals and their by-products, firefighting foams, pesticides, lawn and agricultural products, disinfection products, wood preservatives, home goods, as well as pharmaceutical and personal care products (PCPs) ([EPA, 2024](#)). In addition to industrial sources, these contaminants are often sent to landfills and wastewater treatment plants (WWTP) and subsequently discharged to surface waters. Many of these compounds do not readily biodegrade in the aquatic environment. Consequently, they often persist in water and are readily transported downstream because of a unique combination of physical and chemical properties that make them highly mobile and resistant to natural degradation.

In the last several years, emerging compounds have become the primary concern for the residents living in and receiving drinking water from the Cape Fear River Basin. Per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane are currently the primary contaminants of emerging concern in the Cape Fear River Basin due to their impact on human health in drinking water. The presence of these contaminants has been documented through sampling by university researchers, DEQ, the NC Collaboratory, public water and wastewater utility providers and other local and state entities.

After observing elevated concentrations of 1,4-dioxane [reported](#) as part of the EPA's Third Unregulated Contaminant Monitoring Rule ([UCMR3](#), 2013-2015), DWR initiated a study of 1,4-dioxane in surface waters of the Cape Fear River Basin (October 2014) with the objective of identifying potential sources, understanding changes in concentrations, and documenting data that will help the state develop a regulatory strategy. During the study, elevated levels of 1,4-dioxane were identified mainly downstream of the Greensboro, Reidsville and Asheboro WWTPs. DWR continues to work with these facilities to decrease the concentration of 1,4-dioxane in their discharges and requires effluent monitoring to ensure compliance with the CWA. DWR has also added ambient instream monitoring for 1,4-dioxane concentrations in areas where potential contamination might occur. Available instream 1,4-dioxane data is reported throughout the subbasin chapters. A 1,4-dioxane specific chapter (Chapter 13) with detailed Cape Fear River Basin studies and DEQ actions addressing the contaminant is included as part of the basin plan.

Researchers from North Carolina State University (NCSU) detected elevated levels of PFAS (including GenX) in the Cape Fear River in 2013-2015. The next year, DEQ, along with DHHS, began investigating PFAS in the basin to identify the potential source of contamination. The source of GenX was traced to Chemours in Bladen County along the west bank of the Cape Fear River in the Lower Cape Fear River subbasin. Other PFAS compounds, some of which are no longer manufactured, are being found in surface and ground water throughout the basin. The sources of these compounds into the Cape Fear River system are from contaminated wastewater, groundwater and atmospheric deposition.

Due to the changing nature of the science and due to the extent and magnitude of PFAS contaminants found in the Cape Fear River Basin as well as what corrective actions to take, PFAS was not discussed in detail within the subbasin chapters of this plan. A PFAS specific chapter was completed after finalizing the water quality and quantity watershed portions of the plan. The most up to date information on the extent of PFAS contamination within the Cape Fear River Basin, completed studies, and what actions have been

taken by DEQ and EPA are summarized in the PFAS chapter (Chapter 12). DEQ is actively working to identify sources of PFAS and working to reduce the loading to the Cape Fear River system.

As science advances, laboratories are beginning to detect these compounds and researchers are discovering new details about their impacts. The science and research about emerging contaminants are quickly expanding, so DEQ has created a list of resources to help residents learn more. The latest information and updates can be found on the NC DEQ [Emerging Compounds](#) webpage.

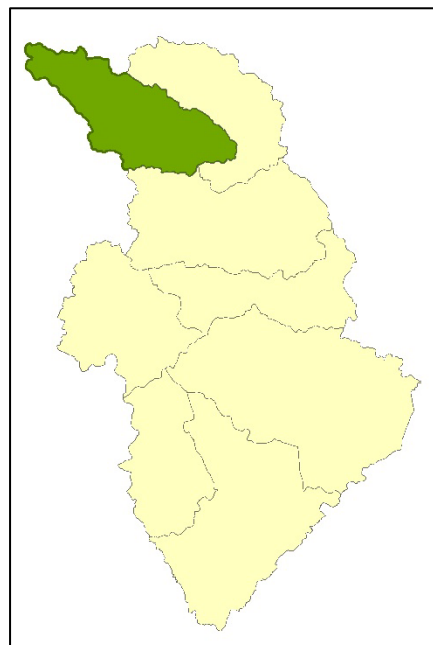
11.8 Water Quality on the Watershed Scale (HUC 10)

To determine the source of pollutants in a watershed, it is useful to evaluate them on a smaller scale. Smaller-scale evaluations can also help identify where monitoring and restoration is needed or being conducted. North Carolina assigns numbers to surface waterbodies. For water quality assessment purposes, these numbers are referred to as assessment unit numbers (AU#). A letter attached to the end of the AU# indicates that the assessment unit has been segmented, or broken into smaller pieces, to target the water quality assessment and the data associated with it. AU#'s that have water quality data associated with them are discussed here on a watershed (HUC 10) scale. Not all stream segments are monitored by DWR. DWR does, however, value qualitative information from stakeholders throughout the basin to understand what is impacting water quality in a particular area. Information provided by stakeholders is incorporated into each watershed plan along with recommendations to protect and improve water resources in the watershed.

11.8.1 Goshen Swamp Watershed (0303000701)

The Goshen Swamp watershed spans 185 square miles across northeastern Sampson and northwestern Duplin counties. The upper reaches of this watershed are Goshen Swamp and Railer Branch, which meet east of Suttontown, an unincorporated community. As this river flows southeast, it is joined by Panther (Creek) Branch, Halls Marsh and Herrings Marsh Run before joining the Northeast Cape Fear River. In 2019, the land cover in this watershed was primarily agricultural land (51%), wetlands (21%) and forest land (17%), followed by developed land (6%) and grassland/shrub (4%).

As of May 2022, there were many permitted facilities and fields located in this 185 square-mile watershed. A total of 110 animal feeding operations (AFOs) with a total allowable head count of 593,096, an allowable weight of 85.9 million pounds and 198 lagoons were located in this watershed. There are two non-discharge permitted facilities (one major and one minor) with 18 fields covering approximately 0.28 square miles located near the upper reaches of this watershed and downstream from the Goshen Swamp and Reedy Branch confluence. A minor NPDES industrial permitted facility with an as-built flow totaling 500,000 gallons per day (GPD) is located on Panther (Creek) Branch. Facilities discharging into Panther (Creek) Branch have maintained a variance from the water quality



action level for chloride since 1996. There are also four NPDES stormwater and five state stormwater permits in this watershed.

11.8.1.1 Panther (Creek) Branch and Goshen Swamp and Physical and Chemical Monitoring

There are three surface water quality monitoring stations that have been active since the early 2000s in this watershed. The most upstream surface water quality monitoring station, B9130000, is located on Panther (Creek) Branch [AU#: 18-74-19-3a and 18-74-19-3b]. After Panther (Creek) Branch joins Goshen Swamp [AU#: 18-74-19a and 18-74-19b] the next surface water quality monitoring station is B9190500. Downstream from station B9190500 is monitoring station B9191000. Together these three stations receive drainage from almost the entire 185 square miles of this watershed. Panther (Creek) Branch and Goshen Swamp are class C waters with a supplemental swamp classification, due to natural characteristics of swamps, such as low dissolved oxygen and pH. Information regarding dissolved oxygen in waterways of the Northeast Cape Fear River subbasin can be found in Section 11.10.2.

Along Panther (Creek) Branch there is one discharge from a minor NPDES permitted facility (NC0001970) with an as-built flow of 500,000 GPD. Specific conductance is monitored downstream from this facility at station B9130000. This monitoring station has recorded high specific conductance in Panther (Creek) Branch due primarily to the permitted facility, which has a chloride variance that has been in place since 2011; however, Deans Pickles previously held chloride variances for its discharge dating back to 1996 (*Figure 11-10*). The 2020 Annual Chloride Reduction Report discusses Bay Valley Foods efforts to study and evaluate chloride removal technologies and chloride reduction strategies.

Surface water quality at monitoring station B9130000 indicates that during 2016 to 2020 fecal coliform bacteria exceeded the 400 colonies/100 mL standard during approximately 41% (23 of 56) of the sampling events with multiple sampling events recording values of 60,000 colonies/100 mL. These are some of the highest fecal coliform concentrations observed in the Cape Fear River Basin. Notably, these elevated concentrations of fecal coliform bacteria have occurred more often in the most recent 10 years (2011 – 2020) of sampling when compared to the historical record at this station (*Figure 11-11*). The number of DEQ permitted animal feed operations (AFOs) have not increased over this 10 year period, however, there has been a substantial increase in the number of deemed permitted animal dry litter poultry operations. Based on the 2022 Census of Agricultural, there was a 78.6 % increase in the poultry inventory numbers reported for Duplin County between 2012 and 2022 for a total reported inventory in 2022 of 22 million birds (*Table 11-8*; see Chapter 1 Appendix for additional agricultural statistics).

While the exact nonpoint source of these elevated fecal coliform bacteria levels is unknown, it is worth noting that on January 20, 2021, during a Structure Evaluation Inspection site visit at animal feeding operation (AWS820352), DWR staff documented with pictures and water samples that waste was flowing from one of the hog house's foundation to a stormwater drain system that discharges to a ditch that flows to an unnamed tributary to Panther (Creek) Branch on an adjoining property. Water samples confirmed waste was present in the ditch confirming an unpermitted discharge to surface waters. A Notice of Violation (NOV) and civil penalties were assessed for several issues identified during the January 2021 inspection. The violations included failure to prevent discharge of waste to surface waters or wetlands (Permit No. AWG100000, Section I 1.) and failure to report any failure of any component of the animal

waste management system resulting in a discharge to ditches, surface waters or wetlands (Permit No. AWG 100000, Section III 17a.) as required by their permit ([NOV-2021-DV-0170 letter](#)). A follow-up compliance inspection was completed in July 2021 and all issues were corrected and no additional concerns identified. This example illustrates the need for proper maintenance of these facilities along with permitting and associated compliance inspections to ensure environmental protections. The fecal coliform bacteria concentrations at B9130000 collected in 2021 and 2022 ranged between 5 and 14,000 colonies/100 mL with 37.5% (9 of 24) of the samples exceeding the standard in this two year period. Although high fecal coliform bacteria drain from Panther (Creek) Branch into Goshen Swamp, the fecal coliform bacteria measured in Goshen Swamp at station B9190500 throughout the year is often below the 400 colonies/100 mL standard, having only one or two exceedances of the water quality standard during the most recent five years on record. Interestingly, between 2016 and 2020, the most downstream station on Goshen Swamp (B9191000) recorded fecal coliform bacteria levels comparable to the values detected in Panther (Creek) Branch, reaching a maximum value of 31,000 colonies/100 mL.

Annual mean total nitrogen concentrations in Panther (Creek) Branch were often considerably higher than total nitrogen in Goshen Swamp (*Figure 11-12*). This is due to the nitrate+nitrite concentrations that have exceeded 3 mg/L at least once each year since 2009; except in 2012 and 2013. Annual mean nitrate+nitrite concentrations in Panther (Creek) Branch have exceeded 1 mg/L multiple times since 2002 (*Figure 11-13*). Panther (Creek) Branch is impacted by high ammonia concentrations as annual mean total Kjeldahl nitrogen values typically hover around 1 mg/L but have occasionally exceeded 1.5 mg/L (*Figure 11-14* and *Figure 11-15*).

Annual mean total phosphorus concentrations in Panther (Creek) Branch have also exceeded 0.2 mg/L since 2009 (*Figure 11-16*). Elevated nutrients (total nitrogen and phosphorus) in Panther (Creek) Branch contribute to the nutrient levels in Goshen Swamp. Both waterways have nutrient values often higher than concentrations considered normal for minimally impacted waters. Notably, the most downstream section of Goshen Swamp contains wetlands that help with nutrient removal.

DWR conducted screening level Mann-Kendall seasonal trend tests for dissolved oxygen, pH, fecal coliform bacteria, nitrate+nitrite at stations B9130000 and B9191000 that resulted in a significant increasing trend calculated at 95% confidence from data collected from 2000 to 2019. Both DWR and Mallin et al. (2022), reported significant increases in total phosphorus based on a series of statistical analyses conducted on data collected from 2000 to 2019 at station B9130000. Significant decreases in ammonia were also reported from data collected at station B9191000 from 2000 to 2019. DWR also found a significant decreasing trend in specific conductivity for data collected at station B9130000 between 2000 and 2019.

Figure 11-10: Annual Mean Specific Conductance Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

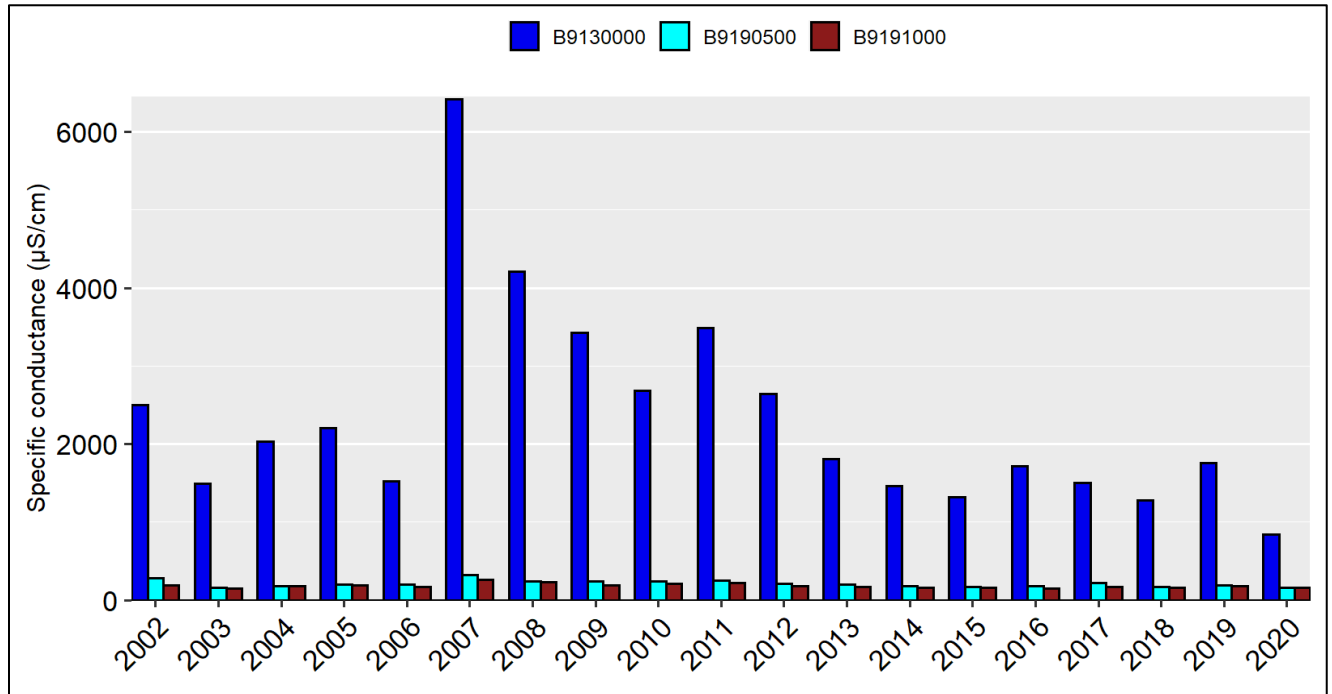


Figure 11-11: Annual Mean Fecal Coliform Bacteria Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

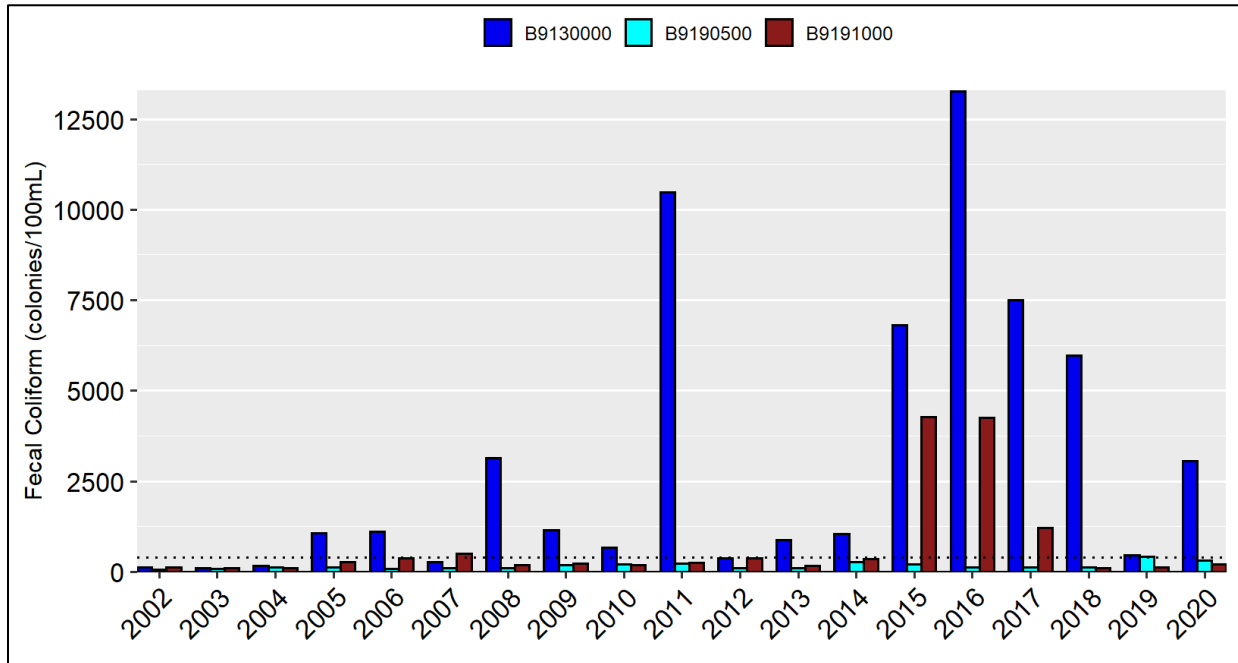


Figure 11-12: Annual Mean Total Nitrogen Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

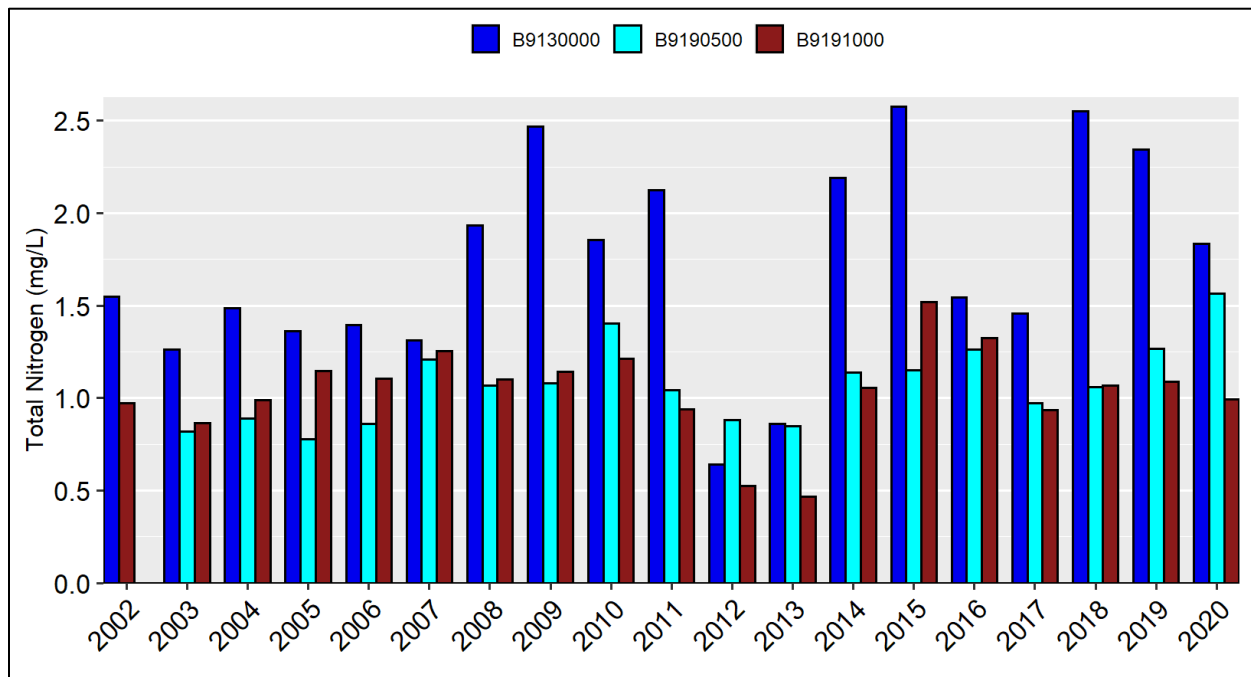


Figure 11-13: Annual Mean Nitrate+Nitrite Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

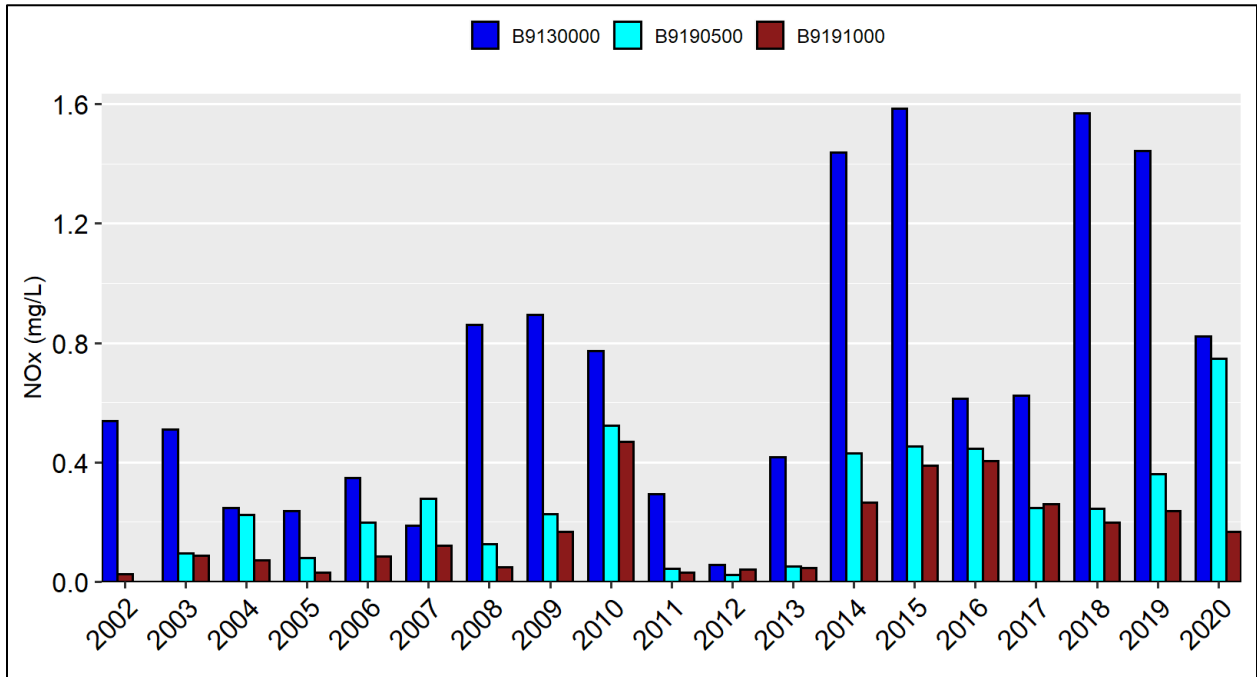


Figure 11-14: Annual Mean Ammonia Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

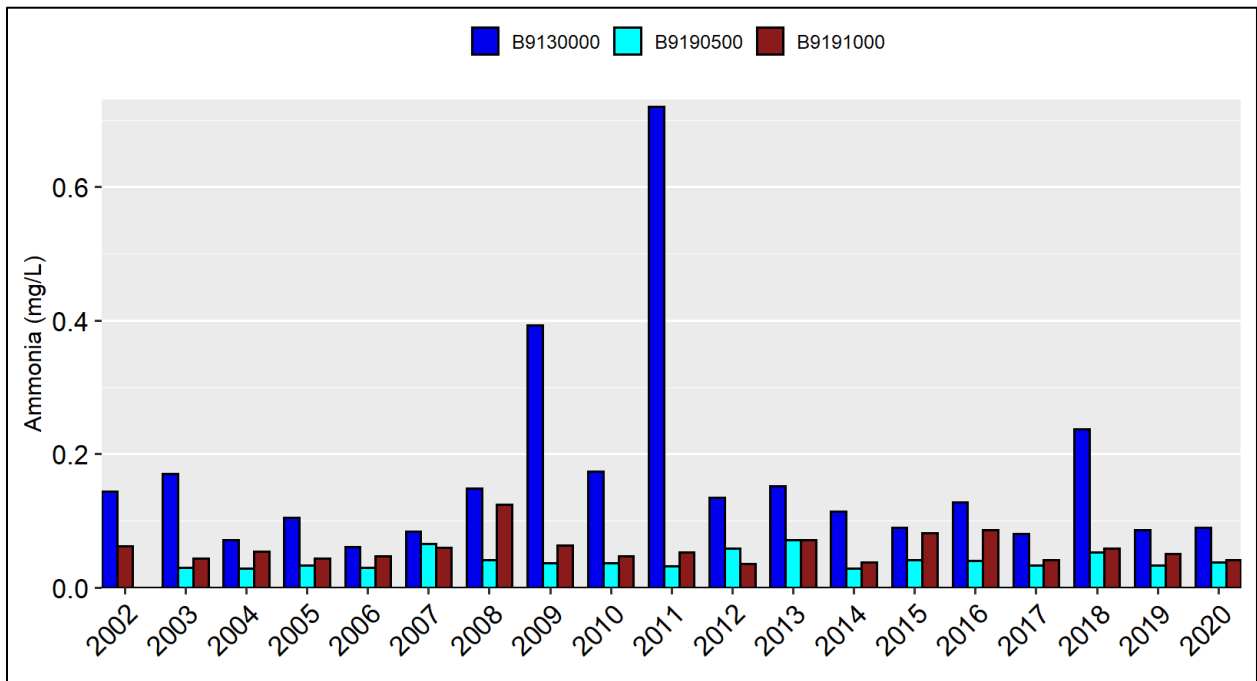


Figure 11-15: Annual Mean Total Kjeldahl Nitrogen Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.

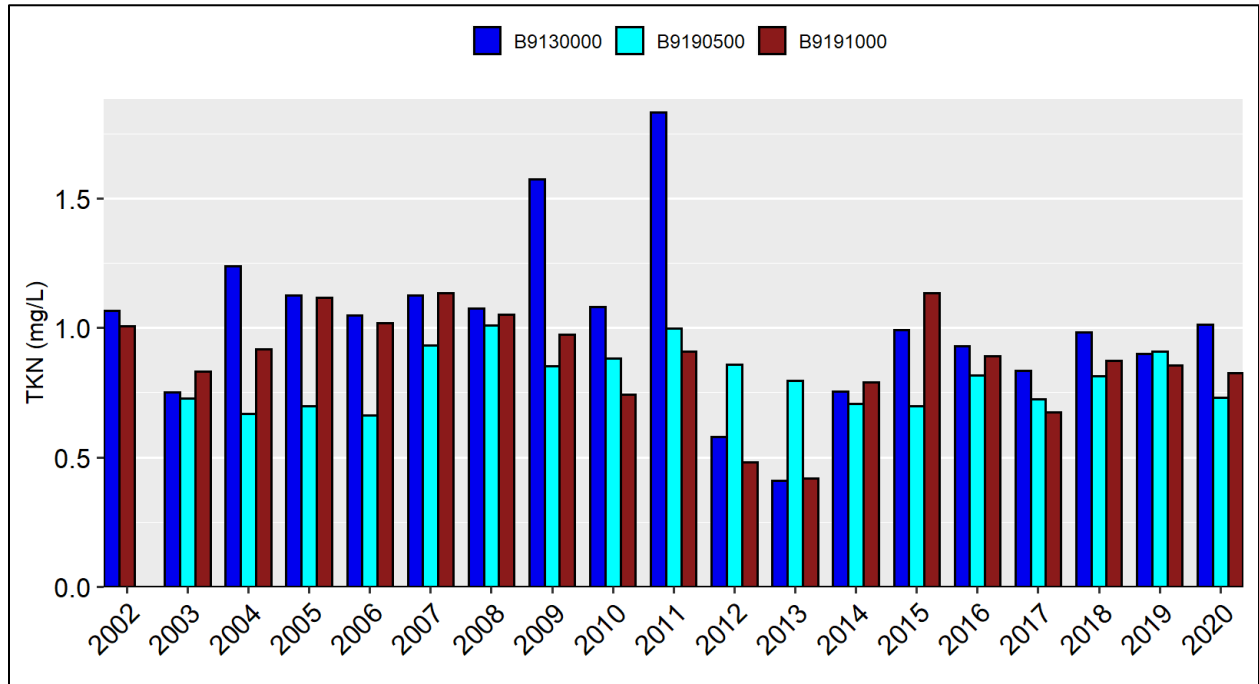
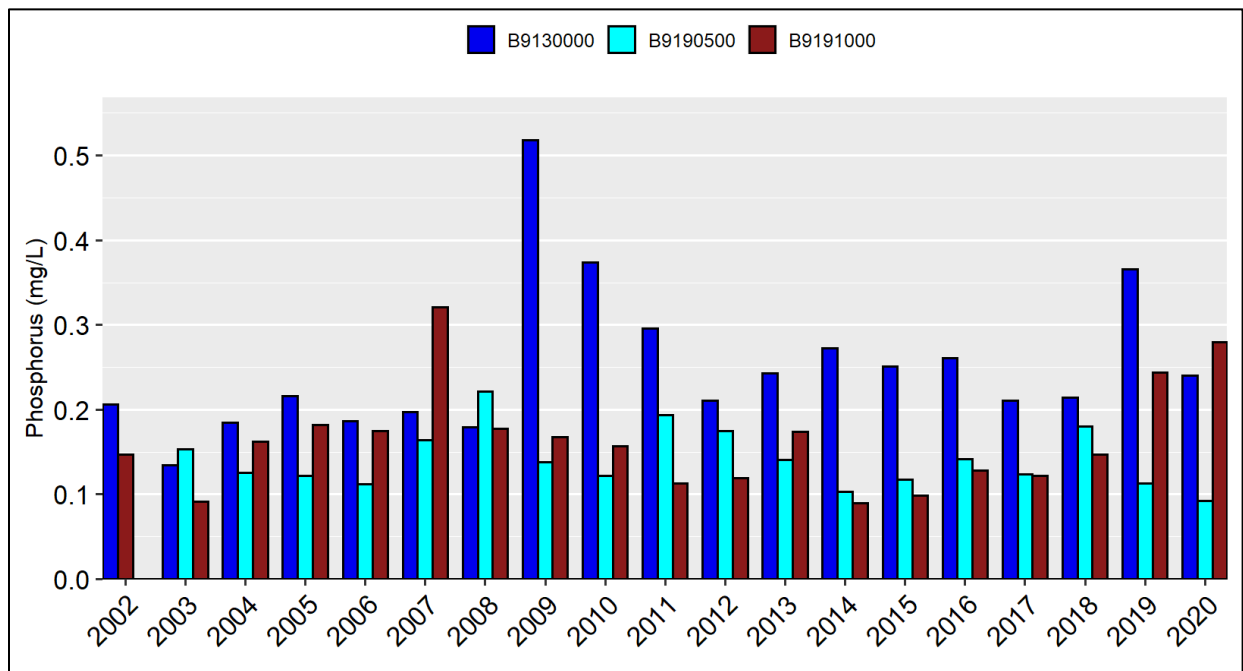


Figure 11-16: Annual Mean Total Phosphorus Results for Stations on Panther (Creek) Branch (B9130000) and Goshen Swamp (B9190500 and B9191000) between 2002 and 2020.



11.8.1.2 Panther (Creek) Branch Biological Monitoring

The biological community in Panther (Creek) Branch downstream from the discharge of Bay Valley Foods Inc. was last monitored by the Biological Assessment Branch in 1993 at site BB391 recording a bioclassification of Poor [AU#: 18-74-19-3b]. As part of the chloride variance, the NPDES facility (Bay Valley Foods Inc.) conducts a biological community assessment prior to renewal of its permit. In 2019, the benthic community in Panther (Creek) Branch and Goshen Swamp were monitored using methodologies outlined in *Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates*. This recent biological community monitoring found that the upstream monitoring stations located in Panther (Creek) Branch and Goshen Swamp (1 and 3) were rated with the Severe bioclassification while downstream stations (2, 5 and 6) recorded Moderate bioclassification ratings (Eaton Scientific, LS and The Three Oaks Engineering, 2019, *Table 11-13*). The report also mentions “the benthic macroinvertebrate community seem to be driven more by the presences or absence of flow than potential impairments from the discharge [Bay Valley Foods outfall] (Eaton Scientific, LS and The Three Oaks Engineering, 2019). They also found impacts from the discharge are likely too small to be significant when comparing Panther (Creek) Branch to the lower Goshen Swamp stations (Eaton Scientific, LS and The Three Oaks Engineering, 2019). More information regarding the benthic macroinvertebrate community monitoring by Bay Valley Foods can be accessed by contacting DWR’s NPDES Complex Permitting Branch.

Notably, during the benthic macroinvertebrate monitoring conducted in Panther (Creek) Branch high dissolved oxygen and pH conditions were observed in the swamp waters. As stated in their report: “Swamp systems in North Carolina are defined as systems with low pH and DO, however the 8.5 pH and 9.3 mg/l DO [dissolved oxygen] recorded at Panther Br 1 is elevated to the point of indicating an algae bloom (NCDENR 2013b). Algae blooms require two things, sunlight and excess nutrients. The sunlight part of bloom conditions here must include the lack of buffer on the stream just above the road, where the farm mows its large lawn right down to the water's edge, providing ample direct sunlight. The source of nutrients is not so obvious. It could be runoff from the well-manicured lawns, or it could be coming from one of the many fields in the watershed” (Eaton Scientific, LS and The Three Oaks Engineering, 2019).

Table 11-13: Benthic Macroinvertebrate Study in Panther (Creek) Branch and Goshen Swamp.

Sampling Date	Site	Method	Total Taxa Richness	EPT Taxa Richness	Biotic Index Value	Bioclassification Rating
March 13, 2019	1 – Panther Creek	Swamp	53	1	8.26	Severe
March 13, 2019	2 – Panther Creek	Swamp	51	3	7.47	Moderate
March 13, 2019	3 – Goshen Swamp	Swamp	47	2	7.56	Severe
March 14, 2019	5 – Goshen Swamp	Swamp	53	4	7.26	Moderate
March 14, 2019	6 – Goshen Swamp	Swamp	60	7	7.26	Moderate

11.8.1.3 Goshen Swamp Biological Monitoring

Goshen Swamp above the confluence with Bear Swamp [AU#: 18-74-19a] spans 16.6 freshwater miles and has remained on the impaired waters list for excursions of the aquatic life standard for benthos since monitoring began in 2003. Between 2003 and 2013, every sampling event recorded a Severe rating (*Table*

11-14). The poor water quality appears to be mostly a function of dense agriculture and animal operations within the watershed. Goshen Swamp has received a Severe rating three consecutive times.

Table 11-14: Biological Community Analysis in the Goshen Swamp at Station BB322.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
2003	Basin Sample	Swamp	6.17	7.25	Severe
2009	Basin Sample	Swamp	6.18	7.38	Severe
2013	Basin Sample	Swamp	6.63	7.03	Severe

Link to biological report: <https://www.ncwater.org/?page=672&SiteID=BB322>

11.8.1.4 Goshen Swamp Watershed Summary

Water quality in Goshen Swamp and Panther (Creek) Branch is impacted by both point and nonpoint sources of pollution. Point sources in this watershed are limited to a single NPDES industrial discharger that has a variance from the water quality standard for chloride concentrations. Bay Valley Foods (NC0001970) is required to continue efforts to reduce the discharge of chlorides and monitor chloride levels. Nonpoint sources of pollution in this watershed include both swine and poultry feeding operations, agriculture practices, manure applications to cropland, well-manicured lawns, septic systems and/or straight pipes, domestic animals and wildlife.

Biological monitoring shows poor water quality possibly caused by the nonpoint sources of pollution and flow dynamics. The impact from nonpoint sources is evident in the multiple spikes in fecal coliform bacteria exceeding the 400 colonies/100 mL standard, reaching values of 60,000 colonies/100 mL. Fecal coliform bacteria concentrations in Panther Branch, a tributary of Goshen Swamp, exceeded the 400 colonies/100 mL water quality standard at least 1 out of 2.5 samples collected during the most recent five years (2016-2020) on record. Notably, many tributaries along Goshen Swamp have been identified as containing measurable manure effects from swine and/or poultry animal feeding, including Young Swamp, Big Branch, King Branch, Bear Swamp and Nahunga Creek (Harden, 2015).

While streamflow in Goshen Swamp appears to mitigate some of the nonpoint source pollution impacts by upstream sources, the monitoring station furthest downstream near the confluence with Northeast Cape Fear River recorded elevated fecal coliform bacteria levels. Nutrients (total nitrogen and phosphorus) were higher than concentrations considered normal for minimally impacted streams in both Panther (Creek) Branch and Goshen Swamp. Although there is not a water quality standard for nutrients, the contribution of nutrients to a waterway can result in eutrophication and associated algal blooms as demonstrated and documented in Panther (Creek) Branch. The elevated ammonia concentrations and the elevated fecal coliform bacteria concentrations could indicate one or more potentially failing septic systems and/or sewer system leaks. Mallin et al. (2022) also noted several small blooms in Goshen Swamp and Panther Branch.

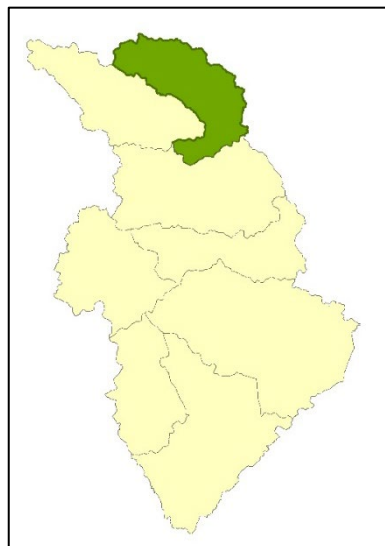
Panther (Creek) Branch has documented elevated fecal coliform bacteria concentrations at 150 times the water quality standard and nutrient levels sufficient to produce an algal bloom. The fecal coliform bacteria

concentrations detected in this watershed are the highest of all the watersheds in the Northeast Cape Fear River subbasin. While determining the nonpoint sources of pollution will require additional investigation, this report will note that it is unlikely that these high fecal coliform bacteria concentrations are from the only permitted NPDES industrial wastewater discharger (Bay Valley Foods Inc.) as they do not treat domestic wastewater. DWR will continue to monitor the Goshen Swamp and Panther (Creek) Branch watersheds. Best management practices to address the nutrient and fecal coliform bacteria levels are necessary to improve water quality in this watershed. Additional recommendations for the Goshen Swamp watershed include:

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Working with the local County Health Department in having straight pipes that may be identified during stream walks removed and septic systems repaired.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders)

11.8.2 Headwaters Northeast Cape Fear River Watershed (0303000702)

The Headwaters Northeast Cape Fear River watershed spans 162 square miles across southern Wayne and northeastern Duplin counties. The upper reaches of this watershed are the Northeast Cape Fear River and Lewis Branch, which join west of the Williams community. Prior to leaving this headwaters watershed, the river flows southeast and joins with Polly Run Creek, Poley Branch, Mathews Creek, Burn Coat Creek and Panther Creek before its confluence with Goshen Swamp. The primary land cover in this watershed is agricultural land (47%), wetlands (22%) and forest land (20%), followed by developed land (7%) and grassland/shrub (4%). There are three surface water quality monitoring stations on Northeast Cape Fear River. There has been no benthic macroinvertebrate or fish community monitoring in this watershed since 1998.



As of May 2022, there were many permitted facilities and fields located in this watershed. A total of 106 animal feeding operations with a total allowable head count of 442,840, an allowable weight of 55.4 million pounds and 161 lagoons were located in the watershed. There are four non-discharge permitted facilities (three major and one minor) with 59 fields covering approximately 1.45 square miles located near the upper reaches of this watershed, near the confluence of Jumping Run

Branch with the Northeast Cape Fear River and downstream of the confluence of Goshen Swamp with the Northeast Cape Fear River. There are five NPDES-permitted facilities (two major and three minor) with as-built flows totaling 2.9 MGD. The NPDES-permitted facilities are located in the upstream reaches of the Northeast Cape Fear River, near Great Branch (Hussey Pond) and near the confluence of Goshen Swamp with the Northeast Cape Fear River. There are also 10 state stormwater permits in this watershed.

11.8.2.1 Northeast Cape Fear River Physical and Chemical Monitoring

Since 1991, there has been at least one surface water quality monitoring station located on the Northeast Cape Fear River [AU#: 18-74-(1)a, 18-74-(1)b, 18-74-(1)c1a, 18-74-(1)c1b and 18-74-(1)c2]. Presently, there are three surface water quality monitoring stations located on the Northeast Cape Fear River. The Northeast Cape Fear River is class C water with a supplemental swamp classification, due to natural characteristics of swamps such as low dissolved oxygen and pH. Information regarding dissolved oxygen in waterways of the Northeast Cape Fear River subbasin can be found in Section 11.10.2. Two of the three surface water monitoring stations are B9080000 and B9090000. These two stations are located near the upper reaches of this watershed, capturing water quality information on the drainage from approximately 15% of the land area. A third station, B9191500, is located below the confluence with Goshen Swamp capturing the remaining drainage from 98% of this watershed.

The upper reach of the Northeast Cape Fear River [AU#: 18-74-19a] spans 3.4 freshwater miles. This segment of the river is on the impaired waters list for excursions of the aquatic life standard for chloride; however, there is a variance from the standard in place for the industrial permittee Mount Olive Pickle Company (NC0001074). The 2022 Chloride Variance Review discusses Mt. Olive Pickle Company's efforts to study and evaluate chloride removal technologies and reduction strategies (NCDEQ, 2022). The Town of Mount Olive WWTP is a major permitted facility with an as-built flow rate of 1.0 MGD. This facility discharges into a zero summer 7Q10 section of Northeast Cape Fear River. This facility has a few instances of non-compliance during inspections and flow violations in 2010 and 2018 that proceeded to enforcement cases. In 2021, this facility entered a Special Order by Consent (EMC SOC WQ S20-0021) to conduct required repairs and enhancements to the spray irrigation facility permitted under WQ0029169.

Specific conductance has been monitored at the water quality monitoring station B9080000. This station has recorded water with elevated conductance values downstream from the discharge location of Mount Olive Pickle Company. The high specific conductance is most likely due to the high concentrations of chloride in its discharge and detected at station B9080000 (*Figure 11-17*). Between 2016 and 2020, the instream chloride concentration ranged from 58 to 1,200 mg/L with a median concentration of 350 mg/L.

During 2016 to 2020, both the upper (B9090000) and lower (B9191500) surface water quality monitoring stations recorded multiple sampling events with fecal coliform bacteria concentrations more than 400 colonies/100 mL. At the upper water quality monitoring station (B9090000) fecal coliform exceeded 400 colonies/100 mL during 21% of the sampling events over this 5-year (2016-2020) timeframe. The downstream water quality monitoring station (B9191500) recorded fecal coliform bacteria exceedances during 25% of the sampling events over this same 5-year timeframe. These recent increases in fecal coliform concentrations have driven the annual mean value to exceed 400 colonies/100 mL in the headwaters of the Northeast Cape Fear River (*Figure 11-18*).

Nutrient and turbidity monitoring at station B9080000 was discontinued in 2016. Infrequent monitoring data available between 1991 and 2016 makes interpretation of the changes in water quality difficult. Between 2016 and 2020, elevated fecal coliform bacteria values were recorded in addition to turbidity measurements that ranged from 9.4 to 23 NTUs (

Table 11-15). These are the highest turbidity measurements collected at these monitoring stations during this period, indicating some elevated fecal coliform bacteria loads may be related to contributing runoff from nonpoint sources of pollution.

Figure 11-17: Annual Mean Specific Conductance Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

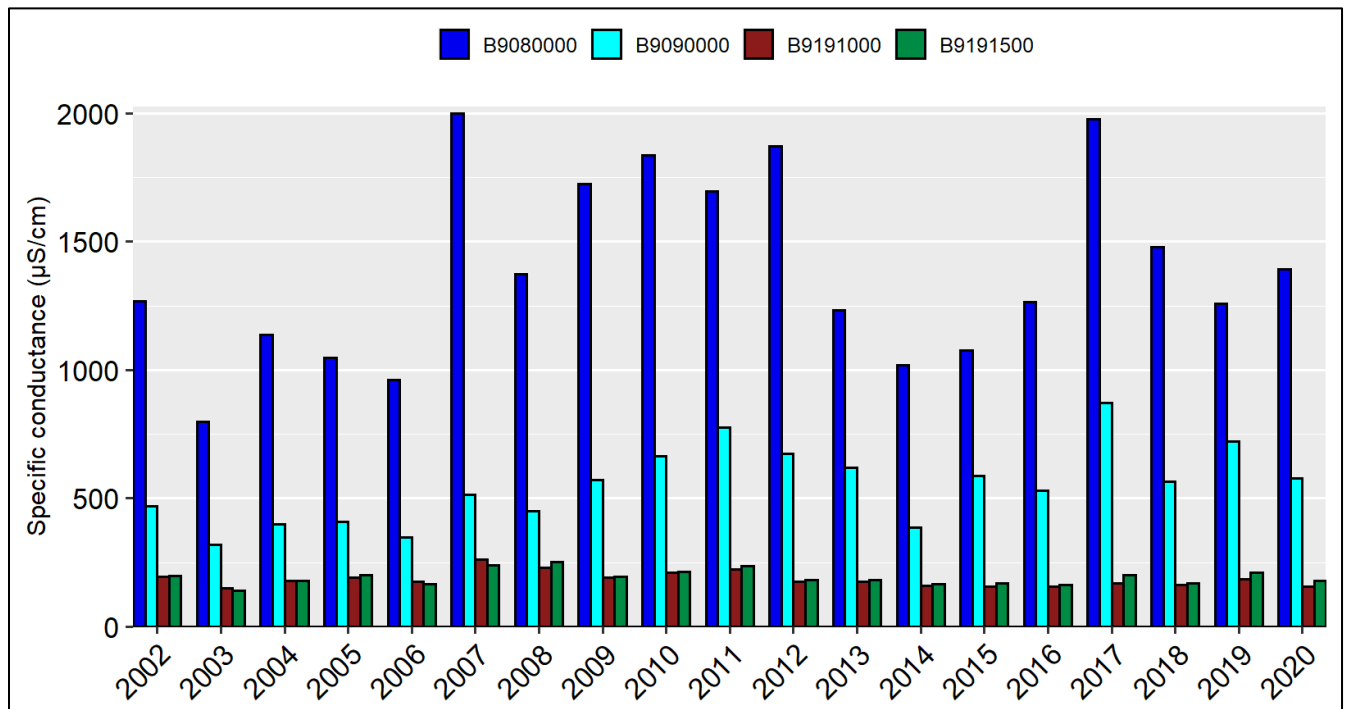


Figure 11-18: Annual Mean Fecal Coliform Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

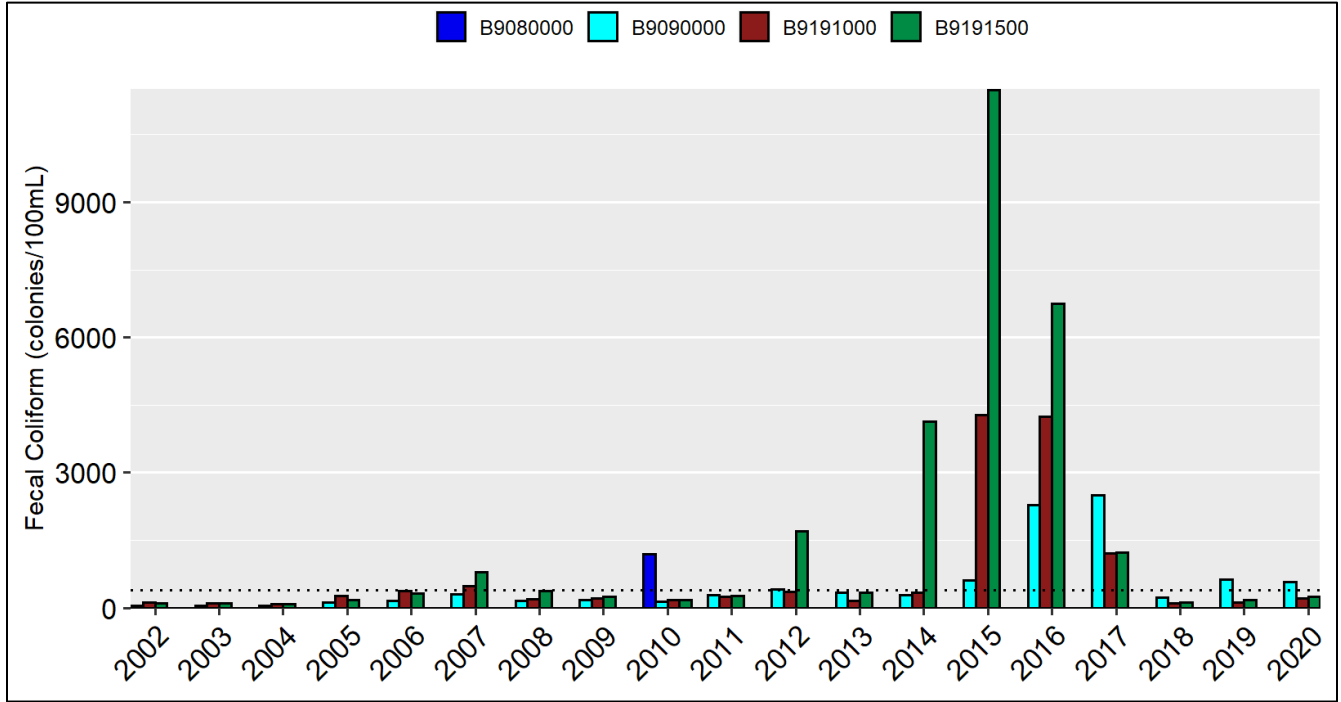


Table 11-15: Fecal Coliform Bacteria Values Greater Than 1,000 colonies/100 mL Collected Between 2016 and 2020 with Associated Turbidity Records for Station B9090000.

Station ID	Monitoring Location Name	Year	Month	Day	Fecal Coliform Value (Colonies/100 mL)	Turbidity Value (NTU)
B9090000	Northeast Cape Fear River at NC 403 near Williams	2017	5	30	1600	9.4
		2019	6	10	1500	23
		2020	1	13	2600	16
		2020	12	17	1600	17

Annual mean total nitrogen concentrations collected during 2016 to 2020 at the upper station (B9090000) and lower station (B9191500) indicate dilution is aiding in reducing the total nitrogen loads flowing from upstream to downstream (Figure 11-19). However, total nitrogen concentrations at both stations are often above the concentrations considered normal for minimally impacted streams with concentrations at the upper station recording nearly double the concentrations measured at the downstream station. Notably, annual mean nitrate+nitrite concentrations (NO_x) were exceptionally high at stations B9080000 and B9090000 with values that typically approach or exceed 1 mg/L (Figure 11-20). Exceptionally high ammonia concentrations were recorded in 2015 (Figure 11-21). These elevated ammonia concentrations are possibly attributed to ammonia limit violations between April to June from the Mount Olive Pickle Company effluent. These elevated ammonia concentrations contributed to the elevated total Kjeldahl nitrogen concentrations observed in this waterway in 2015 (Figure 11-22).

Similar to total nitrogen, total phosphorus at the upper (B9090000) and lower (B9191500) monitoring stations have concentrations greater than the concentrations considered normal for minimally impacted streams. Annual mean total phosphorus concentrations were exceptionally high in 2015; however, the point and/or nonpoint sources of these elevated phosphorus concentrations is unclear (Figure 11-23).

DWR conducted screening level Mann-Kendall trend seasonal tests for dissolved oxygen, fecal coliform bacteria, nitrate+nitrite at stations B9090000 and B9191500, resulting in significant increasing trends calculated at 95% confidence from data collected from 2000 to 2019. Mallin et al. (2022) also reported significant increases in ammonia, nitrate, total nitrogen and fecal coliform bacteria based on a series of statistical analyses conducted on data collected from 2000 to 2019 at station B9090000. DWR and Mallin et al. (2022) reported significant decreases in ammonia and increases in fecal coliform bacteria at station B9191500 from data collected from 2000 to 2019. DWR screening level Mann-Kendall seasonal trend tests showed significant increasing trends for ammonia, total kjeldahl nitrogen, turbidity and specific conductivity for data collected at station B9090000 and decreasing trend in ammonia at station B9191500 between 2000 and 2019.

Figure 11-19: Annual Mean Total Nitrogen Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

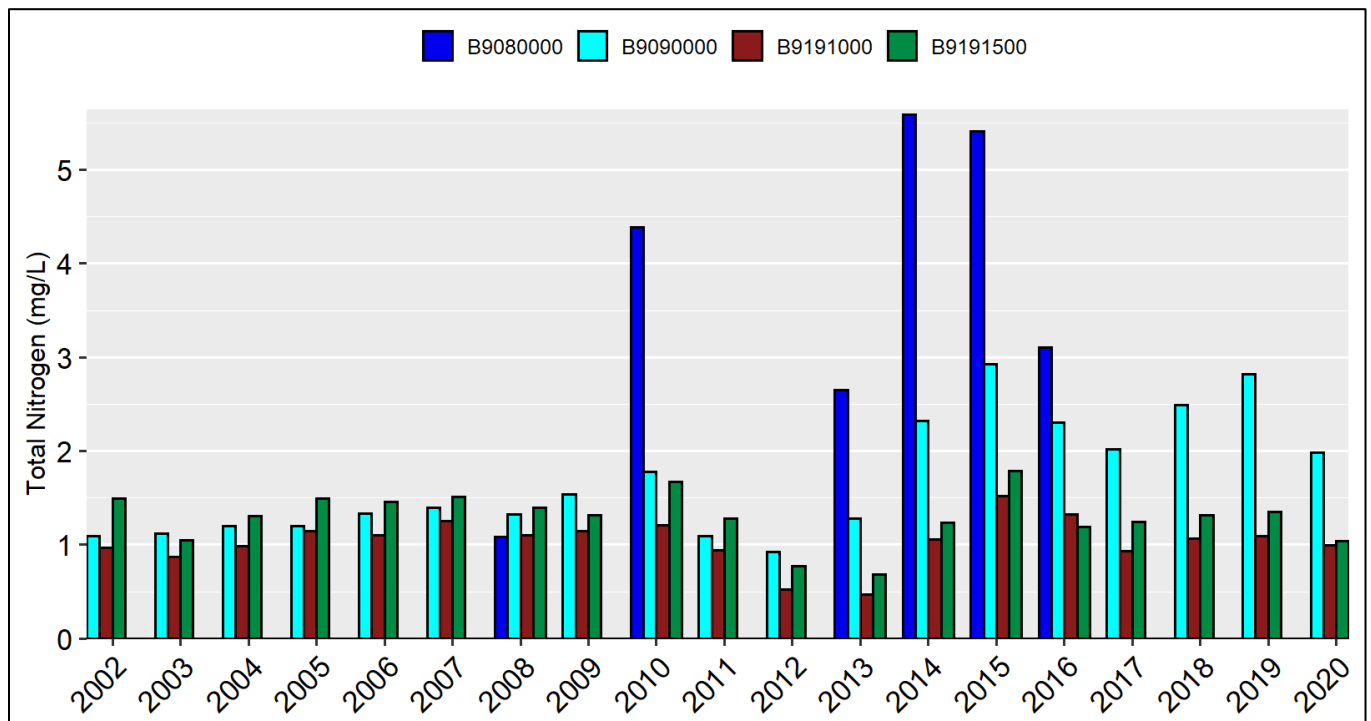


Figure 11-20: Annual Mean Nitrate+Nitrite Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

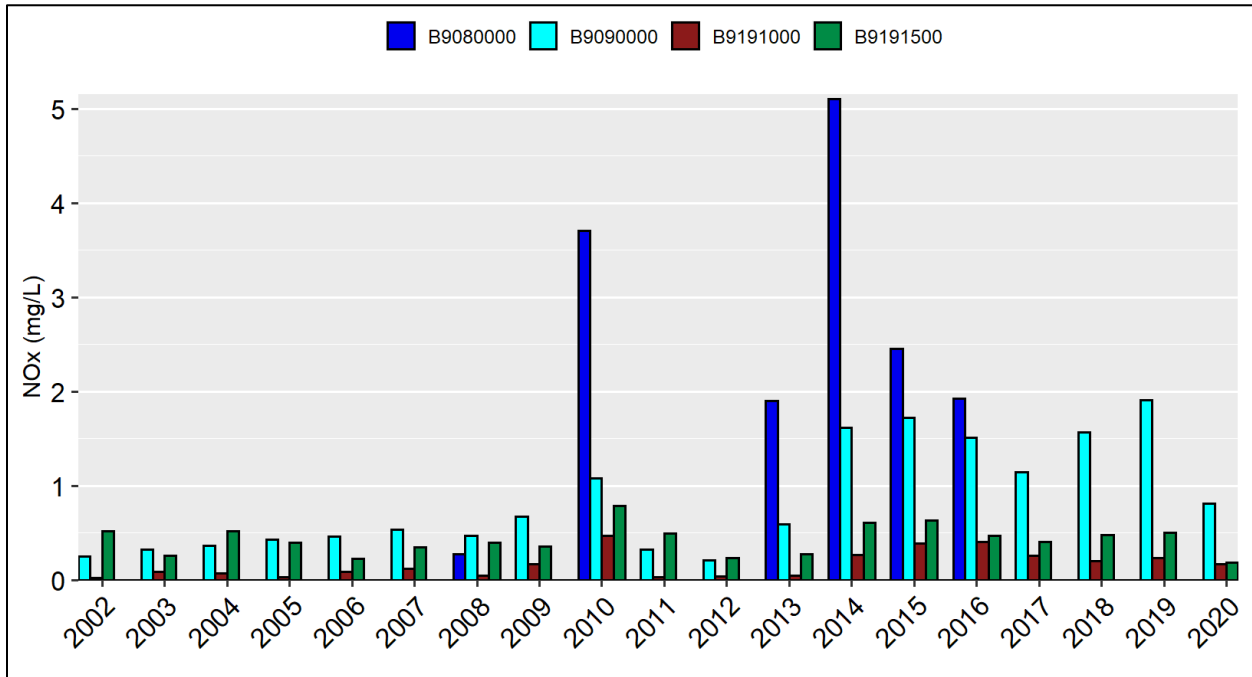


Figure 11-21: Annual Mean Ammonia Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

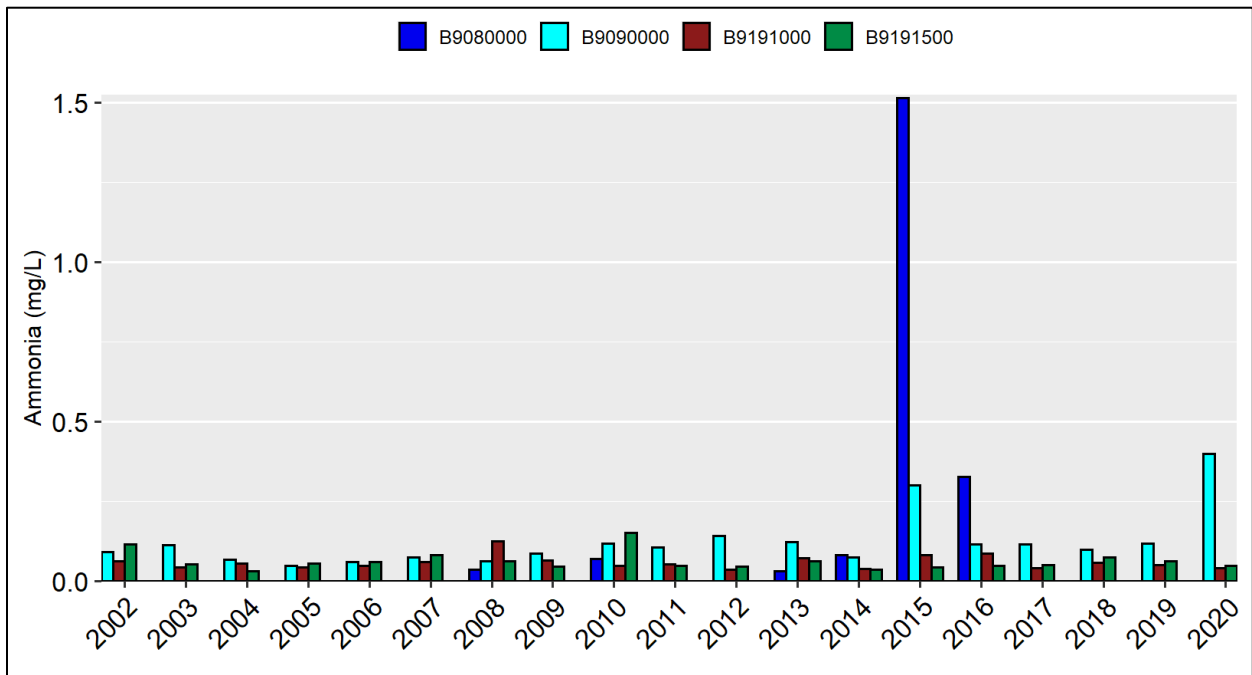


Figure 11-22: Annual Mean Total Kjeldahl Nitrogen Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.

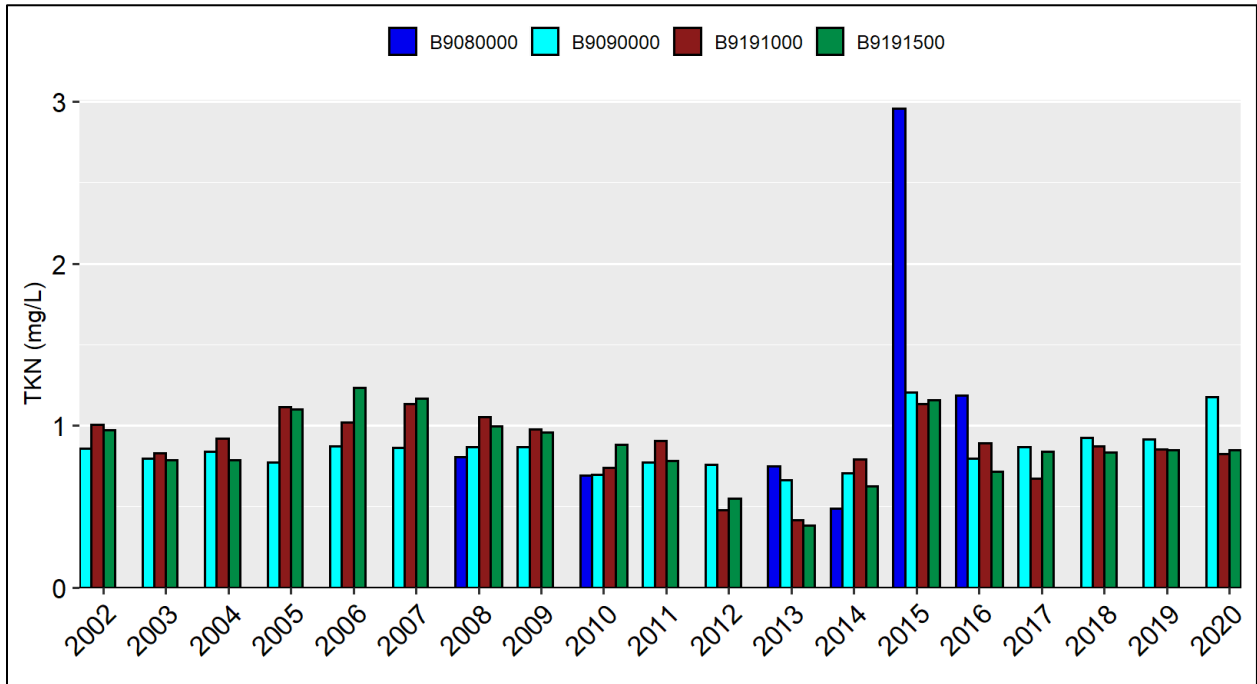
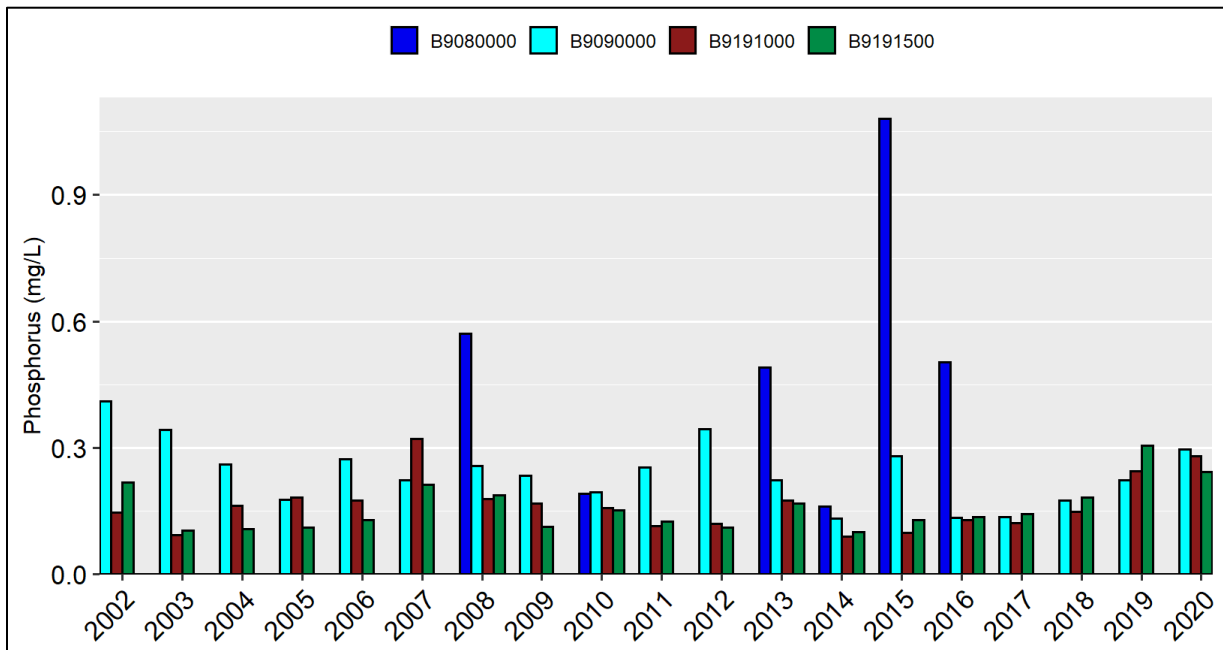


Figure 11-23: Annual Mean Total Phosphorus Results for Stations on Northeast Cape Fear River (B9080000, B9090000 and B9191500) and Goshen Swamp (B9191000) between 2002 and 2020.



11.8.2.2 Headwaters Northeast Cape Fear River Watershed Summary

Water quality in Northeast Cape Fear River is impacted by both point and nonpoint sources of pollution. Point sources in this watershed include discharges from several minor NPDES permitted facilities and two major NPDES permitted facilities. Major classified permitted facilities include the Town of Mount Olive Wastewater Treatment Plant (NC0020575) and Duplin Bioenergy (NC0058271). Mount Olive is required to continue efforts to reduce the discharge of chlorides and monitor chloride levels. Nonpoint sources of pollution in this watershed include swine and poultry feeding operations, agriculture practices, manure applications to cropland, septic systems and/or straight pipes, domestic animals and wildlife.

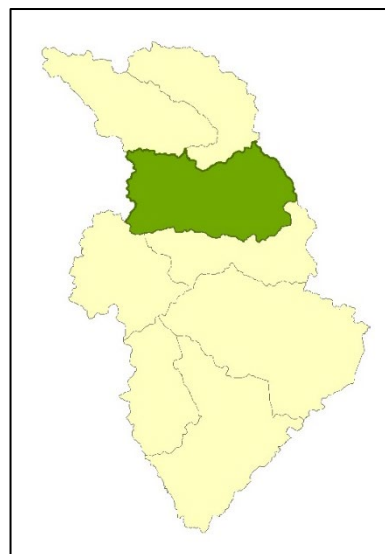
Elevated fecal coliform levels exceeding the 400 colonies/100 mL water quality standard were detected in approximately 1 in 4 samples collected in both the upper and lower reaches of the Northeast Cape Fear River within the headwaters. Poley Branch is a tributary of the Northeast Cape Fear River that was identified as having measurable manure effect from swine and poultry animal feeding operations (Harden, 2015). Nutrient (nitrate+nitrite, as well as phosphorus) concentrations were higher than those considered normal for minimally impacted streams. Increasing nitrate+nitrite concentrations were also reported in the Northeast Cape Fear River. Poor water quality from elevated fecal coliform bacteria levels and nutrient concentrations in this watershed caused by dense agriculture, animal feeding operations, nonpoint sources and point sources is transported downstream.

Based only on concentrations, it appears the headwaters of Northeast Cape Fear River influence the downstream water quality more than the adjoining Goshen Swamp. There are also possible impacts from tributaries not monitored by the current surface water quality regime; however, it is unclear which tributaries are most impactful. *Localized water quality monitoring and best management practices to address the nutrients and fecal coliform bacteria levels are necessary to improve water quality in this watershed. Additional recommendations for the Northeast Cape Fear River watershed include:*

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Working with the local County Health Department to have straight pipes that may be identified during stream walks removed and septic systems repaired.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Improving nutrient reductions at permitted facilities to reduce the nitrogen and phosphorus loads delivered downstream.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).

11.8.3 Limestone Creek – Northeast Cape Fear River Watershed (0303000703)

The Limestone Creek – Northeast Cape Fear River watershed spans 257 square miles primarily across central Duplin County. The mainstem river in this watershed is the Northeast Cape Fear River, which is joined by Grove Creek, Limestone Creek, Stocking Head Creek and Muddy Creek before leaving this watershed. Cabin Creek, which flows into Limestone Creek, is the only primary recreational water (Class B) in this watershed.



The primary land cover in this watershed is agricultural land (34%), forest land (28%) and wetlands (23%), followed by developed land (7%) and grassland/shrub (7%). There is one biological community monitoring station, two surface water quality monitoring stations and one lake monitoring station in this watershed. There has been limited fish community monitoring in this watershed since 1998 and many of the benthic macroinvertebrate community monitoring stations have not been revisited since at least 2001.

As of May 2022, there were many permitted facilities and fields located in this watershed. A total of 157 AFOs with a total allowable head count of 605,291, an allowable weight of 72.19 million pounds and 240 lagoons were in the watershed. There are six non-discharge permitted facilities--two major and four minor--with 35 fields covering approximately 0.55 square miles, located in the western side of the watershed near Beaverdam Branch, Maxwell Creek and Grove Creek. All of these rivers are tributaries of Northeast Cape Fear River. Notably, there are four NPDES-permitted facilities located near similar streams as the non-discharge permitted facilities, including Grove Creek and Beaverdam Branch. There is also a NPDES permit near Persimmon Branch. These five NPDES permitted facilities have an as-built flow totaling 820,000 GPD. There are also 13 NPDES stormwater and 74 state stormwater permitted facilities.

11.8.3.1 Northeast Cape Fear River Physical and Chemical Monitoring

The Limestone Creek – Northeast Cape Fear River watershed is positioned directly below the Headwaters Northeast Cape Fear River watershed. As such, the water quality monitoring of the Northeast Cape Fear River is continued through this watershed with one surface water quality monitoring station located below the confluence with Limestone Creek named B9196000 [AU#: 18-74-(1)c2 and 18-74-(1)c3]. The Northeast Cape Fear River maintains the class C water with a supplemental swamp classification, due to natural characteristics of swamps, such as low dissolved oxygen and pH. Information regarding dissolved oxygen in waterways of the Northeast Cape Fear River subbasin can be found in Section 11.10.2.

During 2016 to 2020, approximately 12% of the sampling events recorded fecal coliform bacteria concentrations more than 400 colonies/100 mL. Fecal coliform bacteria concentrations detected at this station (B9196000) are less than the levels upstream (B9191500) (*Figure 11-24*). Upon reviewing the 2010 to 2020 compliance history for Kenansville WWTP (NC0036668) and another nearby general-permitted facility, only one limit violation existed for fecal coliform bacteria between these two facilities. These

elevated fecal coliform bacterial levels are most likely attributed to nonpoint sources of pollution in the watershed.

Annual mean total nitrogen concentrations were typically higher at the downstream station (B9196000) compared to the upstream station (B9191500) in recent years (Figure 11-25), primarily due to higher nitrate+nitrite concentrations (Figure 11-26). This is accented by the relatively stable annual mean total Kjeldahl nitrogen concentrations that typically hover around 0.8 mg/L (Figure 11-27). DWR conducted screening level Mann-Kendall trend seasonal tests for fecal coliform bacteria, nitrate+nitrite nitrogen and total Kjeldahl nitrogen at station B9196000 that showed significant increasing trends calculated at 95% confidence from data collected from 2000 to 2019. Notably, between 2010 and 2020, the Kenansville WWTP had very few enforcement cases based on violations of biological oxygen demand and ammonia between 2010 and 2020.

Annual mean total phosphorus concentrations at the downstream station (B9196000) were often in sync with the upstream monitoring station (B9191500) (Figure 11-28). Exceptions occurred in 2018 and 2019 when the upstream monitoring station spiked in concentration resulting in annual mean values above 0.2 mg/L. The annual mean total phosphorus concentrations in this section of Northeast Cape Fear River were often the second highest compared to the downstream surface water quality monitoring stations. The highest annual mean total phosphorus concentrations were detected in the next station downstream (B9480000). These sustained total phosphorus concentrations are greater than concentrations considered normal for minimally impacted streams.

Figure 11-24: Annual Mean Fecal Coliform Bacteria Results on Northeast Cape Fear River (B9191500 and B9196000) between 2002 and 2020.

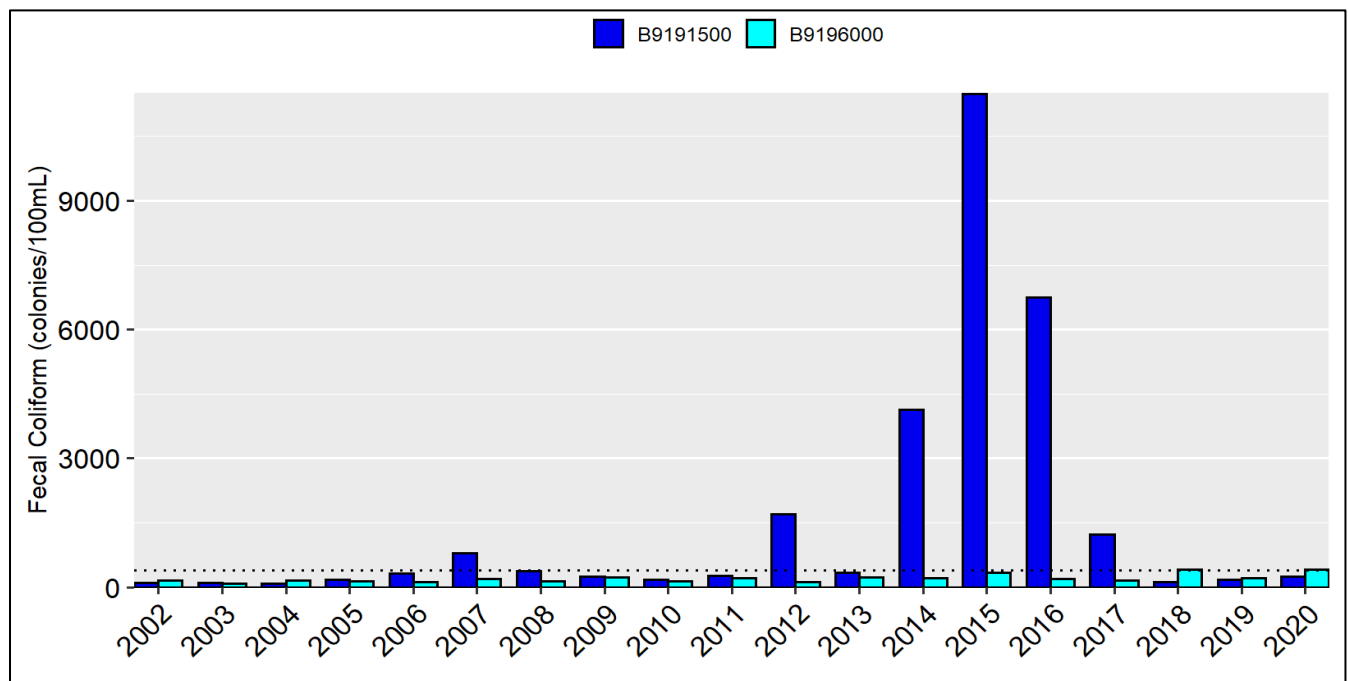


Figure 11-25: Annual Mean Total Nitrogen Results on Northeast Cape Fear River (B9191500 and B9196000) between 2002 and 2020.

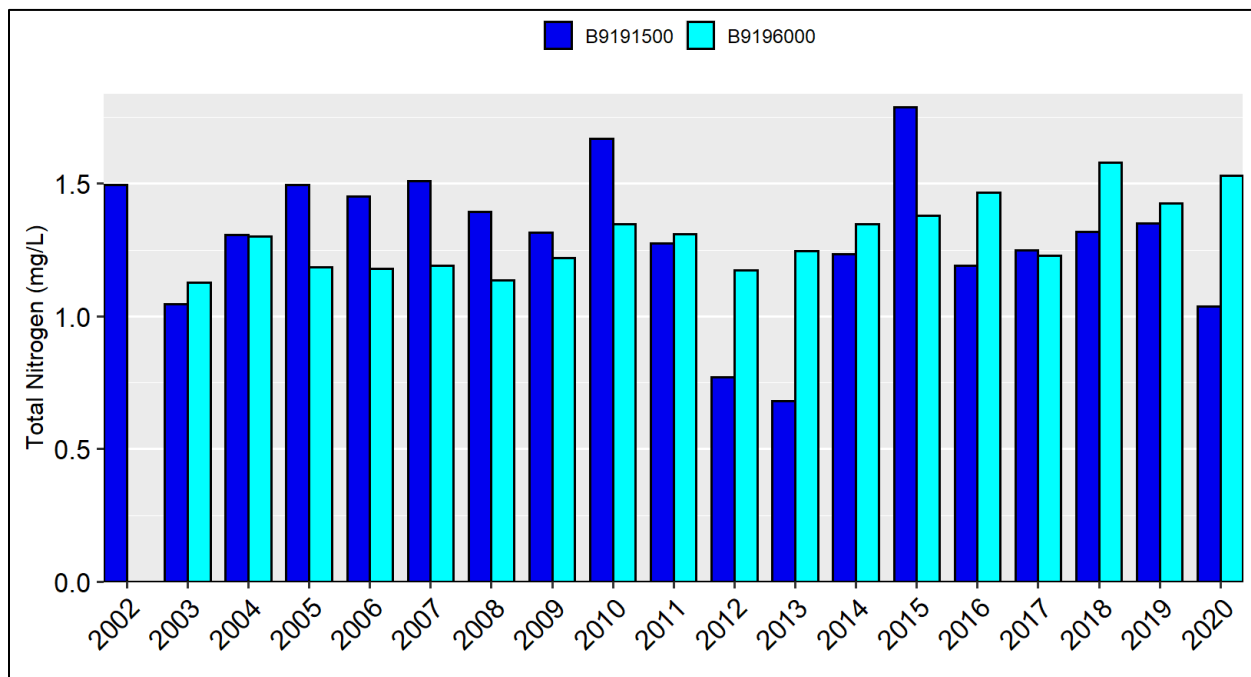


Figure 11-26: Annual Mean Nitrate+Nitrite Results on Northeast Cape Fear River (B9191500 and B9196000) between 2002 and 2020.

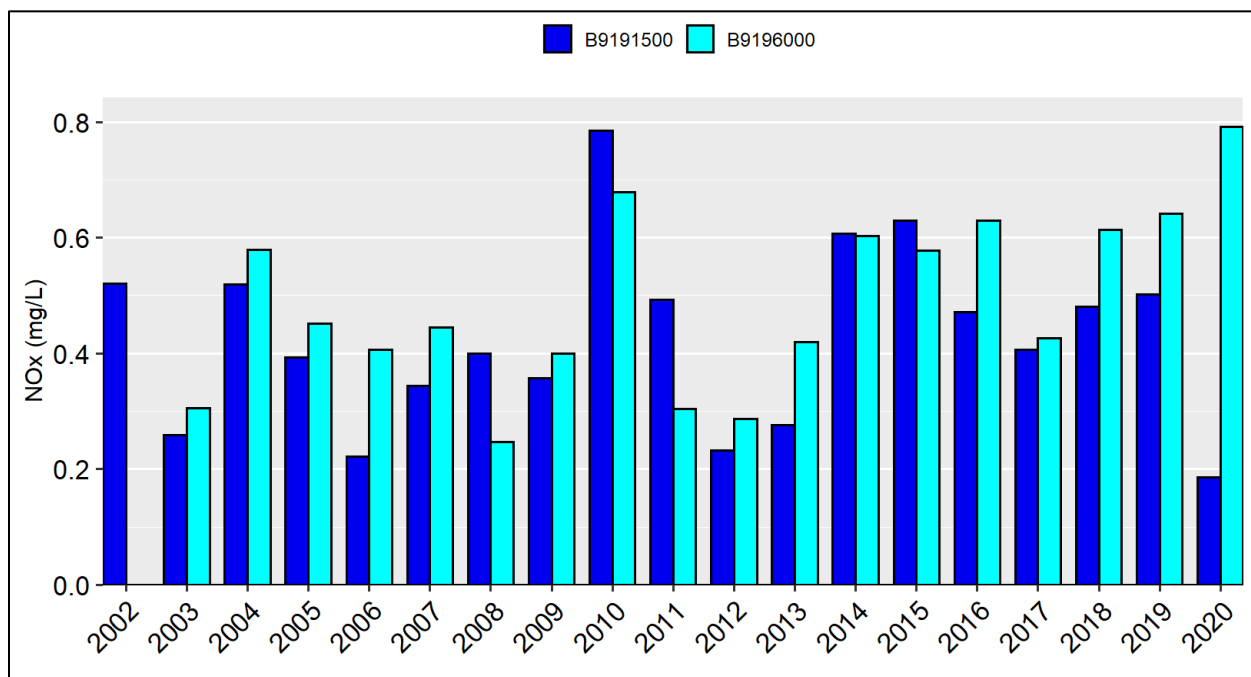


Figure 11-27: Annual Mean Total Kjeldahl Nitrogen Results on Northeast Cape Fear River (B9191500 and B9196000) between 2002 and 2020.

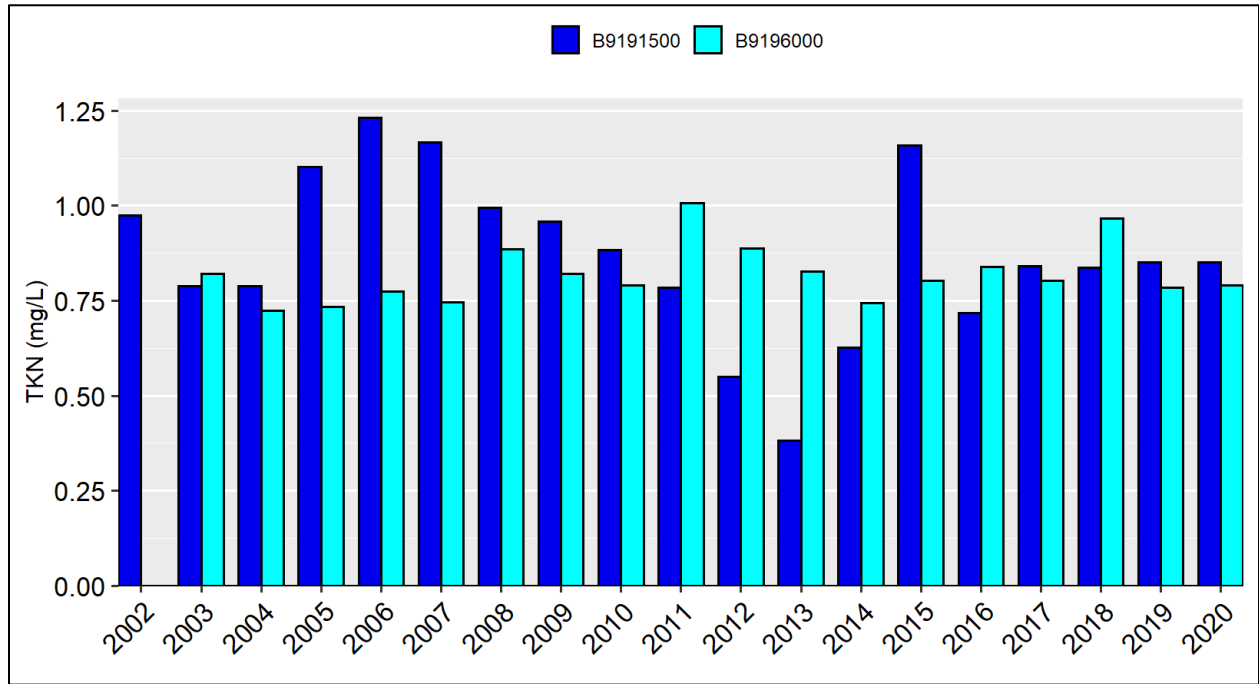
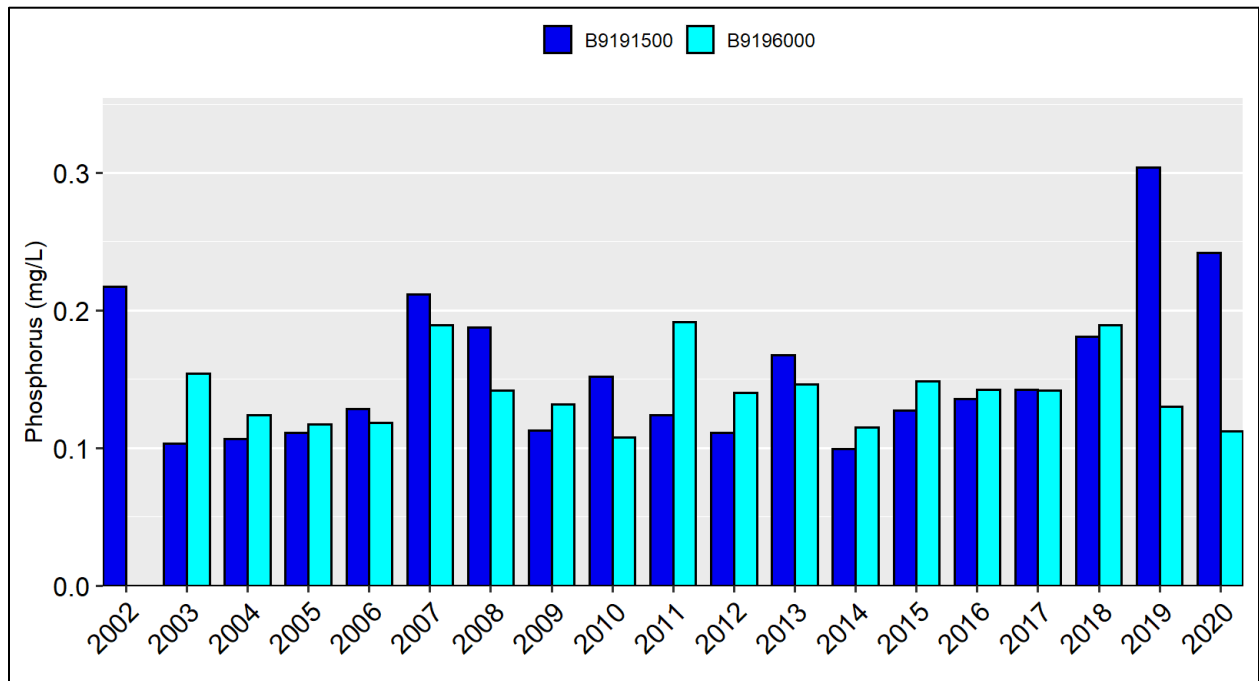


Figure 11-28: Annual Mean Total Phosphorus Results on Northeast Cape Fear River (B9191500 and B9196000) between 2002 and 2020.



11.8.3.2 Limestone Creek Biological Monitoring

Limestone Creek has co-located benthic macroinvertebrate and fish community monitoring stations positioned before the confluence with Northeast Cape Fear River [AU#: 18-74-23]. The fish community monitoring station was last sampled in 2008 and was not rated due to the limitations of rating fish communities in North Carolina Coastal Plain rivers and streams.

The benthic macroinvertebrate community monitoring station reported a Fair rating during the sampling event in 2018 (Table 11-16). This was the first Fair bioclassification recorded at this location. This resulted in 16.4 freshwater miles of Limestone Creek being listed on the impaired waters list for excursions of the aquatic life standard for benthos in 2020. The current survey revealed a lack of fauna based on both species richness and abundance.

Analysis of the substrate data from this location indicates that since 1993 boulder (25%) has disappeared and has been replaced with increasing estimates of sand: 1993 (65%), 1995 (75%), 1998 (100%), 2003 (90%), 2008 (100%) and 2018 (100%). As indicated in the 2008 site analysis, the substrate composition at this location has changed significantly since monitoring began in 1993. The substrate now consists entirely of fine sand, which has completely inundated both the boulder substrate and the benthos. This substrate transition is supported by the benthos community as taxa often associated with boulder habitat (*Neureclipsis sp.*, *Nyctiophylax moestus*, *Brachycentrus numerous*, *Paragnetina kansensis*, *Acroneuria abnormis*, *Procloeon sp.* and *Brachycercus sp.*) were collected only during the 1993 sample. Additionally, there is evidence that instream woody debris and snags, which are very important refugia in sandy coastal plain streams, have been manually removed.

Table 11-16: Biological Community Analysis in the Limestone Creek at Station BB319.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1993	Basin Sample	EPT	4.51	4.51	Excellent
1995	N/A	EPT	5.34	5.34	Poor
1998	Basin Sample	EPT	5.02	5.02	Good-Fair
2003	Basin Sample	EPT	4.96	4.96	Good-Fair
2008	Basin Sample	EPT	4.72	4.72	Good-Fair
2018	Basin Sample	EPT	5.13	5.13	Fair

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB319>

11.8.3.3 Muddy Creek Biological Monitoring

Muddy Creek spans 14 freshwater miles and is on the impaired waters list for excursions of the aquatic life standard for benthos based on results from a 2003 benthic macroinvertebrate community rating of Fair at station B125 [AU#: 18-74-25]. Muddy Creek is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. This was the second consecutive Fair rating. As time and resources allow, DWR should sample this benthic macroinvertebrate community location to determine if the aquatic life in this creek has improved.

11.8.3.4 Cabin Creek Physical and Chemical Monitoring

Cabin Lake [AU#: 18-74-23-2] is a part of the Cabin Lake Recreational Park, which is owned by Duplin County. Located between the towns of Kenansville and Beulaville, the lake was formed from the damming of Cabin Creek in 1993. Land use within the watershed consists of farmlands forests and animal operations. Swimming and boating with electric motors are permitted at this lake. This lake was monitored four times from May through September 2018. Two sites were sampled on each monitoring visit: one site located near the dam (CPFCL4) and the other near the middle of the lake (CPFCL2). In response to the availability of nutrients in Cabin Lake, chlorophyll *a*, an indicator of algal productivity, ranged from 3.2 to 61.0 ug/L.



Chlorophyll *a* values at one of the two sites sampled in August was greater than the state water quality standard of 40 ug/L. Based on calculated NCTSI scores for 2018, Cabin Lake was determined to have elevated biological productivity (**eutrophic conditions**) in May and September and exceptionally elevated biological productivity (**hypereutrophic conditions**) in June, July and August. Overall, the trophic status of Cabin Lake was found to be at the high end of eutrophic, bordering hypereutrophic (mean NCTSI score = 4.9).

11.8.3.5 Stocking Head Creek and Maxwell Creek Physical and Chemical Monitoring

A combined total of 30.7 freshwater miles in Stocking Head Creek [AU#: 18-74-24], Maxwell Creek [AU#: 18-74-24-1] and two unnamed tributaries to Stocking Head Creek [AU#: 18-74-24ut4 and 18-74-24ut5] are on the impaired waters list for excursions of the recreational standard for fecal coliform bacteria. Both Stocking Head Creek and Maxwell Creek are class C waters with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH.

In May 2018, NC DEQ entered into a Settlement Agreement with the NC Environmental Justice Network (NCEJN), the Rural Empowerment Association for Community Help (REACH) and the Waterkeeper Alliance to “improve regulatory oversight of swine operations and better protect neighboring communities from health and environmental impacts.” In May 2020, a preliminary report for the Cape Fear River Animal Feeding Operations Monitoring Study (CFRAFOMS) was included in [Appendix G](#) of the [Title VI: Increasing Equity, Transparency, and Environmental Protection in the Permitting of Swine Operations in North Carolina](#) report. The report evaluated the analytical data obtained from water samples collected from eleven surface water quality monitoring stations in Duplin and Pender counties and represents monitoring results from April 2018 to October 2019. Ten of the 11 water quality monitoring stations and one reference, or background, station were included in the study. The reference station was located in the Harrisons Creek watershed in Pender County. The remaining stations were located in watersheds with high concentrations of permitted swine AFOs. Seven were located in the Stocking Head Creek watershed.

One was located in the Rockfish Creek watershed. One is located in the Muddy Creek watershed and one was located in the Six Runs Creek watershed.

The results of the preliminary [report](#) indicated that “it appears that nutrient and pathogen concentrations are higher for the test stations in the concentrated AFO areas as compared to the reference station with no AFOs in the drainage area. The next step for this study is to determine the source of the nutrients and pathogens. Source identification for ubiquitous parameters such as nutrients and pathogens can be difficult.” DWR is working to identify next steps. In the meantime, a new, permanent water quality monitoring station (B9245000) was established in Stocking Head Creek.

Data collected from station B9245000 show that fecal coliform bacteria levels and nitrate+nitrite concentrations continue to be a concern as fecal coliform bacteria levels were often above the water quality standard and nitrate+nitrite concentrations exceeded 10 mg/L both years. It is worth noting that monitoring was suspended in 2020 between April and August due to COVID-19 restrictions. Eight samples were collected at the close of 2020 and compared to 12 samples from 2019. The range of fecal coliform bacteria values for 2019 were 50 to 2,400 colonies/100 mL. In 2020, the range was 170 to 6,800 colonies/100 mL ([Figure 11-29](#)). Nitrate+nitrite ranges were 0.45 to 14 mg/L in 2019 and 5.6 to 12 mg/L in 2020 ([Figure 11-30](#)). Total phosphorus concentrations ranged from 0.12 to 0.39 mg/L in 2019 and 0.1 to 1.8 mg/L in 2020 ([Figure 11-31](#)).

Turbidity and fecal coliform bacteria values exceeded the water quality standards on December 17, 2020, after 1.76 inches of rainfall ([Figure 11-32](#) and [Figure 11-29](#)). This increased turbidity could also help explain the high total phosphorus concentrations as eroded phosphorus-laden sediment could have been transported into the waterway. This rainfall event also possibly flushed low pH waters in surrounding marsh and wetland areas into Stocking Head Creek, reducing the pH levels ([Figure 11-33](#)). Another notable event was a high nutrient pulse of ammonia concentration at 7.6 mg/L recorded on October 15, 2020 ([Figure 11-34](#)). This event also produced some of the highest values of nitrate+nitrite as well as total Kjeldahl nitrogen with concentrations of 12 mg/L for each. The total phosphorus concentration was 1.8 mg/L, there was a specific conductance value of 602 $\mu\text{S}/\text{cm}$, fecal coliform bacteria levels were recorded at 1,500 colonies/100 mL and turbidity was 30 NTUs. Specific conductance is shown in [Figure 11-35](#). Dissolved oxygen levels fluctuated with the seasons but fell below the water quality standard of 4 mg/L on September 30, 2019 ([Figure 11-36](#)).

A Stocking Head Creek source identification study is recommended. The study could provide additional information regarding the potential sources of elevated fecal coliform bacteria concentrations. Efforts should be made to reduce the bacterial loading from all sources in the watershed.

Figure 11-29: Fecal coliform Bacteria Levels Recorded in Stocking Head Creek at Station B9245000.

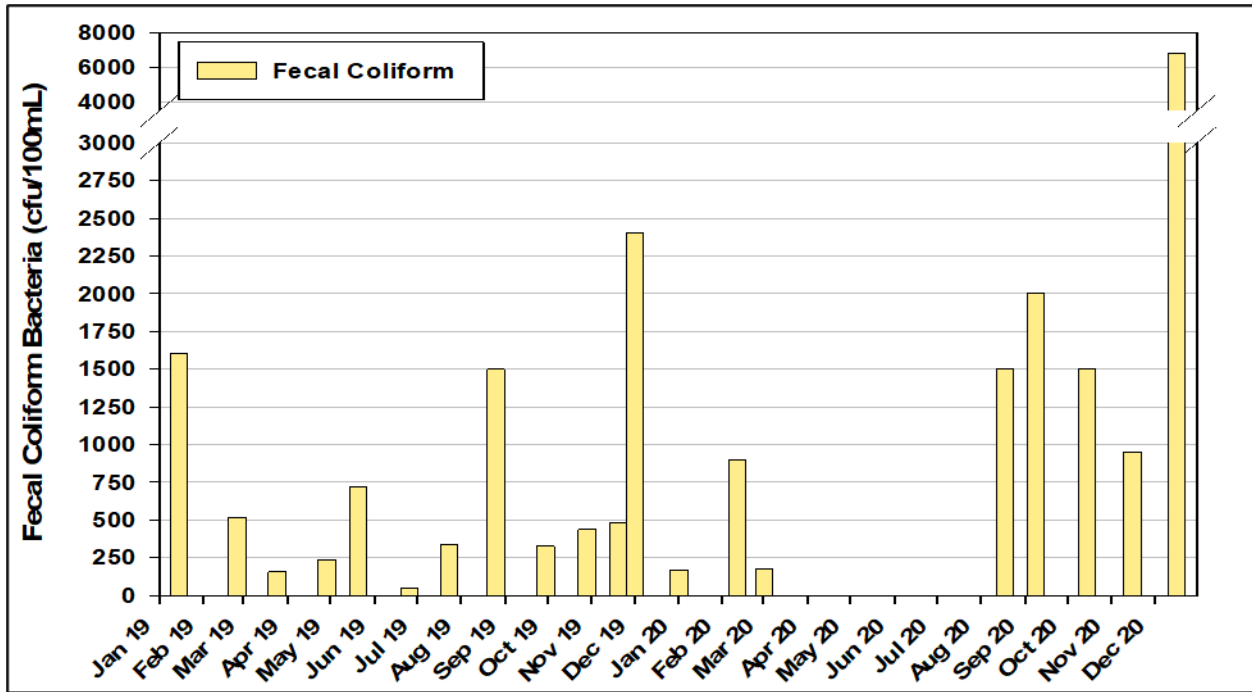


Figure 11-30: Nitrate+nitrite Concentrations (NOx) and Total Kjeldahl Nitrogen Concentrations in Stocking Head Creek at Station B9245000.

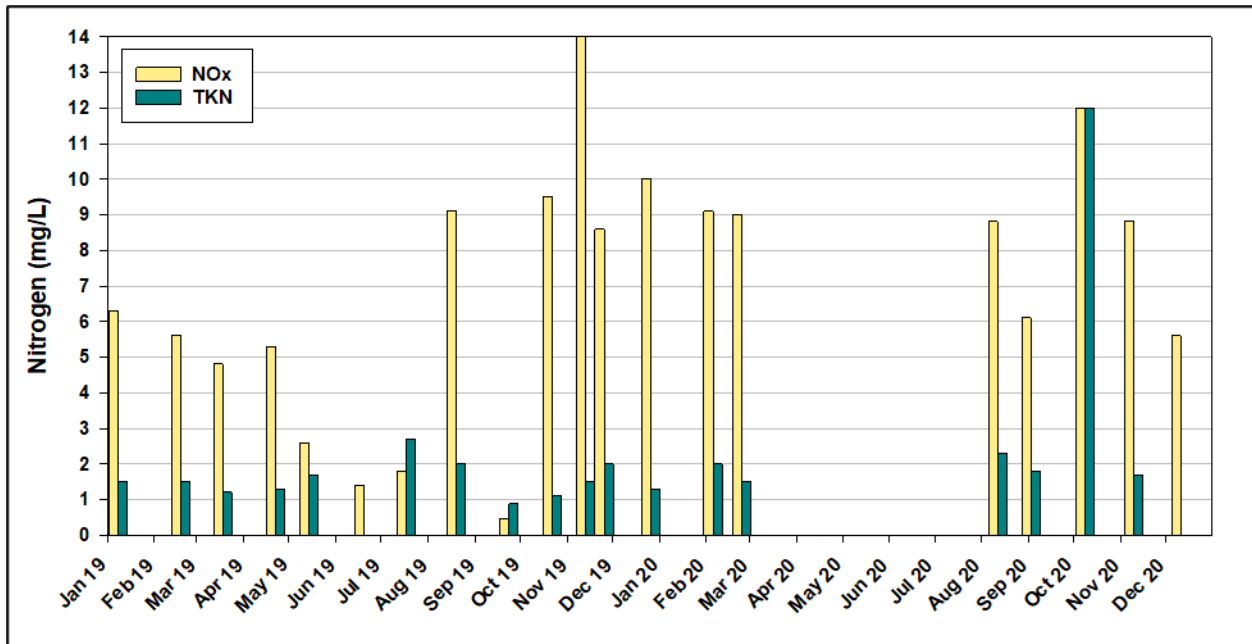


Figure 11-31: Total Phosphorus Concentrations Recorded in Stocking Head Creek at Station B9245000.

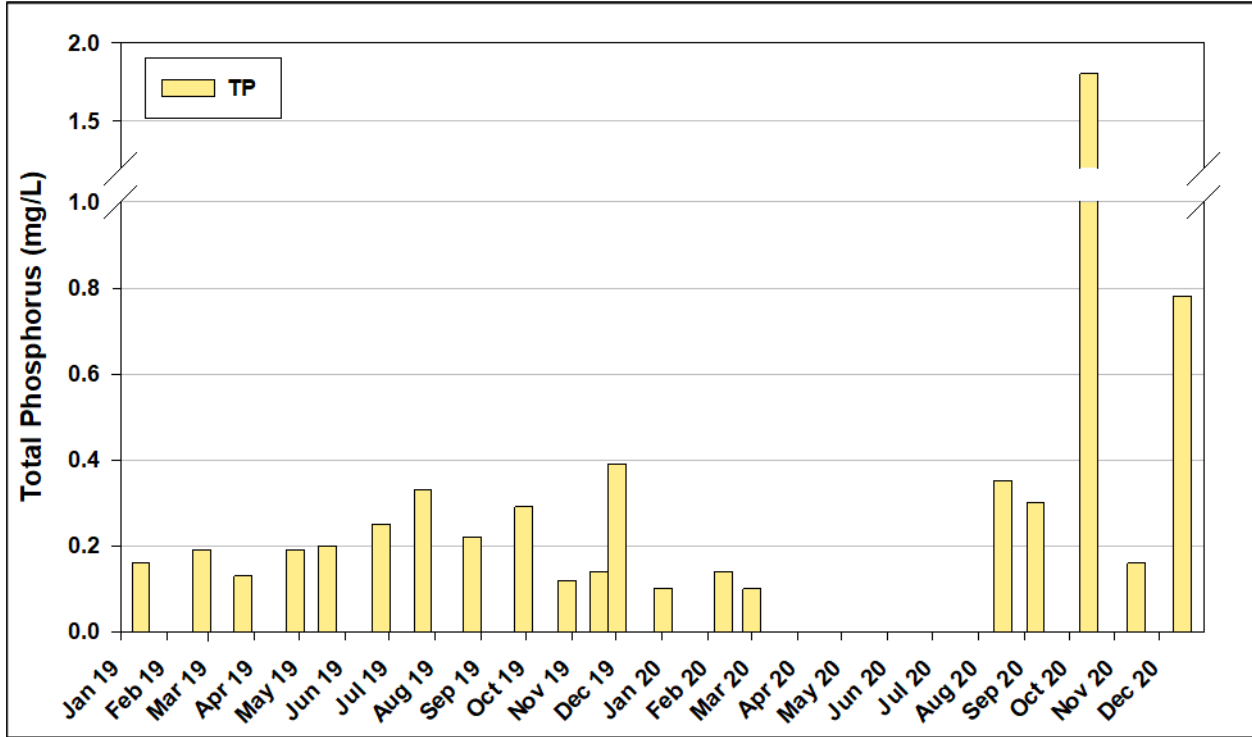


Figure 11-32: Turbidity Levels Recorded in Stocking Head Creek at Station B9245000.

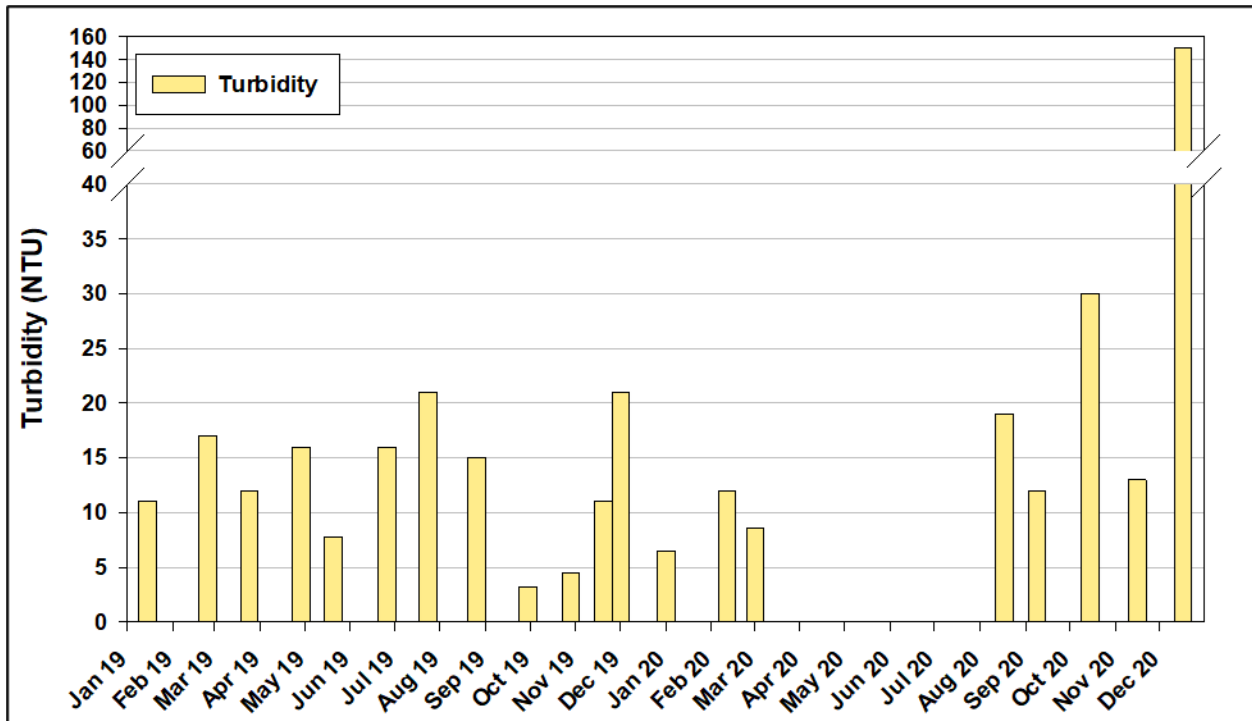


Figure 11-33: The pH Levels Recorded in Stocking Head Creek at Station B9245000.

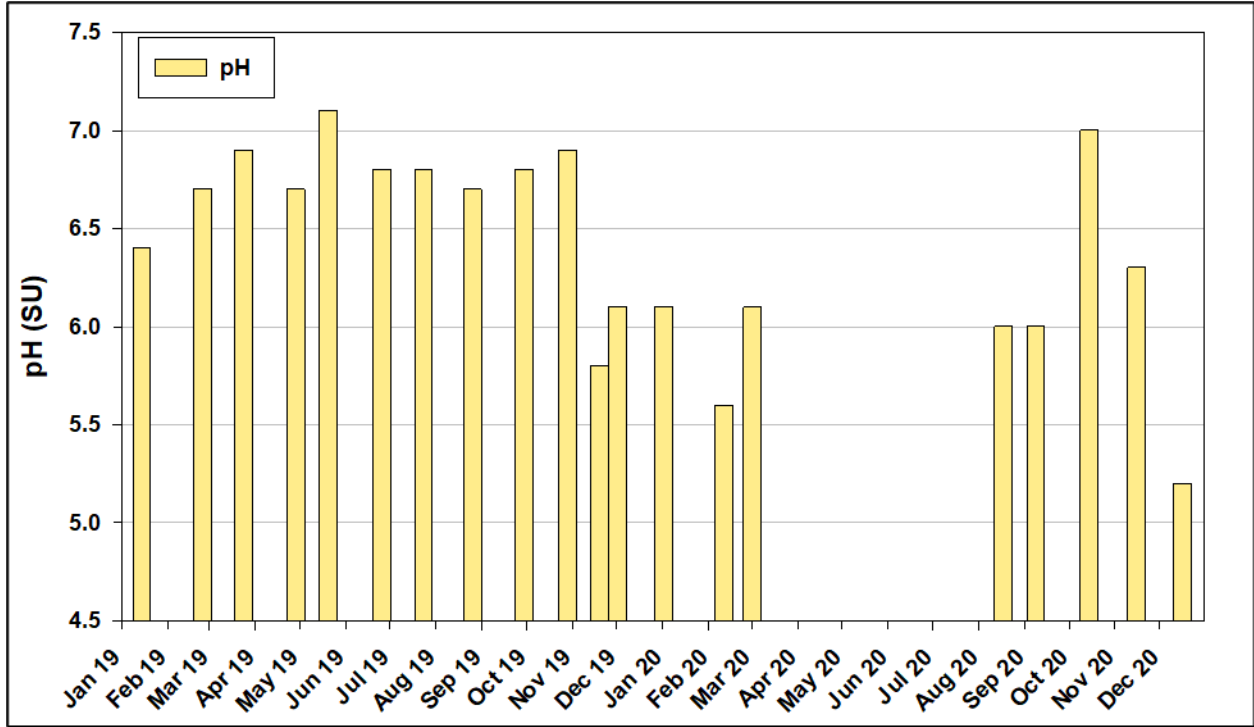


Figure 11-34: Ammonia Concentrations Recorded in Stocking Head Creek at Station B9245000.

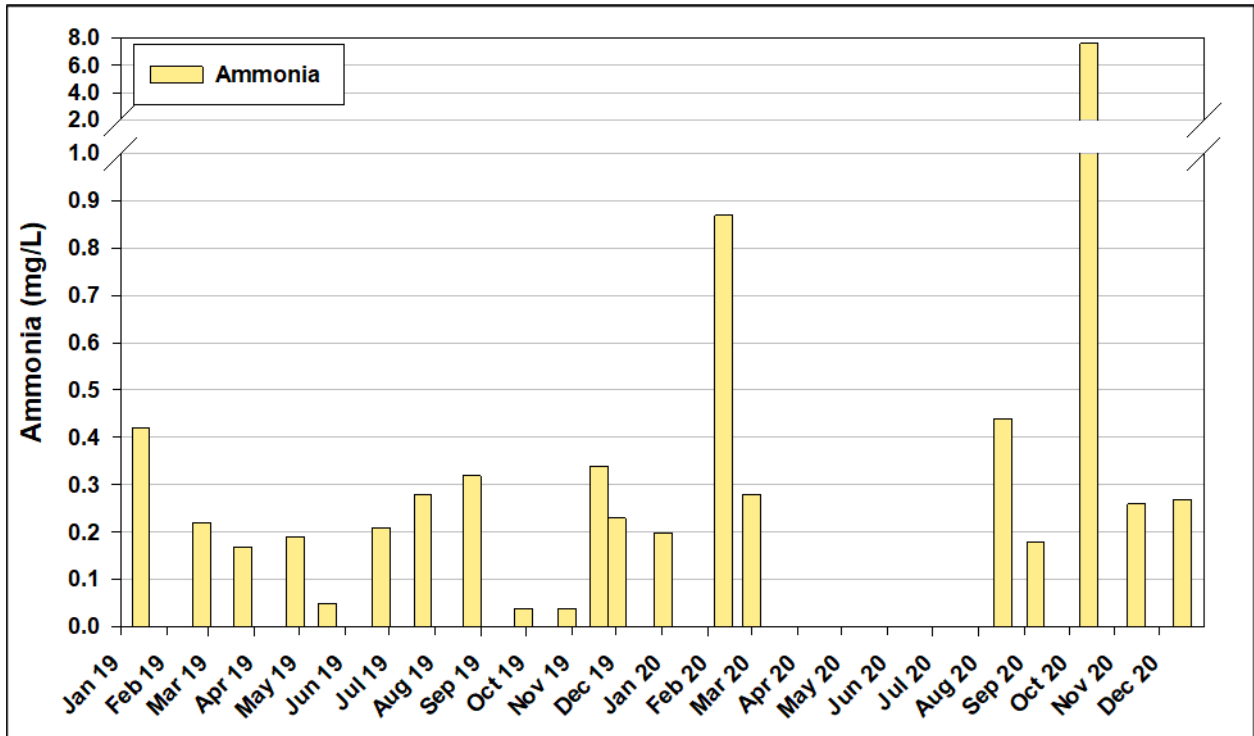


Figure 11-35: Specific Conductance Levels Recorded in Stocking Head Creek at Station B9245000.

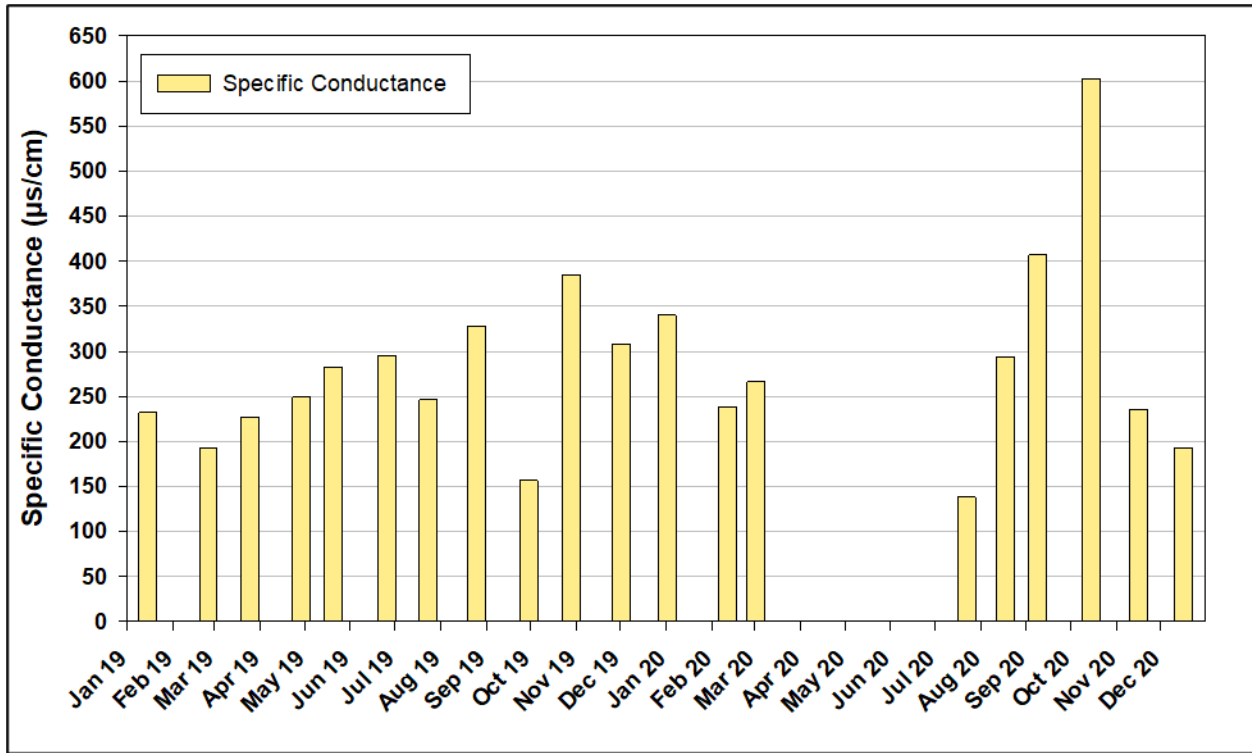
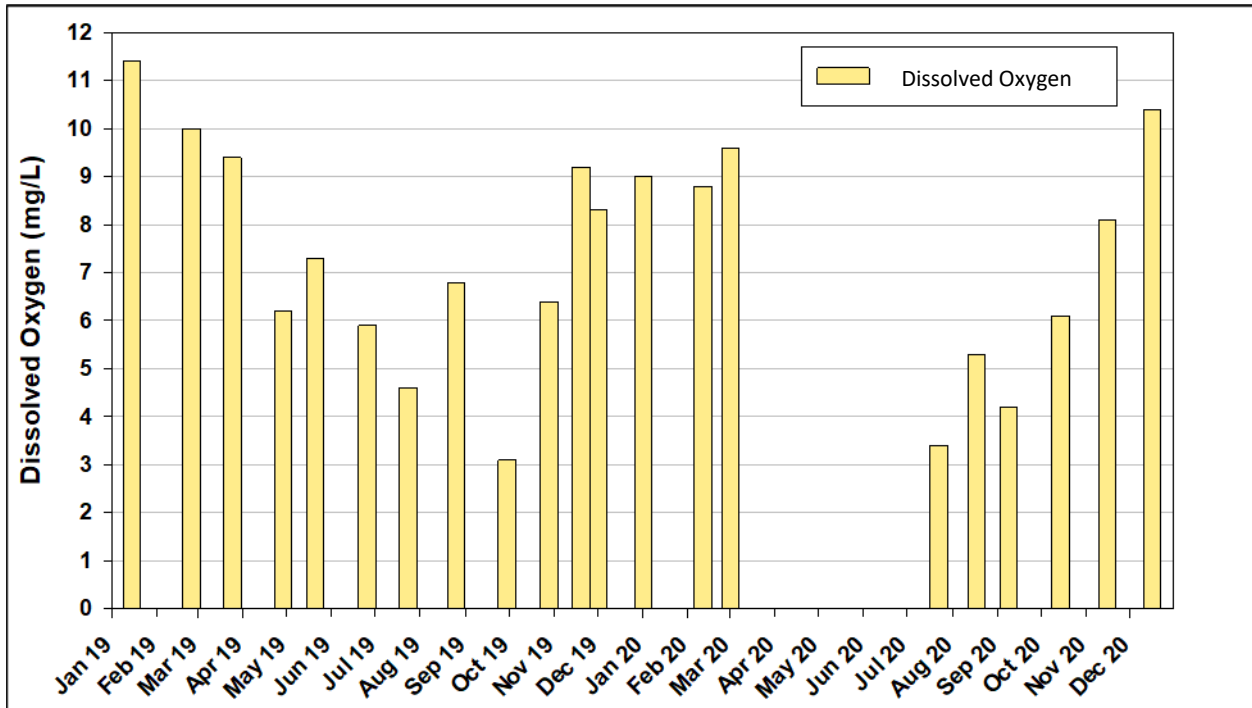


Figure 11-36: Dissolved Oxygen Levels Recorded in Stocking Head Creek at Station B9245000.



11.8.3.6 Limestone Creek – Northeast Cape Fear River Watershed Summary

Water quality in Limestone Creek, Cabin Creek, Muddy Creek, Stocking Head Creek, Maxwell Creek and the Northeast Cape Fear River are impacted by both point and nonpoint sources of pollution. Point sources in this watershed include discharges from several minor NPDES permitted facilities. While two of the point source dischargers are general permits (non-contact cooling water), the other two are the Kenansville (0.3 MGD, NC0036668) and Beulaville (0.52 MGD, NC0026018) WWTPs. The two WWTPs received a few limit violations for effluent; however, this is not a typical occurrence. Nonpoint sources of pollution in this watershed include swine and poultry feeding operations, agriculture practices, manure applications to cropland, septic systems and/or straight pipes, domestic animals and wildlife.

Multiple impairments from nonpoint sources exist in this watershed. Biological community impairments are in Limestone Creek and Muddy Creek and fecal coliform impairments are in Stocking Head Creek, Maxwell Creek and two unnamed tributaries of Stocking Head Creek. In addition to these impaired waterbodies, Cabin Creek has exceptionally elevated biological productivity and recent sampling recorded exceedances of the 40 ug/L water quality standard for chlorophyll *a*, possibly due to excess nutrients. In the mainstem Northeast Cape Fear River, total nitrogen (total Kjeldahl nitrogen plus nitrate+nitrite) concentrations are increasing over time and total phosphorus concentrations are around historic levels.

An increasing trend in fecal coliform bacteria concentrations was detected at both the upstream and downstream monitoring stations on Northeast Cape Fear River. This increasing trend, alongside the elevated fecal coliform bacteria concentrations from Stocking Head Creek, is concerning because these concentrations flow downstream. Poor water quality from elevated fecal coliform bacteria levels in this watershed are most likely caused by nonpoint sources of pollution. This was evident in the samples collected after a rain event in Stocking Head Creek. Additionally, a tributary of Muddy Creek, named Stephens Swamp, had a measurable manure effect from swine and poultry animal feeding operations (Harden, 2015).

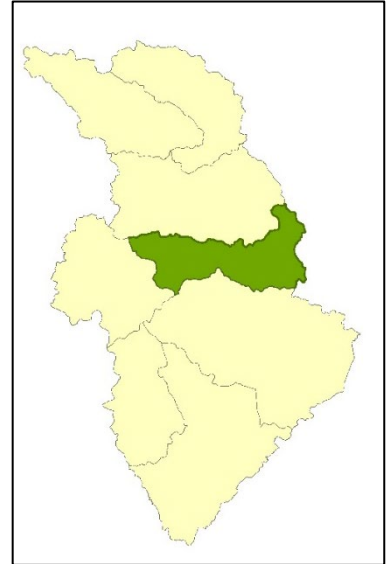
Localized water quality monitoring and best management practices to address the nutrients and fecal coliform bacteria levels are necessary to improve water quality in this watershed. Additional recommendations for the Limestone Creek – Northeast Cape Fear River watershed include:

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Working with the local County Health Department in having straight pipes that may be identified during stream walks removed and septic systems repaired.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).

- As time and resources allow, DWR should pursue sampling of Muddy Creek’s benthic macroinvertebrate community to determine if the aquatic life in this creek has improved.

11.8.4 Cypress Creek – Northeast Cape Fear River Watershed (0303000704)

The Cypress Creek-Northeast Cape Fear River watershed spans 154 square miles across south-central Duplin and western Onslow counties. The upper reaches of this watershed begin in Onslow County and include Back Swamp and Ninemile Creek, which meet southeast of the Cypress Creek community. As the river flows westward, it is joined by Angola Creek before the confluence with the Northeast Cape Fear River east of the Sloan community. The Northeast Cape Fear River is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. Additionally, this waterway has the supplemental classification of High Quality Waters. Before the Northeast Cape Fear River exits this watershed, it is joined by Island Creek before flowing downstream into the Angola Swamp – Northeast Cape Fear River watershed. Based on the 2019 land cover data, the primary land cover in this watershed is slightly different than the upstream watersheds with forest land (31%) covering the largest fraction of land, followed by wetlands (28%) and agriculture (26%). Developed land (7%), grassland/shrub (7%) and open water (1%) comprise the remaining land cover.



As of May 2022, there were many permitted facilities and fields located in this watershed. In total, there are 62 AFOs with a total allowable head count of 207,303, an allowable weight of 21.5 million pounds and 86 lagoons scattered across this entire watershed. There is one non-discharge permitted facility located in the western side of the watershed near Cooks Branch with three fields covering approximately 0.05 square miles. There are two minor NPDES permitted facilities near Reedy Branch with a combined as-built flow totaling 450,000 GPD. There are also five NPDES stormwater and 29 state stormwater permitted facilities.

Between 2010 and 2020 Rose Hill WWTP (0.45 MGD, NC0056863) had several enforcement cases based on limit violations for ammonia and biological oxygen demand throughout the years in addition to a few for fecal coliform and dissolved oxygen. During a recent permit renewal, a significant decrease in dissolved oxygen concentrations was observed downstream from this facility in Reedy Branch. During a site visit conducted in December 2022, DWR found this facility’s effluent not to be the primary cause for concern. Instead, existing low-flow conditions exacerbated by beaver dams appeared to be the cause of low dissolved oxygen in Reedy Branch.

11.8.4.1 Northeast Cape Fear River Biological Monitoring

Northeast Cape Fear River [AU#: 18-74-(25.5)] was last sampled in 2008. This assessment unit is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. Notably, this assessment unit also has the High Quality Water classification. State biologists reported that this site rated Good-Fair in 2008, an improvement from Poor in 1998. Prior

to this 2008 sampling event, between 1985 through the summer of 1998, five benthic samples collected were rated Excellent (3) or Good (2) (*Table 11-17*). In 2003 and 2004, this site was not sampled due to high water levels. This site is still recovering from drought conditions seen throughout North Carolina in 2007 and 2008. Additional sampling should occur here to ascertain the non-drought condition of this waterbody.

Table 11-17: Biological Community Analysis in the Northeast Cape Fear River at Station BB126.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1993	Basin Sample	Full Scale	4.57	5.49	Good
1998	Basin Sample	Full Scale	4.84	5.6	Excellent
1998	Special Study	Full Scale	4.32	6.87	Poor
2008	Basin Sample	Full Scale	4.28	6.14	Good-Fair

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB126>

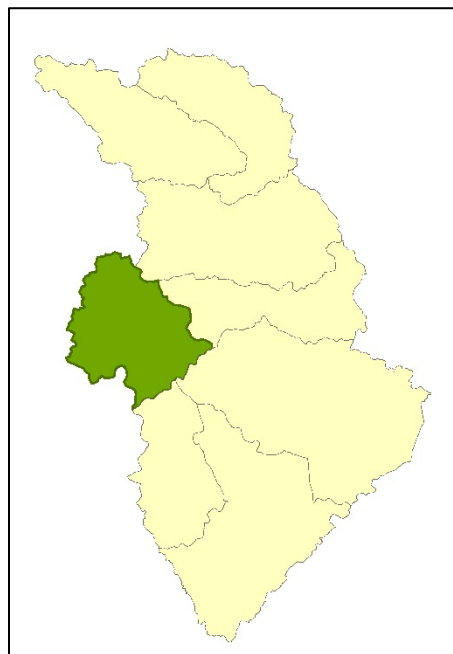
11.8.4.2 Cypress Creek – Northeast Cape Fear River Watershed Summary

Water quality in this watershed is poorly understood due to a lack of water quality monitoring. The most recent biological samples were collected in 2008. Due to the lack of surface water quality monitoring in this watershed recommendations are limited. Recommendations for Cypress Creek watershed include:

- Continuously working with the Rose Hill WWTP (NC0056863) to prevent limit violations for ammonia and biological oxygen demand, fecal coliform and dissolved oxygen.
- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).

11.8.5 Rockfish Creek Watershed (0303000705)

The Rockfish Creek watershed spans 178 square miles across Sampson, Duplin and Pender counties. The mainstem river in this watershed is Rockfish Creek formed by the combination of Murpheys Creek and Big Beaverdam Creek. The creek flows southeast and is joined by Duff Creek, Doctors Creek and Little Rockfish Creek, leaving the watershed to join Northeast Cape Fear River. Duff Creek (Lake Tut) is the only primary recreational (Class B) waterway in this watershed. Like other watersheds in this subbasin, the primary land cover is agricultural land (32%), forest land (29%), wetlands (23%), followed by grassland/shrub (9%) and developed land (7%).



As of May 2022, there were many permitted facilities and fields located in this watershed. A total of 70 AFOs with a total allowable head count of 402,731, an allowable weight of 53.16 million pounds and 133 lagoons were in the watershed. There are four land application fields covering approximately 0.06 square miles located in the northern side of this watershed near Taylors Creek. There are also four NPDES permitted facilities in this watershed. Two minor permitted facilities, Wallace Chicken Processing Plant and Rosemary Feed Mill - Rose Hill, are located near Duff Creek and the confluence with Rockfish Creek. Another, Penderlea Elementary School WWTP, is located near Crooked Run. The Wallace Regional WWTP is the only major permitted facility that discharges into Rockfish Creek and is located near Little Rockfish Creek (Boney Mill Pond). Combined, these four NPDES permitted facilities have an as-built flow totaling 5.12 MGD. There are also seven NPDES stormwater and 41 state stormwater permitted facilities.

Between 2018 and 2020, the Wallace Regional WWTP had enforcement cases for ammonia, biological oxygen demand and a single enforcement case for fecal coliform bacteria. In discussing the compliance history with the Wilmington Regional Office (WiRO), it was revealed that the issues observed at the plant in 2018 were related to equipment damage as a result of Hurricane Florence. The WWTP continued to be plagued with equipment-related issues, with various correspondences throughout 2021 and 2022 with the town indicating issues with malfunction decanters and diffusers in two of the three sequencing batch reactor basins, blower issues and issues with the carpet media on both filters needing to be replaced leading to fouling. The town has consistently communicated with the WiRO on these issues and the timeline by which the issues were resolved ([link to factsheet](#)).

11.8.5.1 Little Rockfish Creek Physical, Chemical and Biological Monitoring

Little Rockfish Creek [AU#: 18-74-29-6-2 and 18-74-29-6] joins Rockfish Creek between surface water quality monitoring stations B9430000 and B9470000. Little Rockfish Creek is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. This tributary has one water quality monitoring station B9460000. This monitoring station receives drainage from approximately 9.2 square miles. The land cover draining to this station is

composed of agricultural land (30%), wetlands (23%), developed (23%), forest land (20%) and grassland/shrub (4%).

From 2016 to 2020, 32% of sampling events recorded fecal coliform bacteria concentrations in excess of 400 colonies/100 mL. During that period, Little Rockfish Creek posted higher annual mean fecal coliform bacteria values compared to the mainstem Rockfish Creek (*Figure 11-37*). The 2005 Cape Fear River Basinwide Water Quality Plan reported that the fecal coliform bacteria screening criteria was exceeded in this creek and that DWR will determine if more intensive sampling is necessary. DWR conducted screening level Mann-Kendall trend seasonal tests for fecal coliform bacteria, ammonia nitrogen, nitrate-nitrite nitrogen, phosphorus and turbidity at station B9460000 that resulted in significant increasing trends calculated at 95% confidence from data collected from 2000 to 2019. Mallin et al. (2022) also found significant increases in nitrate, total nitrogen, total phosphorus and fecal coliform bacteria in Little Rockfish Creek. There is one biological monitoring station co-located with this water quality monitoring station; however, sampling was last conducted in 2003 and resulted in a Not Rated rating. Similarly, the fish community monitoring station was last sampled in 2008 and resulted in a Not Rated rating as well.

11.8.5.2 Rockfish Creek Biological Monitoring

Rockfish Creek begins north of the Concord community in southeastern Duplin County, flowing south to meet Murpheys Creek and Big Beaver Creek before turning southeast to meet Doctors Creek [AU#: 18-74-29a and 18-74-29b1]. Rockfish Creek is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. Downstream from the confluence is the most upstream biological monitoring station--BB254--in the Rockfish Creek watershed [AU# 18-74-29b2]. Biologists visited this monitoring station in 1998 after the riparian area and parts of the channel of Rockfish Creek were de-snagged, possibly contributing to in-stream habitat degradation reflected in the Fair rating. Since 1998 the biologists have reported that the in-stream habitat has since recovered from that event when the benthos rated Fair. In fact, abundance values for almost every taxon have increased over those measured in 2003 further establishing recovery of the benthic community. Additionally, the specific conductance values for both 2003 and 2013 are significantly lower than that measured in 1998 suggesting nonpoint source runoff has either diminished or lower flows have mitigated its effect on the benthos. Rockfish Creek was rated Good for the first time in 2013. Located approximately three miles downstream from station BB254 is the biological monitoring station BB081. This biological monitoring station is co-located with a water quality monitoring station. Station BB081 was last sampled in 2003 and recorded a Good-Fair bioclassification rating (*Table 11-18*).

Table 11-18: Biological Community Analysis in Rockfish Creek at Stations BB254 and B081.

BB254					
Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1993	Basin Sample	Full Scale	4.85	6.23	Good-Fair
1998	Basin Sample	Full Scale	5.45	6.81	Fair
2003	Basin Sample	Full Scale	5.16	5.97	Good-Fair
2013	Basin Sample	Full Scale	4.94	5.66	Good

BB081					
1993	Basin Sample	Full Scale	5.39	6.8	Fair
1998	Basin Sample	Full Scale	5.56	6.76	Good-Fair
1998	Special Study	Full Scale	5.68	7.08	Fair
2003	Basin Sample	Full Scale	5.08	6.37	Good-Fair

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB254> & <https://www.ncwater.org/?page=672&SiteID=BB81>

11.8.5.3 Rockfish Creek Physical and Chemical Monitoring

There are two surface water quality monitoring stations located downstream from the most upstream biological monitoring station. The most upstream surface water quality monitoring station is B9430000 [AU#: 18-74-29b2 and 18-74-29c]. This station receives drainage from approximately 161 square miles. Approximately two miles downstream is station B9470000 [AU#: 18-74-29d]. Because surface water quality stations B9430000 and B9470000 are near each other, the water quality is similar with some notable exceptions. Rockfish is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH.

During 2016 to 2020, both the surface water quality monitoring stations had multiple samples with fecal coliform bacteria concentrations more than 400 colonies/100 mL. These elevated values can be seen in the multiple annual average values greater than 400 colonies/100 mL between 2009 and 2017 (*Figure 11-37*). Upstream at station B9430000 approximately 37% of the samples collected during this period exceeded this water quality standard. Downstream station B9470000 had slightly less exceedances of the standard with 30% of the sampling events exceeding 400 colonies/100 mL. These are some of the highest percentages of samples exceeding 400 colonies/100 mL of all the watersheds in the Northeast Cape Fear River subbasin. DWR conducted screening level Mann-Kendall trend non-seasonal tests for fecal coliform bacteria at stations B9430000 and B9470000 that resulted in a significant increasing trend calculated at 95% confidence from data collected from 2000 to 2019. Mallin et al. (2022) also reported significant increases in fecal coliform bacteria concentrations based on data collected at B9430000 between 2000 and 2019.

Both surface water quality monitoring stations on Rockfish Creek recorded similarly elevated total nitrogen profiles (*Figure 11-38*). Annual mean total nitrogen values occasionally exceeded 3 mg/L at both stations driven primarily by nitrate+nitrite concentrations. Annual mean nitrate+nitrite concentrations often exceeded 2 mg/L with higher concentrations detected at the downstream station (B9470000) after receiving streamflow from Little Rockfish Creek (*Figure 11-39*). Total Kjeldahl nitrogen (organic nitrogen and ammonia) concentrations at both stations recorded some of their highest annual mean concentrations in 2018 and 2019 (*Figure 11-40*), driven partially by elevated ammonia concentrations (*Figure 11-41*). Rockfish Creek had the highest annual mean total nitrogen concentrations of all the monitored watersheds in the Northeast Cape Fear River subbasin (*Table 11-12*). DWR conducted a screening level Mann-Kendall trend seasonal test for nitrate+nitrite nitrogen at station B9430000 that showed a significant increasing trend calculated at 95% confidence from data collected from 2000 to 2019. Mallin et al. (2022) also reported significant increases in nitrate and total nitrogen from data collected at

station B9430000 between 2000 and 2019. Downstream at station B9470000, screening level Mann-Kendall trend seasonal tests for nitrate-nitrite nitrogen, total kjeldahl nitrogen, phosphorus, turbidity and ammonia nitrogen showed significant increasing trends calculated at 95% confidence from data collected from 2000 to 2019. More discussion on phosphorus concentrations in Rockfish Creek will be discussed later in this chapter.

While nonpoint sources of pollution are contributing to these elevated nutrient concentrations, a portion could be attributed to the NPDES permitted facilities in the river basin. The Wallace Chicken Processing Plant (NC0003344) effluent discharges into Rockfish Creek upstream of both surface water quality monitoring stations. This facility is likely a large source of nitrogen in this watershed. The permit fact sheet indicates that this plant discharged an average TN concentration of 77.5 mg/L and an average TP concentration of 12.1 mg/L, based on effluent data from Jan. 2017 through Jan. 2021 ([link to factsheet](#)). Unfortunately, the permit does not require the reporting of the separate species of nitrogen except for ammonia, which on average was very low, i.e., 0.6 mg/L in summer and 0.3 mg/L in winter. The effluent's annual mean and median total nitrogen concentrations generally increased over time after 2008 (*Figure 11-42*). In December 2020, this permittee requested a flow expansion to 1.5 MGD (approximately 2.32 cubic feet per second, cfs), which became effective April 1, 2020. This facility's discharge is 57% of the instream waste concentration in Rockfish Creek with a summer 7Q10 of 1.77 cfs and a winter 7Q10 of 6.73 cfs. Annual mean total nitrogen concentrations downstream from this discharge were generally higher values after 2008 at stations B9430000 and B9470000 (*Figure 11-38*). It is important to note that the permittee meets all EPA effluent requirements for this type of Industrial Process and Commercial Wastewater Discharger. In addition to discharge from the Wallace Chicken Processing Plant, the Wallace Regional WWTP (NC0003450) discharges between stations B9430000 and B9470000. The Lower Cape Fear River Program has commented that when low-flow periods occur in Rockfish Creek the discharge from the Wallace Regional WWTP outfall can flow upstream to the sampling site (Mallin et al., 2022).

Annual mean phosphorus concentrations at both surface water quality monitoring stations in Rockfish Creek hover around 0.4 mg/L during most years (*Figure 11-43*). These concentrations appear to slightly increase downstream from the confluence with Little Rockfish Creek. These are some of the highest annual mean phosphorus concentrations of all the monitored rivers and streams in the Northeast Cape Fear River subbasin (*Table 11-12*). These annual mean phosphorus concentrations are higher in concentration than those considered normal for minimally impacted streams.

Figure 11-37: Annual Mean Fecal Coliform Bacteria Results for Stations on Rockfish Creek (B9430000 and B9470000) and Little Rockfish Creek (B9460000) between 2002 and 2020.

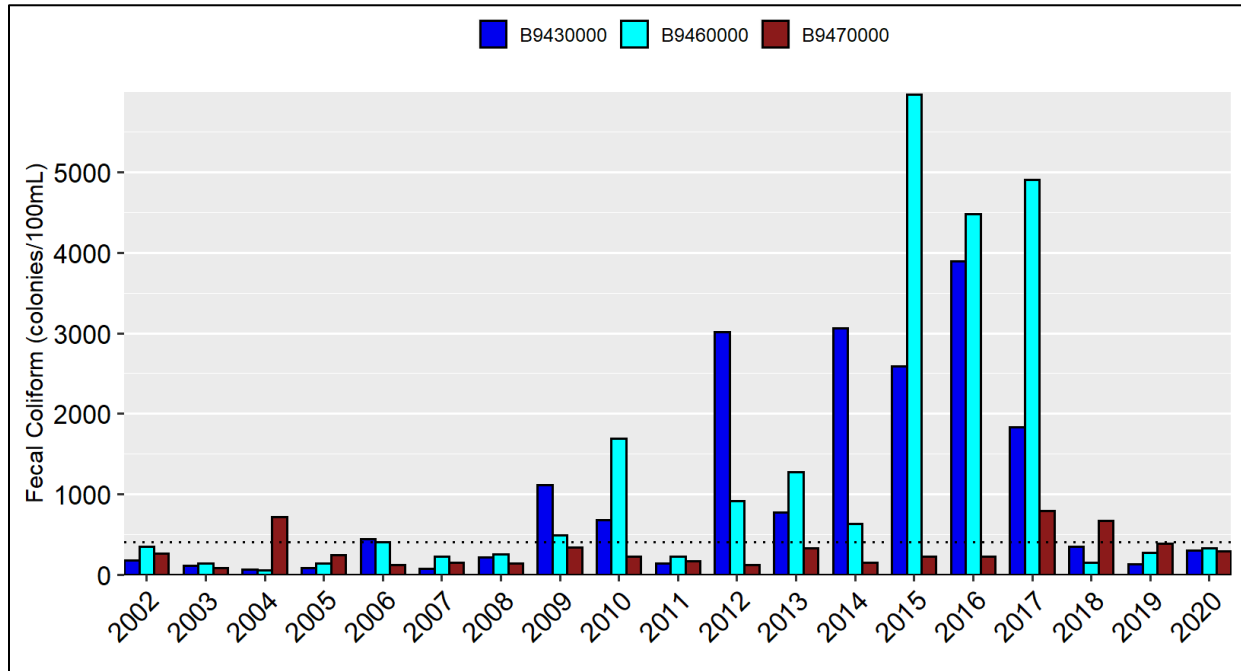


Figure 11-38: Annual Total Nitrogen Results for Stations on Rockfish Creek (B9430000 and B9470000) and Little Rockfish Creek (B9460000) between 2002 and 2020.

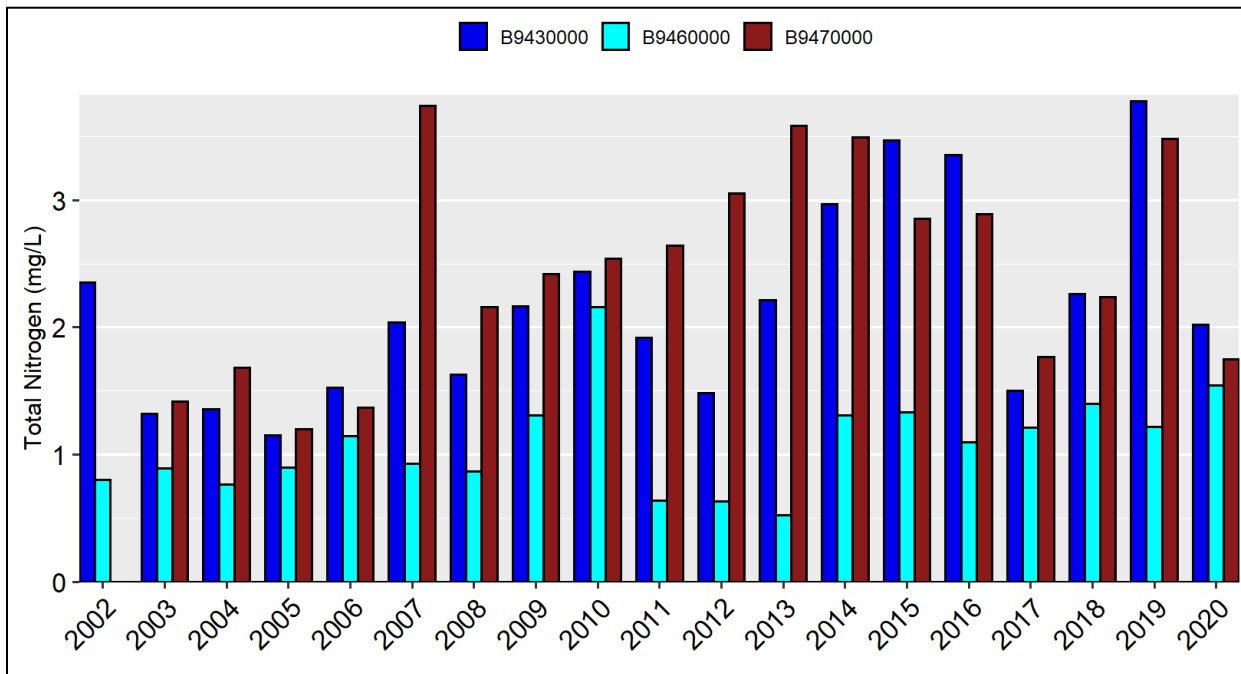


Figure 11-39: Annual Total Nitrate+Nitrite Results for Stations on Rockfish Creek (B9430000 and B9470000) and Little Rockfish Creek (B9460000) between 2002 and 2020.

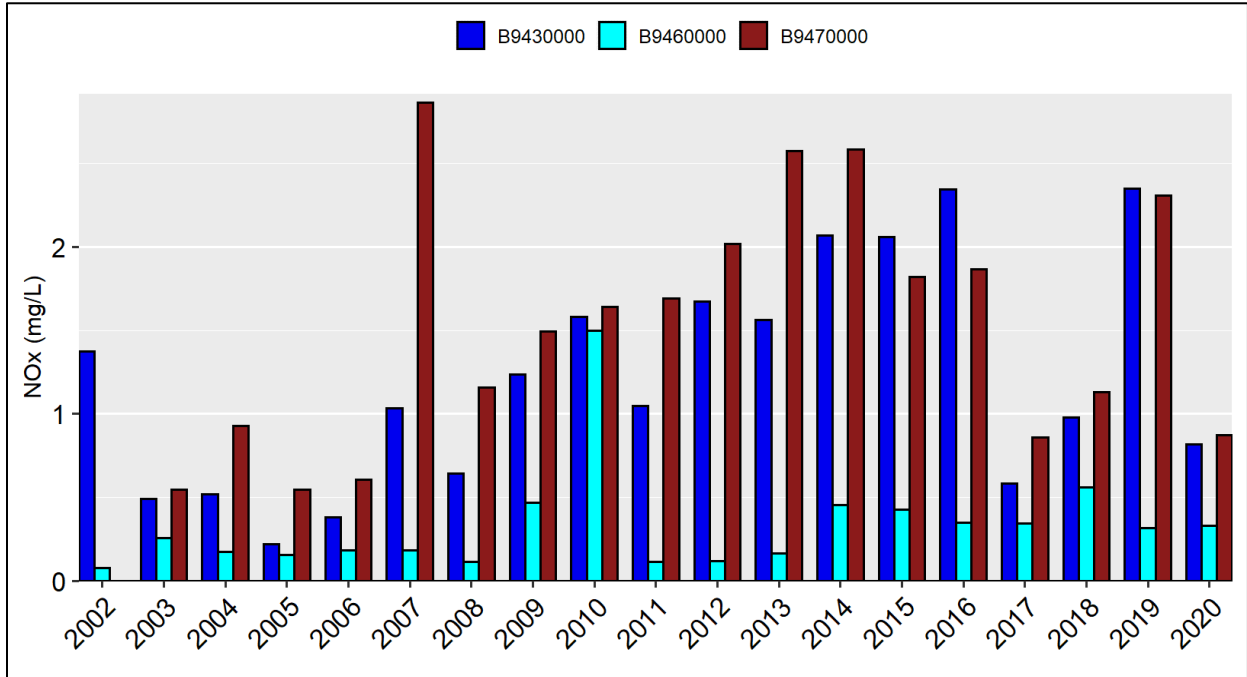


Figure 11-40: Annual Total Kjeldahl Nitrogen Results for Stations on Rockfish Creek (B9430000 and B9470000) and Little Rockfish Creek (B9460000) between 2002 and 2020.

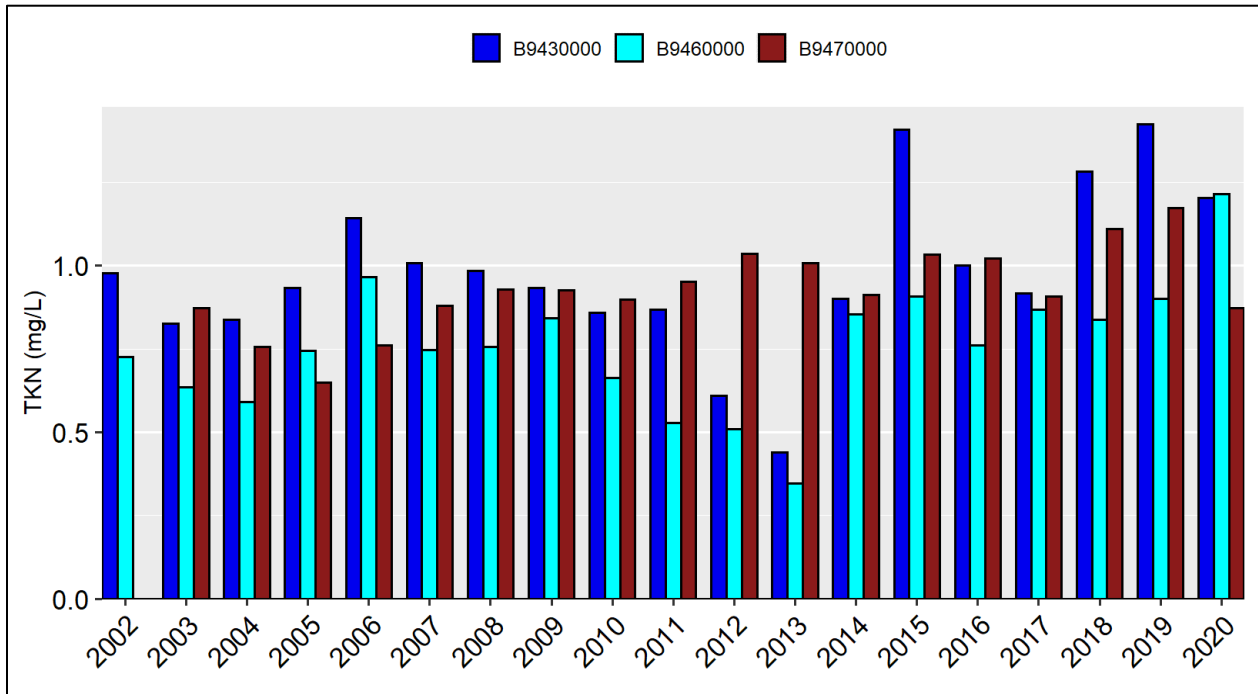


Figure 11-41: Annual Ammonia Results for Stations on Rockfish Creek (B9430000 and B94700010) and Little Rockfish Creek (B9460000) between 2002 and 2020.

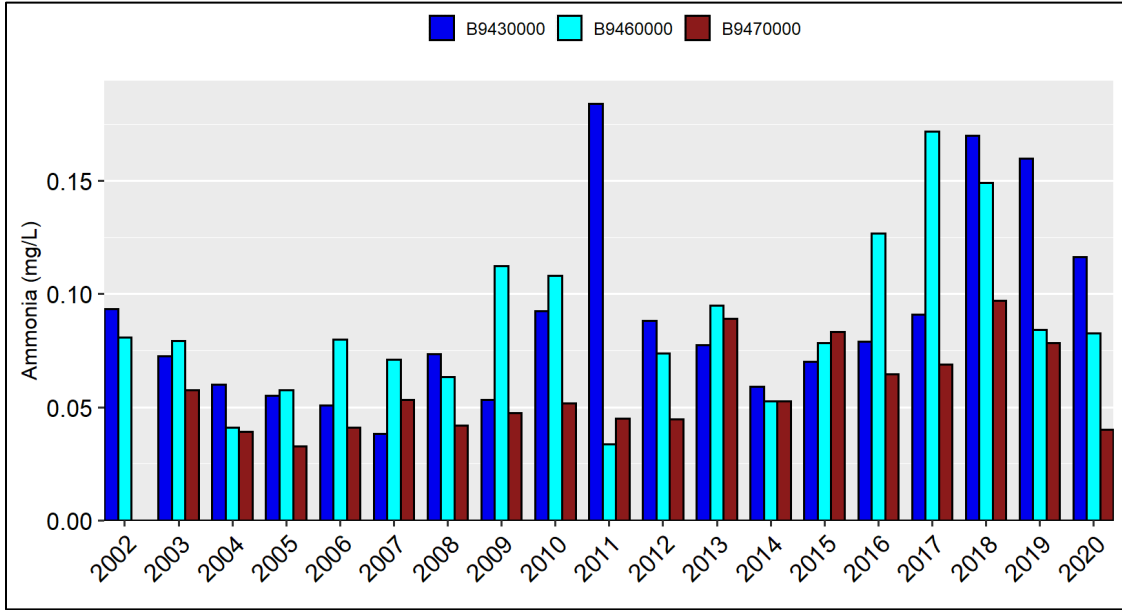


Figure 11-42: Annual Mean and Median Concentrations and Estimated Loading for Nitrogen and Phosphorus based on the Effluent Discharge from NPDES Facility NC0003344 at Outfall 001.

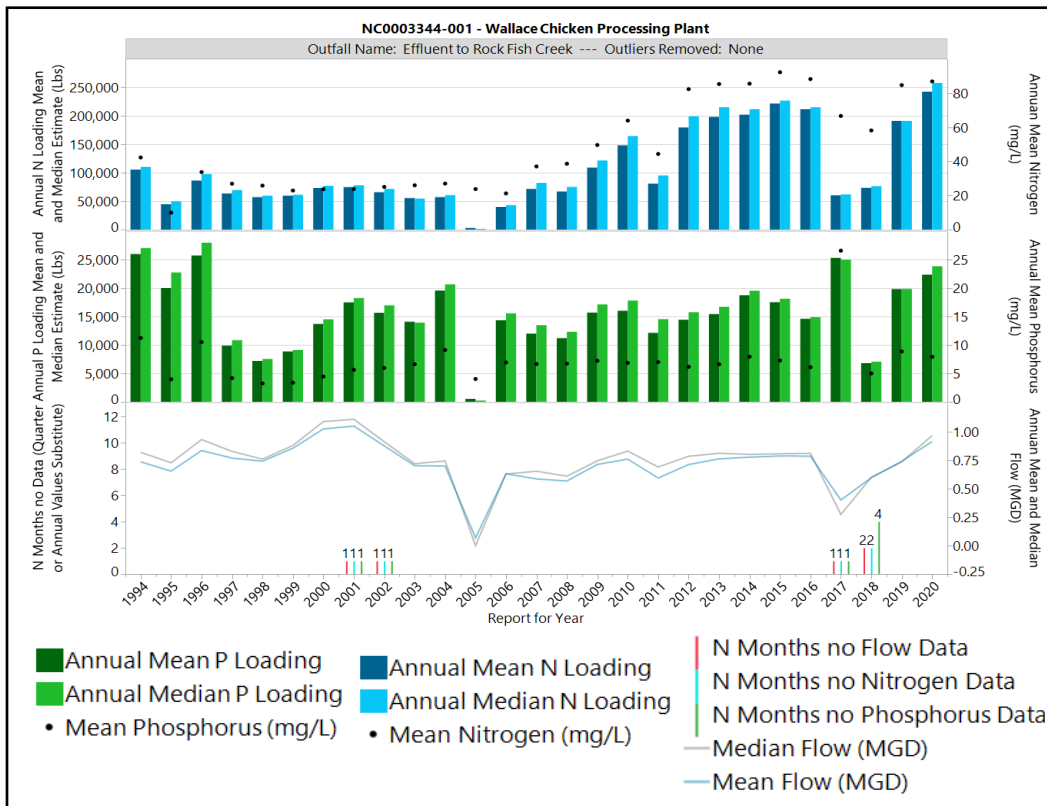
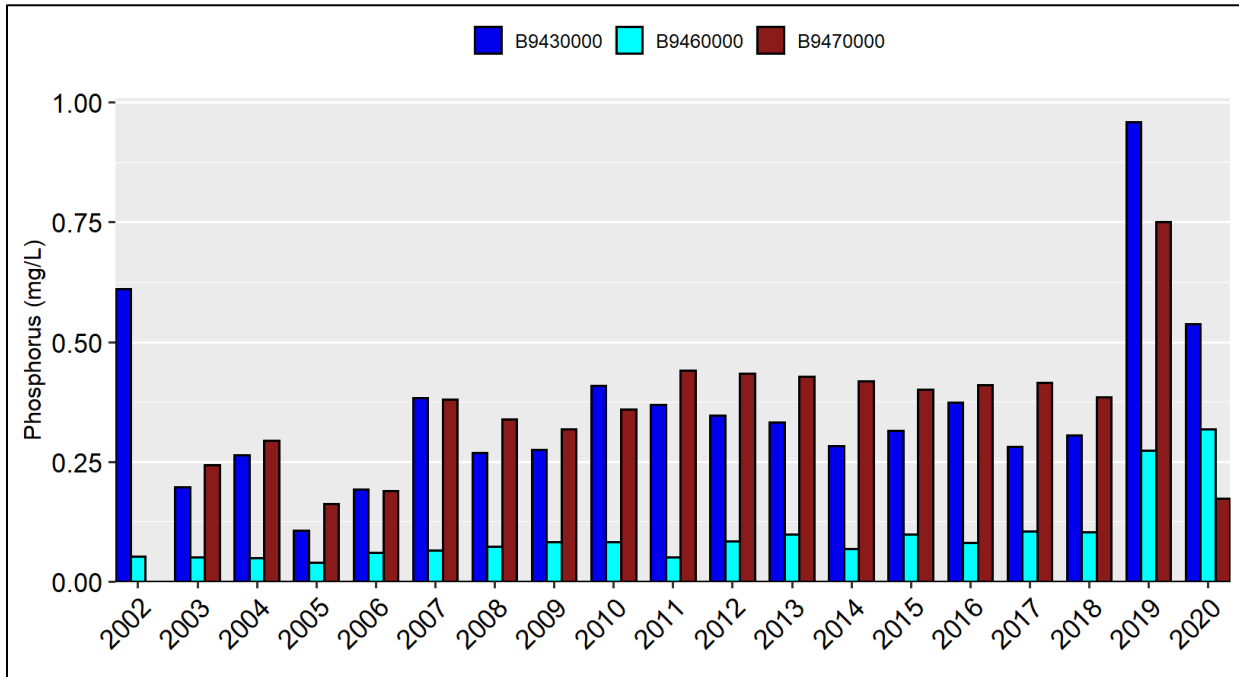


Figure 11-43: Annual Mean Total Phosphorus Results for Stations on Rockfish Creek (B9430000 and B9470000) and Little Rockfish Creek (B9460000) between 2002 and 2020.



11.8.5.4 Rockfish Creek Watershed Summary

Water quality in Rockfish Creek and Little Rockfish Creek are impacted by point and nonpoint sources of pollution. Point sources in this watershed are limited to four NPDES permitted facilities; however, the Wallace Chicken Processing Plant and Wallace Regional WWTP comprise most of the point source discharge into Rockfish Creek. The Wallace Chicken Processing Plant appears to contribute to the increased and increasing nitrogen levels found in Rockfish Creek. Little Rockfish Creek does not contain any point source dischargers of domestic waste; however, fecal coliform bacteria levels were considerably greater than in Rockfish Creek. Nonpoint sources of pollution in this watershed include swine and poultry feeding operations, agriculture practices, manure applications to cropland, urban and impervious surfaces around Wallace, septic systems and/or straight pipes, domestic animals and wildlife.

Nutrient concentrations are also increasing over time and typically exceed 2 mg/L for total nitrogen and 0.4 mg/L for phosphorus. These elevated total nitrogen concentrations are primarily driven by increased nitrate+nitrite concentrations. Rockfish Creek typically has the highest nutrient concentrations, total nitrogen and phosphorus, of all the monitored waterways in the Northeast Cape Fear River subbasin (Table 11-12). These levels are considerably higher than the concentrations considered normal for minimally impacted streams.

Fecal coliform bacteria concentrations are also increasing in Rockfish and Little Rockfish creeks over time and exceeding 400 colonies/100 mL more often in recent years compared to historical surface water monitoring results. Fecal coliform bacteria concentrations in Little Rockfish Creek and Rockfish Creek

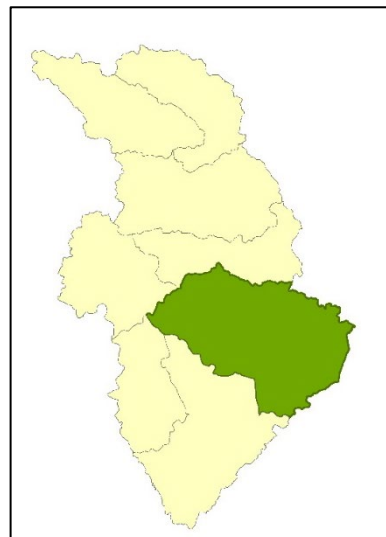
exceeded the 400 colonies/100 mL water quality standard during approximately 1 out of 3 samples collected during the most recent five years on record. Additionally, a tributary of Rockfish Creek named Doctors Creek had a measurable manure effect from swine and poultry animal feeding operations (Harden, 2015). Elevated nutrient and fecal coliform bacteria concentrations from Rockfish Creek and Little Rockfish Creek flow into Northeast Cape Fear River, ultimately impacting downstream water users through bacteria loads and eutrophication. Poor water quality from elevated nutrients and fecal coliform bacteria levels in this watershed are likely caused by both point and nonpoint sources of pollution.

Biological monitoring and fish community monitoring has not occurred in this watershed since 2013 with the latest rating in Rockfish Creek reporting a Good rating for the first time. While this community has recovered from the previous Fair rating in 1998, updated monitoring is necessary to determine if this rating is consistent with current conditions. Localized water quality monitoring and best management practices to address the nutrients and fecal coliform bacteria levels are necessary to improve water quality in this watershed. Additional recommendations for the Rockfish Creek watershed include:

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Working with the local County Health Department in having straight pipes that may be identified during stream walks removed and septic systems repaired.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Continuously improving climactic resiliency at the Wallace Regional Wastewater Treatment Plant (NC0003450) to prevent ammonia, biological oxygen demand and fecal coliform bacteria limit violations.
- Incorporate instream nutrient monitoring for nitrate and nitrite, total Kjeldahl nitrogen and total phosphorus for the Wallace Chicken Processing Plant permitted facility (NC0003344).
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).
- As time and resources allow, DWR should pursue sampling of Rock Fish Creek’s benthic macroinvertebrate community to update the rating.

11.8.6 Angola Swamp – Northeast Cape Fear River Watershed (0303000706)

The Angola Swamp – Northeast Cape Fear River watershed spans 377 square miles across south-central Duplin and Onslow counties. This watershed is directly below the Cypress Creek – Northeast Cape Fear River watershed and the Rockfish Creek watershed. The waterways in those two watersheds come together upstream of the Angola Swamp – Northeast Cape Fear River watershed. The upper region of the watershed includes Moores Creek, Angola Creek, Ashes Creek and Shaken Creek. These creeks flow across this watershed to join with the Northeast Cape Fear River. The Northeast Cape Fear River flows along the western border of this watershed before exiting to the next 10-digit HUC watershed. Much of this watershed is included in either the Angola Bay Game Refuge or Holly Shelter Game Refuge.



As of May 2022, there were many permitted facilities and fields located in this watershed. A total of 32 AFOs with a total allowable head count of 123,144, an allowable weight of 17.9 million pounds and 45 lagoons were located across the northern side of the watershed with a few permitted facilities located along tributaries of Northeast Cape Fear River. There are two non-discharge permitted facilities located near Lewis Creek and Holly Shelter Creek with 32 fields covering approximately 0.39 square miles. There are no NPDES permitted facilities located in this watershed. There is also one NPDES stormwater and 51 state stormwater permits.

11.8.6.1 Angola Creek and Mill Pond Physical and Chemical Monitoring

Angola Creek receives drainage from approximately 39.5 square miles. Angola Creek is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. The surface water quality in this river is monitored by station B9490000 [AU#: 18-74-33-3]. The land cover draining to this station is primarily composed of wetlands (53%), forest land (24%), agricultural land (16%), developed (3%) and grassland/shrub (3%). Since 2001, the land cover draining to this water quality monitoring station has not changed significantly.

During 2016 to 2020, this water quality monitoring station recorded elevated fecal coliform bacterial concentrations in 23% of the samples collected. These values ranged from 1.0 to 31,000 colonies/100 mL. These elevated fecal coliform bacteria concentrations are evident in the high annual mean value in 2015 (*Figure 11-44A*). In addition to elevated fecal coliform bacteria, total nitrogen recorded the highest annual mean concentration in 2015 compared to the historical record (*Figure 11-44B*). These elevated total nitrogen concentrations were primarily driven by heightened total Kjeldahl nitrogen concentrations (*Figure 11-44C*).

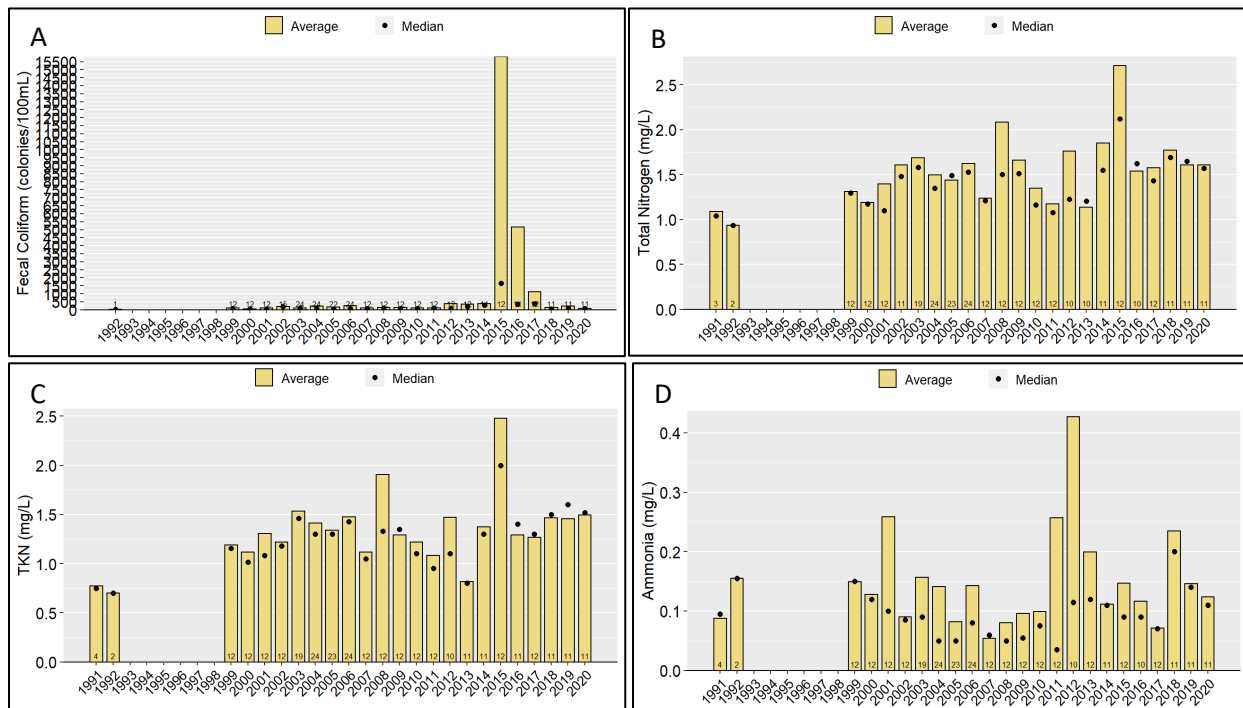
Annual total Kjeldahl nitrogen concentration recorded in Angola Creek are the highest of all the monitored waterways in the Northeast Cape Fear River subbasin (*Table 11-12*). While these total Kjeldahl nitrogen concentrations are primarily composed of organic nitrogen, another component is ammonia. Ammonia concentrations displayed some of the highest annual mean values in Angola Creek compared to the other monitored waterways in the Northeast Cape Fear River subbasin (*Figure 11-44D*). The organic fraction of

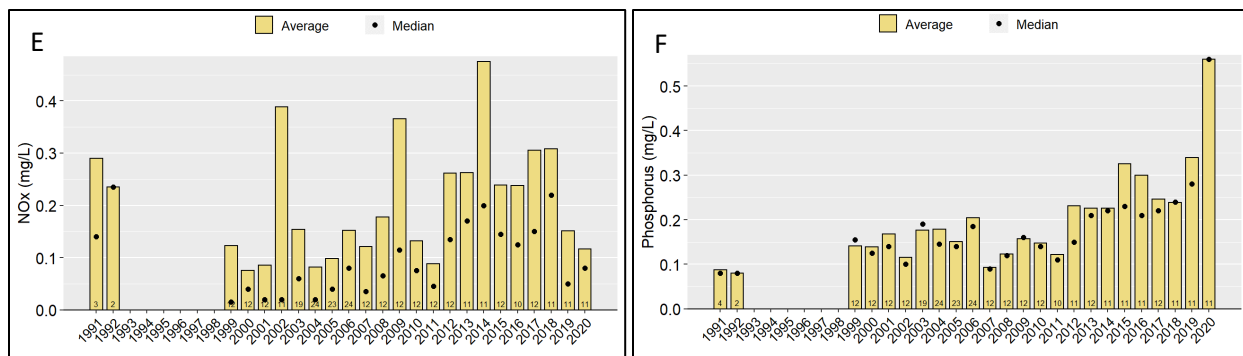
the total Kjeldahl nitrogen concentrations were attributed to flows through forested wetlands, which dominate the Angola Creek drainage area, suggesting that forested wetlands are comparatively critical to produce organic nitrogen based on the Soil and Water Assessment Tool (SWAT) model analysis (NCDENR, 2008).

Total phosphorus concentrations in this watershed were also high, especially in the year 2020, with concentrations greater than considered normal for minimally impacted streams (*Figure 11-44F*). The SWAT model again attributed much of the total phosphorus loads to passive transportation into streams through forested wetlands not designed to trap nutrient loading coming from adjoining lands (NCDENR, 2008). Like many other streams in this subbasin, DWR conducted screening level Mann-Kendall trend seasonal tests for fecal coliform bacteria, dissolved oxygen, nitrate+nitrite and phosphorus at station B9490000 that produced a significant increasing trend calculated at 95% confidence from data collected from 2000 to 2019, as well as a decreasing trend for pH.

Downstream from where Angola Creek joins Holly Shelter Creek, another river named Mill Pond (AU#: 18-74-33-5, Stream Class: C, Sw) joins Holly Shelter Creek. Mill Pond is impaired waters listed for excursions of the aquatic life standard for pH. This was based on water quality monitoring data collected at station B9496000 between 2009 and 2010. This river remains on the impaired waters list.

Figure 11-44: Annual Mean Fecal Coliform Bacteria, Total Kjeldahl Nitrogen, Total Nitrogen, Ammonia, Nitrate+nitrite, Total Phosphorus Results for Stations on Angola Creek 1991 and 2020.





11.8.6.2 Middle Section of Northeast Cape Fear River Physical and Chemical Monitoring

The Angola Swamp – Northeast Cape Fear River watershed is positioned directly below the Cypress Creek - Northeast Cape Fear River watershed and Rockfish Creek watershed. As such, the water quality monitoring of the Northeast Cape Fear River is continued with one surface water quality monitoring station in this watershed located below the confluence with Rockfish Creek [AU#: 18-74-(29.5)]. This water quality monitoring station (B9480000) is located on the Northeast Cape Fear River. The river is class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. Information regarding dissolved oxygen in waterways of the Northeast Cape Fear River subbasin can be found in Section 11.10.2.

As the Northeast Cape Fear River continues to receive runoff from the surrounding landscapes, the elevated fecal coliform bacteria concentrations appear to improve when comparing results from station B9480000 against upstream surface water quality monitoring stations B91960000 and B91915000. During 2016 to 2020, the maximum concentration measured 520 colonies/100 mL. This is still above the water quality standard of 400 colonies/100 mL but is a reduction from the maximum concentrations observed upstream of this monitoring station (*Figure 11-45*). This is possibly due to dilution from the largely undeveloped Angola Swamp drainage area that borders the eastern side of the Northeast Cape Fear River.

The total nitrogen and phosphorus nutrient concentrations measured during this same time frame did not change considerably compared to the upstream monitoring station (*Figure 11-46* and *Figure 11-47*). Annually, the total nitrogen concentrations remained around 1 mg/L and phosphorus concentrations remain above 0.1 mg/L; both of which are higher than the concentrations considered normal for minimally impacted streams. These elevated nutrient concentrations may be due to the elevated total nitrogen and phosphorus concentrations flowing from Rockfish Creek. Chlorophyll *a* is not normally sampled at station B9480000; however, there was a single sample collected in 2019. This single sample had a chlorophyll *a* concentration of 147 mg/L. The chlorophyll *a* standard is 40 mg/L. DWR conducted screening level Mann-Kendall trend seasonal tests for fecal coliform bacteria, total Kjeldahl nitrogen and phosphorus at station B9480000 that produced significant increasing trends calculated at 95% confidence from data collected from 2000 to 2019.

Figure 11-45: Annual Mean Fecal Coliform Bacteria Results for the Northeast Cape Fear River (B9191500, B9196000 and B9480000) and Rockfish Creek (B9470000).

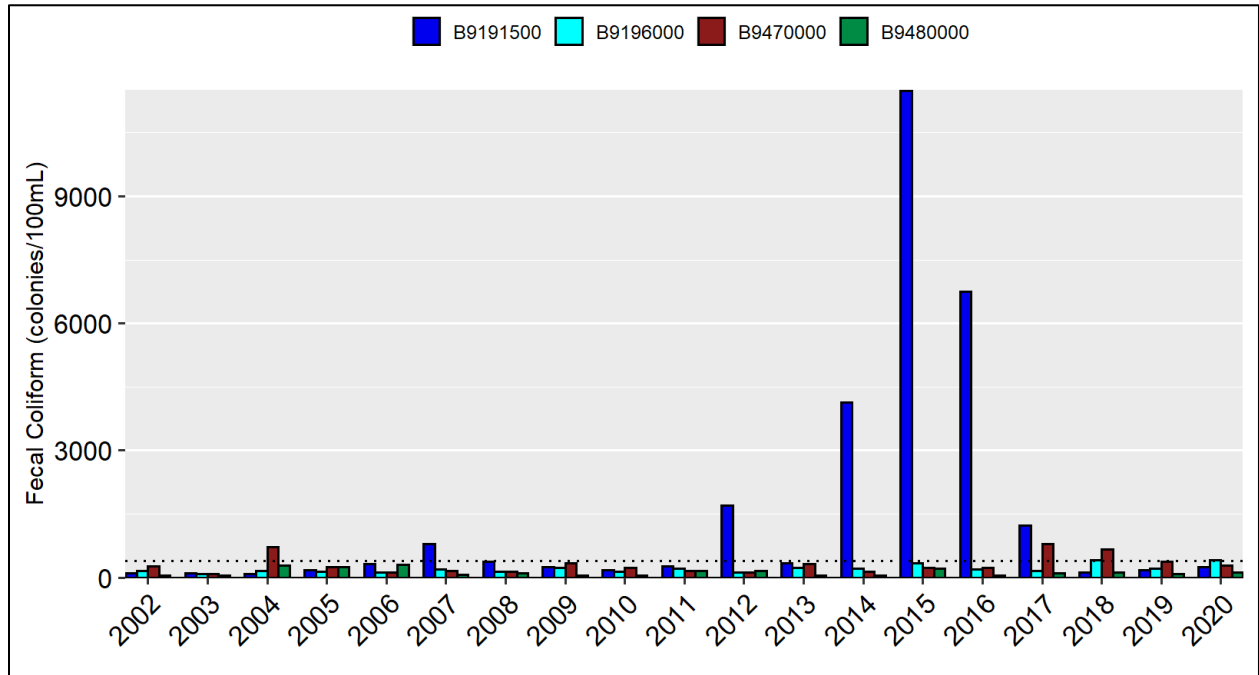


Figure 11-46: Annual Mean Total Nitrogen Results for the Northeast Cape Fear River (B9191500, B9196000 and B9480000) and Rockfish Creek (B9470000).

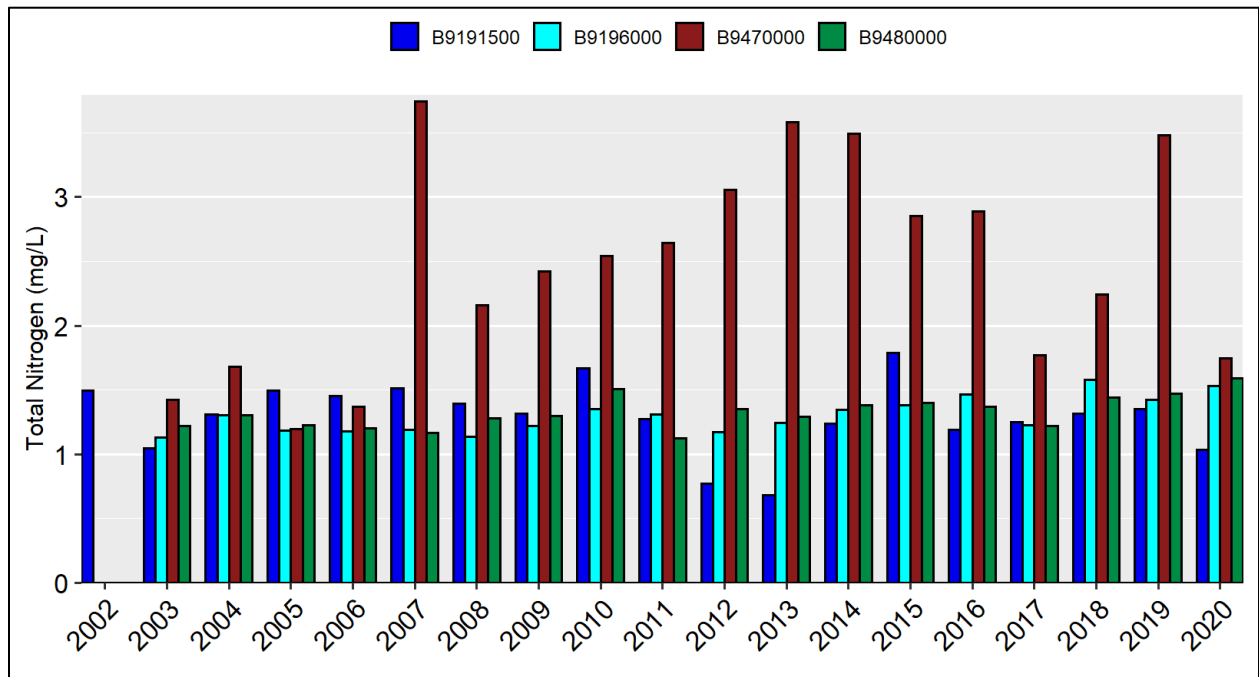
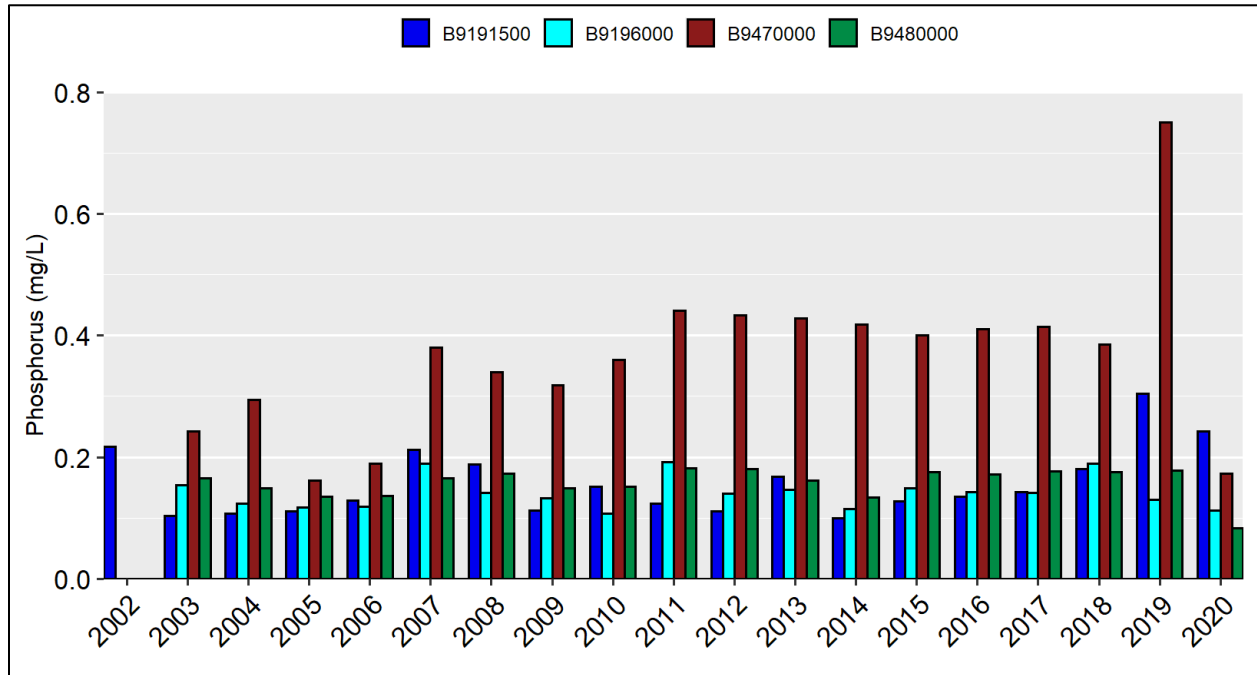


Figure 11-47: Annual Mean total Phosphorus Results for the Northeast Cape Fear River (B9191500, B9196000 and B9480000) and Rockfish Creek (B9470000).



11.8.6.3 Angola Swamp – Northeast Cape Fear River Watershed Summary

The water quality in Angola Creek, Mill Pond and the Northeast Cape Fear River is largely a reflection of the upstream water quality impacts from point and nonpoint sources of pollution. This watershed does not contain any point source dischargers. Nonpoint sources of pollution in this watershed include swine feeding operations, agriculture practices, manure applications to cropland, septic systems and/or straight pipes, domestic animals and wildlife.

Nutrient concentrations, total nitrogen and phosphorus, are higher than levels considered normal for minimally impacted streams. Total Kjeldahl nitrogen and total phosphorus concentrations are also increasing over time. These nutrient concentrations could show improvement if upstream watersheds and the surrounding landscape are able to reduce nutrient inputs to the Northeast Cape Fear River. Targeting nutrient-reducing best management practices in upstream watersheds, tributaries and adjoining lands can help lower these inputs and reduce the nutrient levels in this waterway. The elevated ammonia concentrations recorded in Angola Creek may be stormwater from the only permitted stormwater location or other nonpoint sources of pollution.

While fecal coliform bacteria levels display lower concentrations, this is the last surface water quality monitoring station in the Northeast Cape Fear River before the river changes stream classification from a secondary recreational water (class C) to a primary recreational water (class B). The primary recreational water classification highlights the need to ensure fecal coliform bacterial levels at station B9480000 are lower than the surface water quality standard and protective of bodily contact with the Northeast Cape

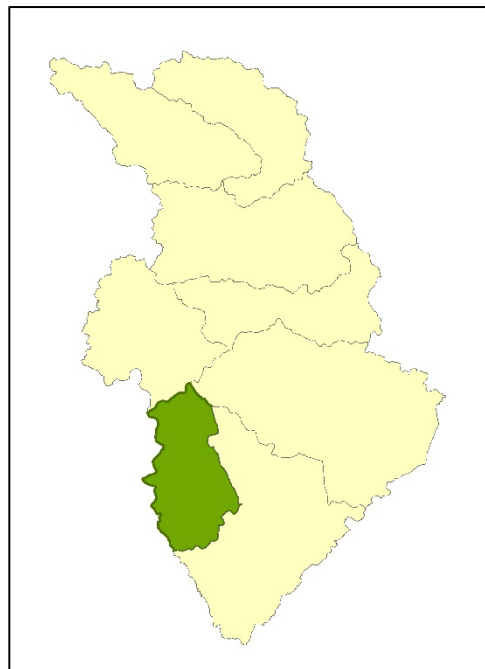
Fear River from N.C. Hwy. 210 to Prince George Creek, stream index 18-74-(47.5). Localized water quality monitoring and best management practices to address the nutrients and fecal coliform bacteria levels are necessary to improve water quality in this watershed. Additional recommendations for the Northeast Cape Fear River – Angola Creek watershed include:

- Mill Pond is impaired for pH and consideration should be given to conducting a natural conditions assessment on this area to determine if this impairment should remain.
- Working with the local County Health Department in having straight pipes that were identified during stream walks removed and septic systems repaired.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).

11.8.7 Long Creek Watershed (0303000707)

The Long Creek watershed spans 141 square miles across west-central Pender County. The upper reaches of this watershed are Cypress Creek and Long Creek, which meet northeast of the Wards Corner community. The creek flows south and is joined by Rileys Creek, Mill Creek and Morgans Creek before leaving this watershed to flow into the Northeast Cape Fear River. In total, there are two benthic macroinvertebrate monitoring stations located within this watershed.

As of May 2022, there were many permitted facilities and fields located in this watershed. A total of 15 AFOs with a total allowable head count of 47,894, an allowable weight of 5.4 million pounds and 17 lagoons are scattered across this entire watershed and their density is less than other watersheds in this subbasin. There are two non-discharge permitted facilities, one major and one minor, with 31 fields covering approximately 1.08 square miles located in this watershed near Cypress Creek and east of Long Creek, before the confluence with the Northeast Cape Fear River. There are two minor NPDES permitted facilities with as-built flow totaling 20,000 GPD located near Cypress Creek (Multiple Species Fish Hatchery – Watha) and Long Creek (Pender High School WWTP–NC0042251). There are also three NPDES stormwater and 22 state stormwater permits.



11.8.7.1 Long Creek Biological Monitoring

The upper reaches of Long Creek [AU#: 18-74-55a] from the source to Cypress Creek spans 7.7 river miles. This waterway maintains the class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. This section of Long Creek is currently on the impaired waters list for excursions of the aquatic life standard for benthos based on benthic macroinvertebrate monitoring station analysis. The latest sampling results from this waterway recorded back-to-back Severe ratings for the biological community. In 2003, very low total taxa (31) were recorded and the community was dominated by very tolerant species such as *Lumbriculidae* and *Orthocladus oliveri*. The abundance of *Sphaerium*, *Musculium* and *Physella* suggested that low dissolved oxygen may sometimes be a problem in Long Creek. The overall rating for Long Creek was Severe (Table 11-19). In 2013, total species doubled, reaching 61 total taxa and three recorded EPT taxa.

Table 11-19: Biological Community Analysis in the Long Creek at Station BB139.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1998	N/A	Swamp	6.65	6.3	Not Rated
2003	Basin Sample	Swamp	NA	8.06	Severe
2013	Basin Sample	Swamp	7.27	8.23	Severe

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB139>

11.8.7.2 Cypress Creek Biological Monitoring

Cypress Creek runs from the source to the confluence with Long Creek (Stream Index#: 18-74-55, Stream Class: C; Sw) spans 8.32 river miles [AU#: 18-74-55-2]. This waterway maintains the class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. This creek has one benthic macroinvertebrate monitoring station, which was sampled as recently as 2013. The 2013 sampling event, as well as the two prior sampling events in 2003 and 1998, were all rated as Moderate. Although the rating has remained constant over time, the EPT taxa counts have declined from nine in 1998, four in 2003 to three in 2013 (Table 11-20).

Table 11-20: Biological Community Analysis in the Cypress Creek at Station BB140.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1993	N/A	EPT	5.76	5.76	Not Rated
1998	N/A	Swamp	5.34	6.79	Moderate
2003	Basin Sample	Swamp	7.9	7.48	Moderate
2013	Basin Sample	Swamp	6.33	7.16	Moderate

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB140>

11.8.7.3 Long Creek Watershed Summary

The water quality in Long Creek and Cypress Creek is impacted by both point and nonpoint sources of pollution. The point source dischargers are most likely a small contribution to the waterways in Long Creek watershed. Nonpoint sources of pollution in this watershed include swine feeding operations, agriculture

practices, manure applications to cropland, septic systems and/or straight pipes, domestic animals and wildlife.

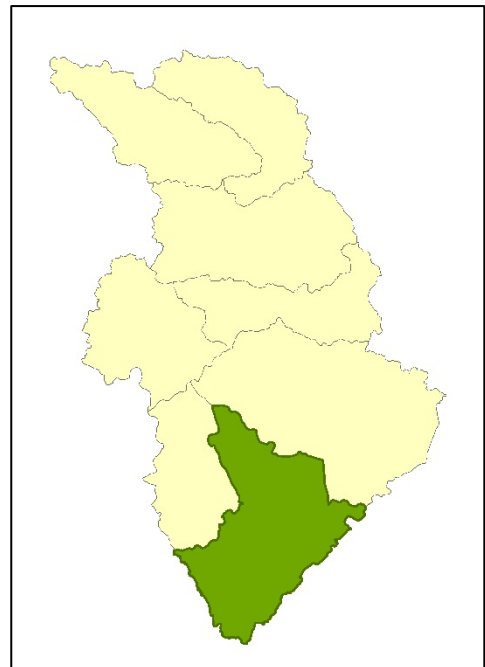
Water quality in this watershed is poorly understood due to a lack of water quality monitoring. The most recent biological community analysis is from 2013. DWR should continue to monitor the Long Creek watershed and evaluate impacts of NPDES discharge into Long Creek. Localized water quality monitoring to identify potential pollution sources contributing to the Severe biological community rating is needed to better understand the water quality in this watershed. Additional recommendations for the Long Creek watershed include:

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Partnering with agencies such as the county Soil and Water Conservation District and the US Department of Agriculture – Natural Resources Conservation Service to help facilitate communication with landowners and encourage them to implement agricultural best management practices.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).
- As time and resources allow, DWR should pursue sampling of Long Creek benthic macroinvertebrate community to update the rating.

11.8.8 Harrisons Creek – Northeast Cape Fear River Watershed (0303000708)

The Harrisons Creek – Northeast Cape Fear River watershed is positioned directly below the Angola Swamp - Northeast Cape Fear River and Long Creek watersheds. This watershed spans 287 square miles across southern Pender County and northern New Hanover County. The primary land cover is wetlands (46.97%), forest land (21.87%) and developed land (15.46%), followed by agriculture (7.79%), grassland/shrub (5.01%), open water (2.28%) and barren land (0.62%).

As the Northeast Cape Fear River continues to flow through this watershed, it receives tributary flow from Burgaw Creek, Lillington Creek, Island Creek, Harrisons Creek, Prince George Creek, Long Creek and Smith Creek before ultimately discharging into the mainstem Cape Fear River west of Wilmington. The mainstem Cape Fear River is on the impaired waters list due to excursions of the aquatic life standard for dissolved oxygen.



A 15.6-mile stretch of the Northeast Cape Fear River (Stream Index: 18-74-(47.5)) in this watershed is designated as a primary recreation water (Class B). This stream reach and the remaining downstream miles to the mouth of the Northeast Cape Fear River are also classified as Primary Nursery Areas by the NC Wildlife Resources Commission. There are six surface water quality monitoring and three benthic macroinvertebrate community monitoring stations in this watershed. In addition to these established water quality monitoring stations, New Hanover County conducts surface water quality monitoring at stations in Island Creek, Prince George Creek and Smith Creek in this watershed. While some of their monitoring conclusions are included in the section below, the Water Quality Monitoring Program section of the New Hanover County website includes additional data, maps and reports (<https://planning.nhcgov.com/1201/Water-Quality-Monitoring-Program>).

As of May 2022, there were many permitted facilities and fields located in this watershed. A total of six AFOs with a total allowable head count of 24,962, an allowable weight of 4.2 million pounds and seven lagoons are located near Burgaw Creek, Pike Creek and Catskin Creek in this watershed. This watershed has the largest density of stormwater permits of all the watersheds in this subbasin with 41 NPDES and 1,593 state stormwater permits. This watershed has more state stormwater permitted facilities than any other HUC 10 watershed in the Cape Fear River Basin. This watershed also contains the most NPDES-permitted facilities and non-discharge permitted facilities of all the watersheds in this subbasin. In total, there are 18 NPDES-permitted facilities, four major and 14 minor, with combined as-built flows totaling 20.636 MGD. Major permitted facilities in this watershed are the Northside WWTP, Global Nuclear Fuel – Americas Wilmington – Castle Hayne WWTP, Fortron Industries and Stepan Company - Wilmington Facility. Notably, not all NPDES-permitted facilities in this watershed discharge into the Northeast Cape Fear River and tributaries. Northside WWTP is located in the Northeast Cape Fear River subbasin; however, the outfall discharges directly into the Cape Fear River. Additionally, two permitted facilities, Stepan Company – Wilmington Facility and Fortron Industries, discharge into both the Northeast Cape Fear River and the Cape Fear River. There are nine non-discharge permitted facilities, seven major and two minor, with 46 fields covering approximately 1.96 square miles. These non-discharge and NPDES permitted facilities are predominantly located near Wilmington.

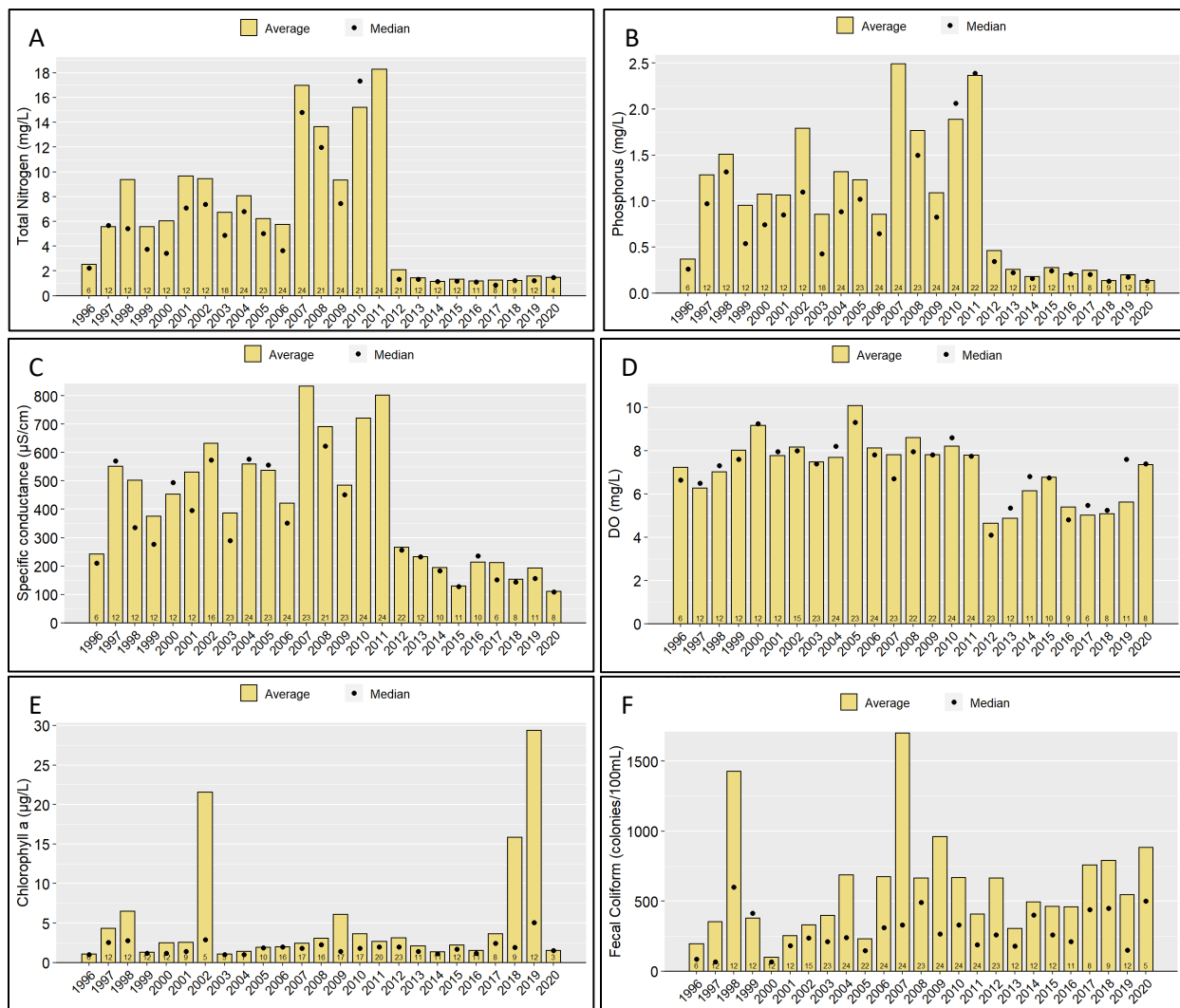
11.8.8.1 Burgaw Creek Physical and Chemical Monitoring

Burgaw Creek has one surface water monitoring station (B9520000). This monitoring station receives drainage from approximately 8.1 square miles. This waterway maintains the class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. The downstream section of Burgaw Creek [AU #: 18-74-39b] spans 9.5 freshwater miles from Osgood Branch to the confluence with the Northeast Cape Fear River. This section of Burgaw Creek is on the impaired waters list for excursions of the aquatic life standard for benthos and copper. As of 2019, the land cover draining to this water quality monitoring station is primarily composed of agricultural land (35%), forest land (31%), developed land (19%), followed by wetlands (9%) and grassland/shrub (6%). Since 2001, there has not been a significant change in land cover aside from a slight increase in forest land and decrease in grassland/shrub.

The water quality in Burgaw Creek changed significantly after the removal of the Burgaw WWTP in 2012. The annual mean total nitrogen concentrations dropped from approximately 18 mg/L in 2011 to <2 mg/L

after 2012 (Figure 11-48A). Similarly, the total phosphorus, specific conductance and dissolved oxygen also showed significant changes after 2011 (Figure 11-48 B, C, D). While it appears overall water quality has improved, nutrient concentrations (total nitrogen and phosphorus) are still higher than those considered normal for minimally impacted streams. Chlorophyll *a* concentrations spiked in 2018 and 2019 with one year recording the highest annual mean value since 1996, possibly due elevated nutrient concentrations (Figure 11-48E). The annual mean fecal coliform bacteria concentrations vary over time, but recent annual averages are hovering around 500 colonies/100 mL (Figure 11-48F). This annual mean concentration is higher than the 400 colonies/100 mL water quality standard. Burgaw Creek discharges upstream of a section of the Northeast Cape Fear River designated as primary recreation waters (Class B).

Figure 11-48: Annual Mean and Median Total Nitrogen, Total Phosphorus, Specific Conductance, Dissolved Oxygen, Chlorophyll *a*, Concentrations for Burgaw Creek (B9520000).



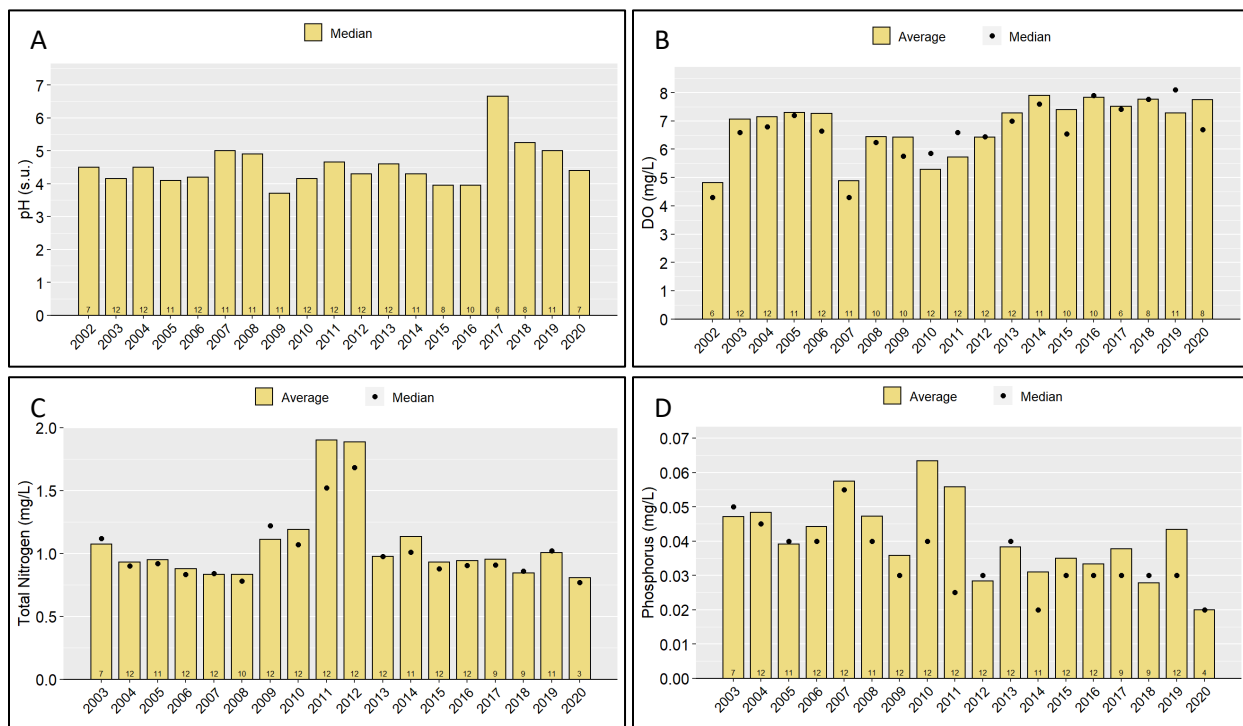
11.8.8.2 Lillington Creek Physical, Chemical and Biological Monitoring

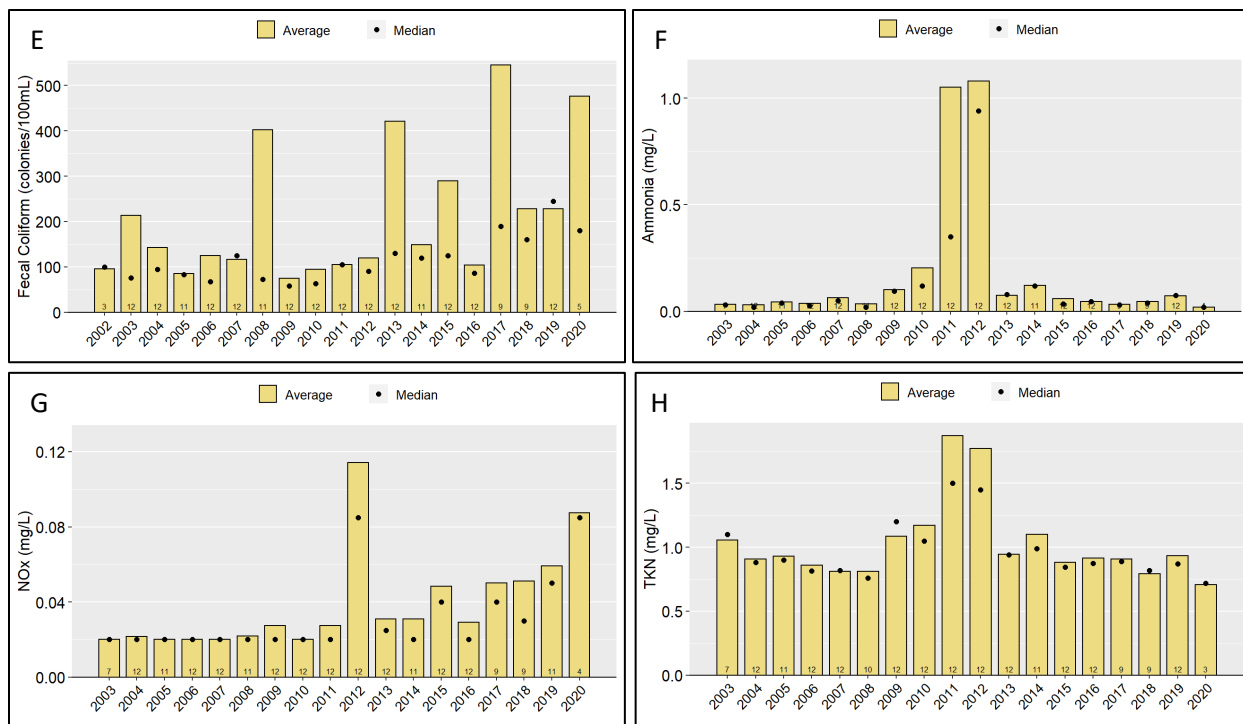
Lillington Creek is a tributary of Northeast Cape Fear River [AU#: 18-74-42]. This waterway maintains the class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. This tributary receives drainage from the Holly Shelter Game Lands and largely undeveloped areas of the Northeast Cape Fear River subbasin. There are no permitted animal feeding operations, NPDES wastewater treatment plants, or non-discharge/land application permits in this creek’s drainage area.

The surface water quality in this creek is monitored by station B9550000. This waterway is on the impaired waters list for pH based on excursion of the aquatic life standard because the values are extremely low. The annual median pH hovered around 4 s.u. since monitoring began in 2002 except for a few years that reached 5 s.u. or greater (*Figure 11-49A*). Annual dissolved oxygen levels are more variable over time ranging from less than 5 mg/L to approximately 8 mg/L (*Figure 11-49*).

Nutrients (total nitrogen and phosphorus) levels have not changed significantly over time with annual mean total nitrogen concentrations often below 1 mg/L and phosphorus concentrations often below 0.05 mg/L (*Figure 11-49C, D*). The total nitrogen concentrations are primarily derived from the total Kjeldahl nitrogen, especially in 2011 and 2012, when high concentrations of ammonia were recorded (*Figure 11-49F*). Fecal coliform bacteria concentrations have spiked more often in recent years; however, annual mean and median values often hover around 200 colonies/100 mL with a few years exceeding the 400 colonies/100 mL water quality standard value (*Figure 11-49E*).

Figure 11-49: Annual Mean and/or Median pH Concentrations for Lillington Creek (B9550000) between 2002 and 2020.





Lillington Creek declined in bioclassification, from Natural in 2003 to Moderate in 2009, the same rating it received in 1997. The change in bioclassification was the result of increased BI and slightly lowered EPT. Biotic Index and EPT BI measured here continues the trend of higher biotic indices since 1997. Habitat scored well in both 2003 and 2009, in part influenced by the mostly forested catchment surrounding Lillington Creek. After the 2009 sampling effort, this station has maintained a Natural rating (*Table 11-21*).

Table 11-21: Biological Community Analysis in the Lillington Creek at Station BB306.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1997	N/A	Swamp	4.51	6.4	Moderate
2003	Basin Sample	Swamp	4.6	6.15	Natural
2009	Basin Sample	Swamp	5.72	6.41	Moderate
2013	Basin Sample	Swamp	4.72	5.9	Natural
2018	Basin Sample	Swamp	4.04	5.39	Natural

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB306>

11.8.8.3 Harrisons Creek Physical and Chemical Monitoring and Merricks Creek Biological Monitoring

Harrisons Creek [AU#: 18-74-49] was considered a reference stream for the special surface water quality monitoring study conducted in Stocking Head Creek, discussed earlier in this chapter. This waterway and Merricks Creek, discussed in the next paragraph, both maintain the class C water with a supplemental

swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. While Harrisons Creek was only monitored for a short period of time in 2019, the results are representative of a stream with nutrient (total nitrogen and phosphorus) concentrations considered normal for minimally impacted streams. The annual mean total nitrogen concentration, primarily composed of organic nitrogen, was around 0.8 mg/L. The 2019 annual mean total phosphorus concentration was below 0.05 mg/L. The dissolved oxygen and pH concentrations were low and representative of possible swamp water influence. Fecal coliform bacteria concentrations did not exceed the 400 colonies/100 mL water quality standard. Turbidity was also low with values typically below 8 NTUs.

Merricks Creek is a tributary of Harrisons Creek [AU#: 18-74-49-2]. The most recent benthic macroinvertebrate community rating in this waterway was Moderate in 2013. While this is still a decline from the 2003 rating of Natural, the biologists noted that with diverse instream habitat and a well-developed cypress riparian zone, the habitat condition was very good. The loss of flow-indicator species, such as *Hydropsychid* caddisflies and *Heptagenid* mayflies between 2003 and 2009, suggests that extended low water levels and reduced flows between samples could be the reason for the 2009 decline in taxa richness. This station continues to rate as Moderate (*Table 11-22*).

Table 11-22: Biological Community Analysis in the Merricks Creek at Station.

Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
1999	Special Study	Swamp	5.51	6.6	Natural
2003	Basin Sample	Swamp	5.8	6.26	Natural
2009	Basin Sample	Swamp	3.69	6.82	Moderate
2013	Basin Sample	Swamp	5.39	6.27	Moderate

11.8.8.4 Smith Creek Physical, Chemical and Biological Monitoring

There is one surface water quality monitoring station on Smith Creek B9720000 [AU#: 18-74-63]. This monitoring station receives drainage from approximately 31.5 square miles. This waterway maintains the class C water with a supplemental swamp classification due to natural characteristics of swamps, such as low dissolved oxygen and pH. As of 2019, the land cover was primarily composed of developed land (67%), wetlands (16%), followed by forest land (8%), grassland/shrub (6%) and agricultural land (5%). Since 2001, there has been an increase of approximately two square miles of developed land and a decrease of approximately two square miles of combined forest land, wetlands and grassland/shrub land.

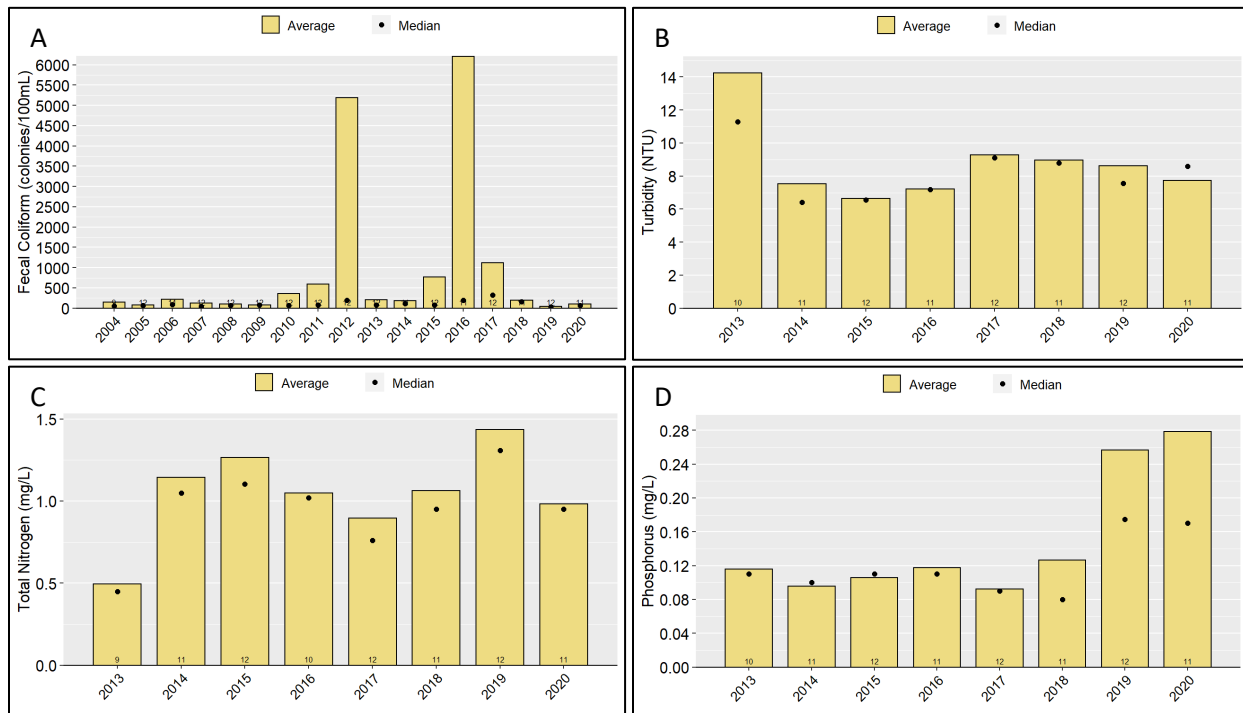
During 2016 to 2020, fecal coliform bacteria results exceeded the 400 colonies/100 mL standard on approximately 18% of the sampling events occurring primarily in 2016 and 2017 (*Figure 11-50A*). After 2017, fecal coliform bacteria concentrations have maintained annual mean values below the 400 colonies/100 mL water quality standard. In addition to fecal coliform bacteria data, New Hanover County has monitored enterococci bacteria levels in Smith Creek since 2008. Its 2021-2022 annual report

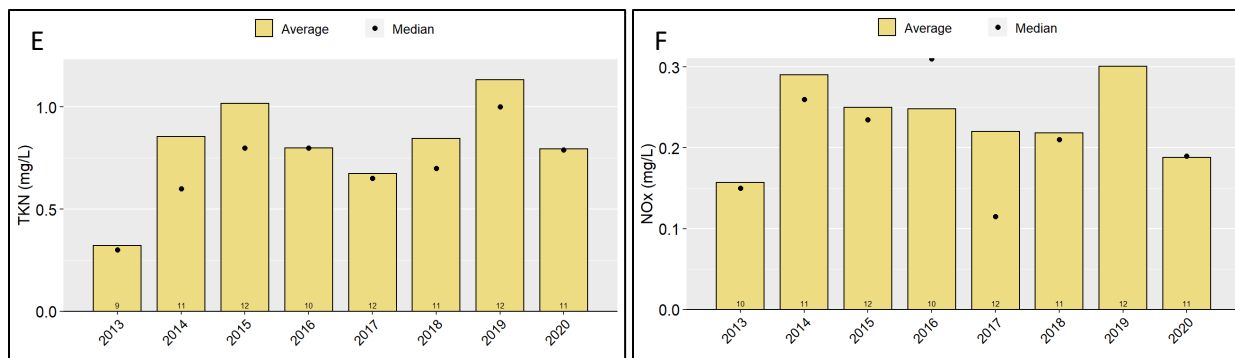
concluded that bacteria levels have moderated over recent years in Smith Creek, and since monitoring began, enterococci bacteria have exceeded 500 colonies/100 mL 24% of the time (Rosov, 2022). Notably, there have been several sanitary sewer overflow events that have impacted Smith Creek between 2010 and 2019.

The turbidity levels measured in Smith Creek (B9720000) (Figure 11-50B) were similar to the levels downstream in the Northeast Cape Fear River (B9740000). While the annual mean turbidity values in both waterways did not exceed the water quality standard of 50 NTU, the elevated turbidity from Smith Creek is likely contributing to decreased water clarity in the Northeast Cape Fear River. New Hanover County’s water quality monitoring has only detected seven exceedances of the turbidity water quality standard in Smith Creek since 2008 (Rosov, 2022).

Annual mean total nitrogen concentrations hover around 1 mg/L, which is higher than concentrations considered normal for minimally impacted streams. Annual mean total phosphorus concentrations are around 0.1 mg/L, which is higher than the concentrations considered normal for minimally impacted streams. In 2019 and 2020, these concentrations exceeded 0.2 mg/L (Figure 11-50 C, D). The total nitrogen signature is a combination of total Kjeldahl nitrogen and nitrate+nitrite (Figure 11-50 E, F).

Figure 11-50: Annual Mean and Median Water Quality Parameter Results in the Smith Creek at Station B9720000.





The Smith Creek (Stream Index#: 18-74-63, Stream Class: C; Sw) benthic macroinvertebrate community was sampled for the first time in 2003 at station BB079. Following this sample collection, Smith Creek received a Severe rating and was placed on the impaired waters list. In 2008, the sampling location was moved upstream (BB496) due to low flows and salt infiltration at the previous sampling location. Instream habitat, EPT taxa and bottom substrate all showed improvements after this station relocation. Since 2003, station BB496 has fluctuated between Natural and Moderate ratings (*Table 11-23*).

Table 11-23: Biological Community Analysis in the Smith Creek at Station BB496 and BB079.

BB079					
Year	Study	Sample Type	EPT BI	Biotic Index	Bioclassification
2003	Basin Sample	Swamp	6.6	7.55	Severe
BB496					
2008	Basin Sample	Swamp	5.99	7.14	Moderate
2013	Basin Sample	Swamp	5.51	6.48	Natural
2018	Basin Sample	Swamp	6.03	6.88	Moderate

Link to Biological Report: <https://www.ncwater.org/?page=672&SiteID=BB496> and <https://www.ncwater.org/?page=672&SiteID=BB79>

Burnt Mill Creek [AU #: 18-74-63-2] is a tributary that flows into Smith Creek. This waterway is on the impaired waters list for excursions of the aquatic life standard for benthos based on the Poor ratings collected in 2001 and 1998 at benthic macroinvertebrate community monitoring stations BB405 and BB073, respectively. This waterway remains on the impaired waters list. Multiple stressors impacting the biological community in Burnt Mill Creek were found as follows in decreasing order: toxicity, habitat degradation by sedimentation and lack of microhabitat, nutrient enrichment and scour due to hydromodification (NCDEQ, 2004).

11.8.8.5 Northeast Cape Fear River in Physical & Chemical Monitoring

The water quality in the lower section of the Northeast Cape Fear River is monitored by three surface water quality monitoring stations [AU#: 18-74-(47.5), 18-74-(52.5) and 18-74-(61)]. Although all three stations are on the same river, they have different stream indexes, classifications and associated water quality standards. *Table 11-24* presents the different segments and associated monitoring stations in order from the upstream to downstream within this watershed. These three monitoring stations also overlap with the Primary Nursery Area classification of the Northeast Cape Fear River from NC Highway 210 to the confluence with the Cape Fear River. The most downstream surface water quality monitoring station (B9740000) receives drainage from approximately 99% of the entire 1,741 square mile area in the Northeast Cape Fear River subbasin. As of 2019, the primary land cover draining to the lowermost station (B9740000) from the entire subbasin is wetlands (37%), forest land (25%) agricultural land (24%), followed by developed land (7%), grassland/shrub (6%) and open water (1%). Since 2001, the land use in this watershed has not changed significantly.

Table 11-24: Surface Water Monitoring Stations along the Northeast Cape Fear River.

Monitoring Station	Station Location	Stream Index Number	Stream Class
B9580000	Northeast Cape Fear River	18-74-(47.5)	B; Sw
B9670000	Northeast Cape Fear River	18-74-(52.5)	C; Sw
B9740000	Northeast Cape Fear River	18-74-(61)	SC; Sw

Fecal coliform bacteria concentrations measured at upstream station B9196000 in the Northeast Cape Fear River are typically higher than concentrations measured at downstream stations B9480000, B9580000, B9670000 and B9740000 (*Figure 11-51*). While upstream concentrations are typically higher than downstream, exceptions occurred in 2002, 2008, 2014, 2015 and 2016. The high annual mean fecal coliform bacteria concentrations recorded in the 15.6-mile stretch of primary recreation waters (Class B) in Northeast Cape Fear River at station B9580000 are noteworthy. During 2016 to 2020, station B9580000 exceeded the 400 colonies/100 mL water quality standard in approximately 4.9% of the samples collected. These exceedances primarily occurred in 2016 and 2017 and may be attributed to fecal coliform bacteria from Angola Creek (*Figure 11-44A*). Angola Creek had high fecal coliform bacteria levels and the confluence of Angola Creek and the Northeast Cape Fear River is below station B9480000 and above station B9580000.

Generally, turbidity values in the Northeast Cape Fear River are low with most stations' annual mean values hovering around 5 NTUs. Turbidity values were often lower in upstream stations compared to the most downstream station B9740000. The most downstream station typically has the highest turbidity values with annual means hovering around 10 NTUs (*Figure 11-52*). Notably, Smith Creek has a relatively similar turbidity profile and flows from that river may be contributing to the higher turbidity recorded downstream.

Annual median pH levels in the Northeast Cape Fear River reach their lowest levels around station B9580000 with values hovering around 6 s.u. (*Figure 11-53*). Afterwards, the values typically increase as the river approaches the confluence with the mainstem Cape Fear River. Similarly, annual mean dissolved

oxygen concentrations reach their lowest levels at stations B9580000 and B9670000 with higher values observed near the mouth of the river (Figure 11-54).

Figure 11-51: Annual Mean Fecal Coliform Bacteria Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

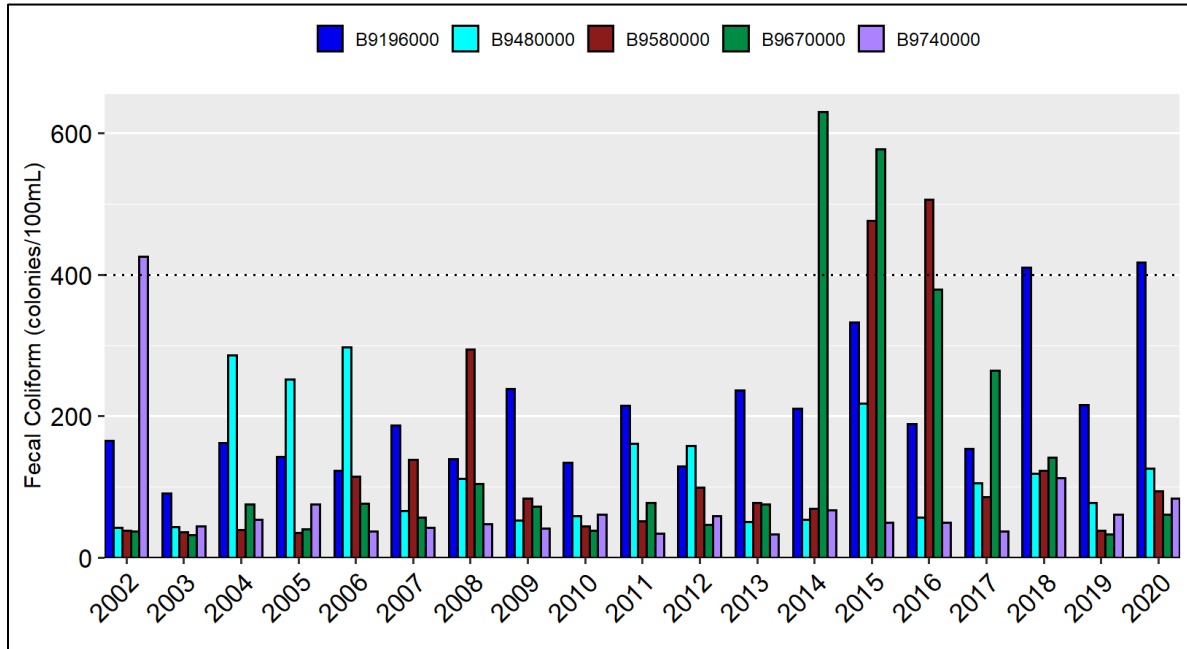


Figure 11-52: Annual Mean Turbidity Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000 and B9740000) between 2002 and 2020.

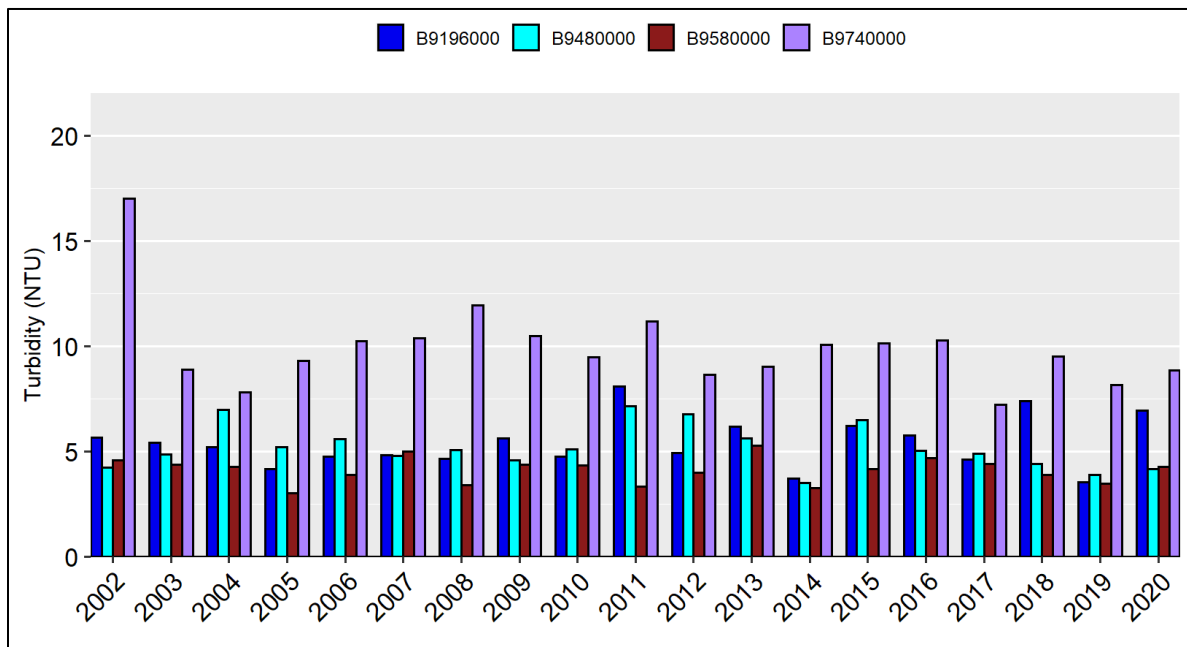


Figure 11-53: Annual Median pH Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

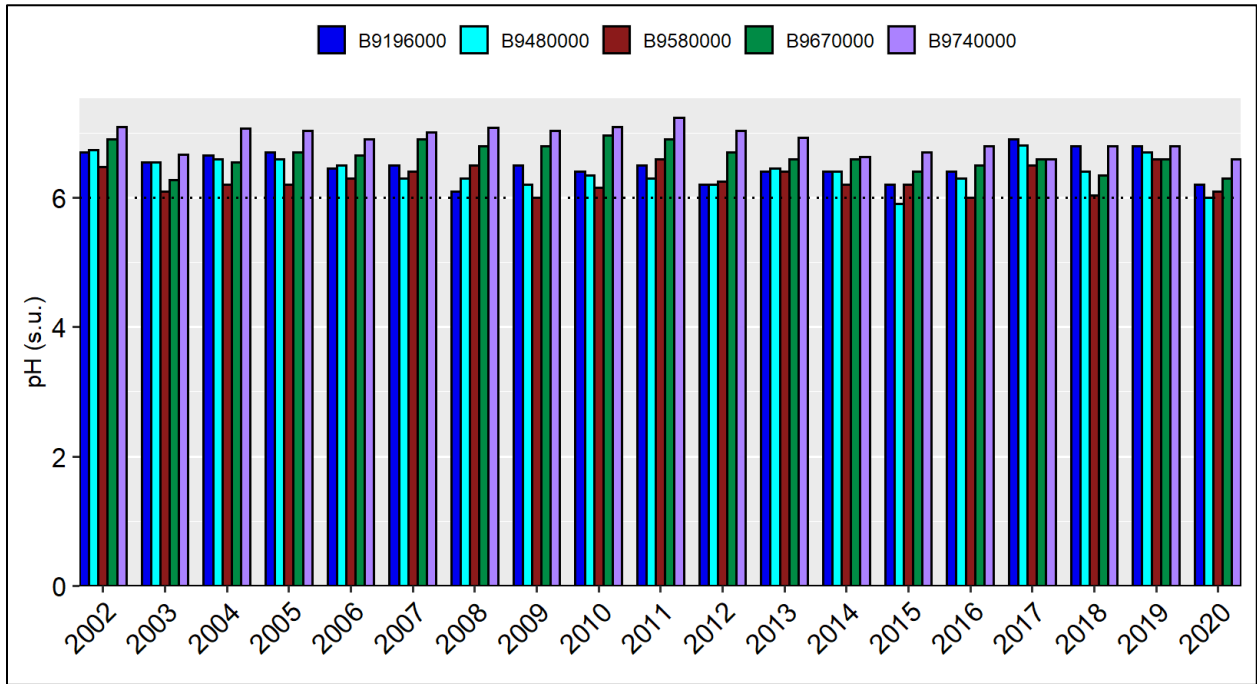
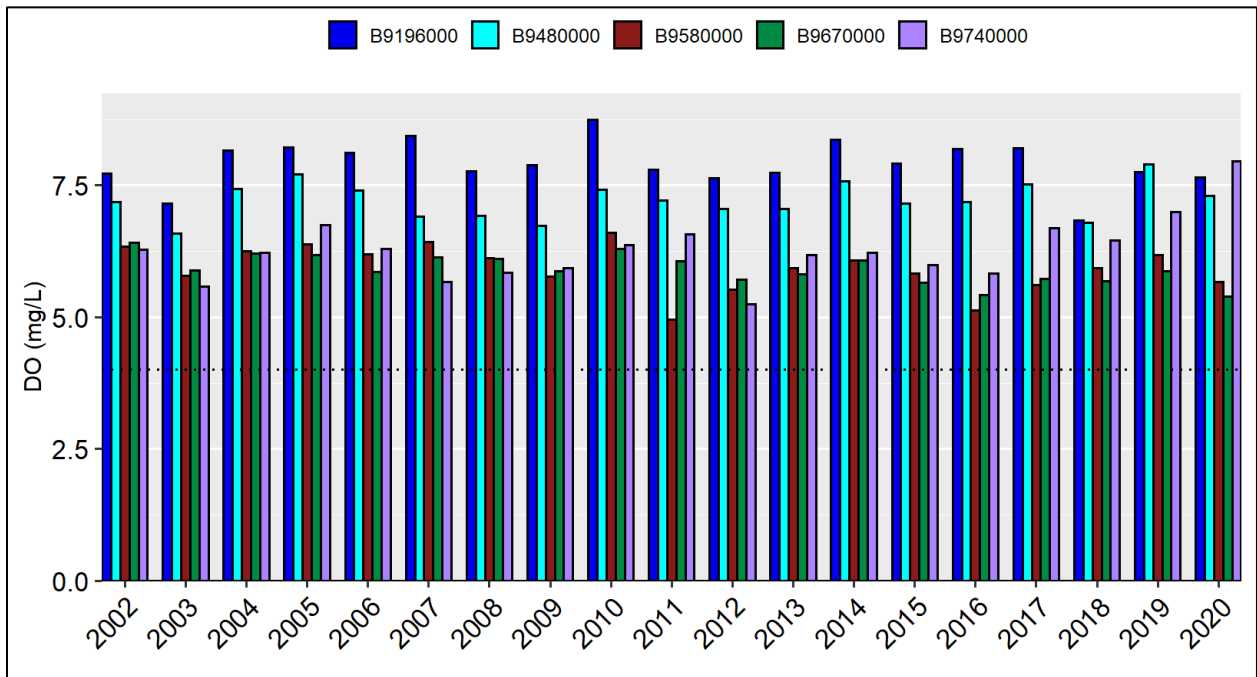


Figure 11-54: Annual Mean Dissolved Oxygen Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.



Annual mean total nitrogen concentrations were often higher at upstream stations (B9196000 and B9480000) compared to downstream stations (B9580000, B9670000 and B9740000) on the Northeast Cape Fear River (Figure 11-55). Similarly, annual mean total phosphorus concentrations were often higher at upstream stations (B9196000 and B9480000) compared to downstream stations (B9580000, B9670000 and B9740000) (Figure 11-56). While downstream nutrient concentrations are lower, the annual mean total nitrogen values at all stations hover around 1.0 mg/L and annual mean total phosphorus concentrations hover around 0.1 mg/L. These nutrient values are higher than concentrations considered normal for minimally impacted streams. Notably, ammonia (Figure 11-57) and nitrate+nitrite (Figure 11-58) concentrations were often higher after the confluence with Smith Creek, while total Kjeldahl nitrogen concentrations were often lower after this confluence (Figure 11-59).

DWR conducted screening level Mann-Kendall trend seasonal tests for fecal coliform bacteria and phosphorus at stations B9580000 and B9670000 that produced a significant increasing trend calculated at 95% confidence from data collected from 2000 to 2019, as well as a decreasing trend in dissolved oxygen concentrations at both stations during this same period. DWR’s screening level Mann-Kendall seasonal trends test at station B9580000 produced an increasing trend for nitrate+nitrite from data collected between 2000 and 2019. Mallin et al. (2022) also reported significant increases in the nitrate, total phosphorus and fecal coliform bacteria concentrations at station B9580000, as well as increases in total phosphorus concentrations at station B9670000 for data collected between 2000 and 2019.

Figure 11-55: Annual Mean Total Nitrogen Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

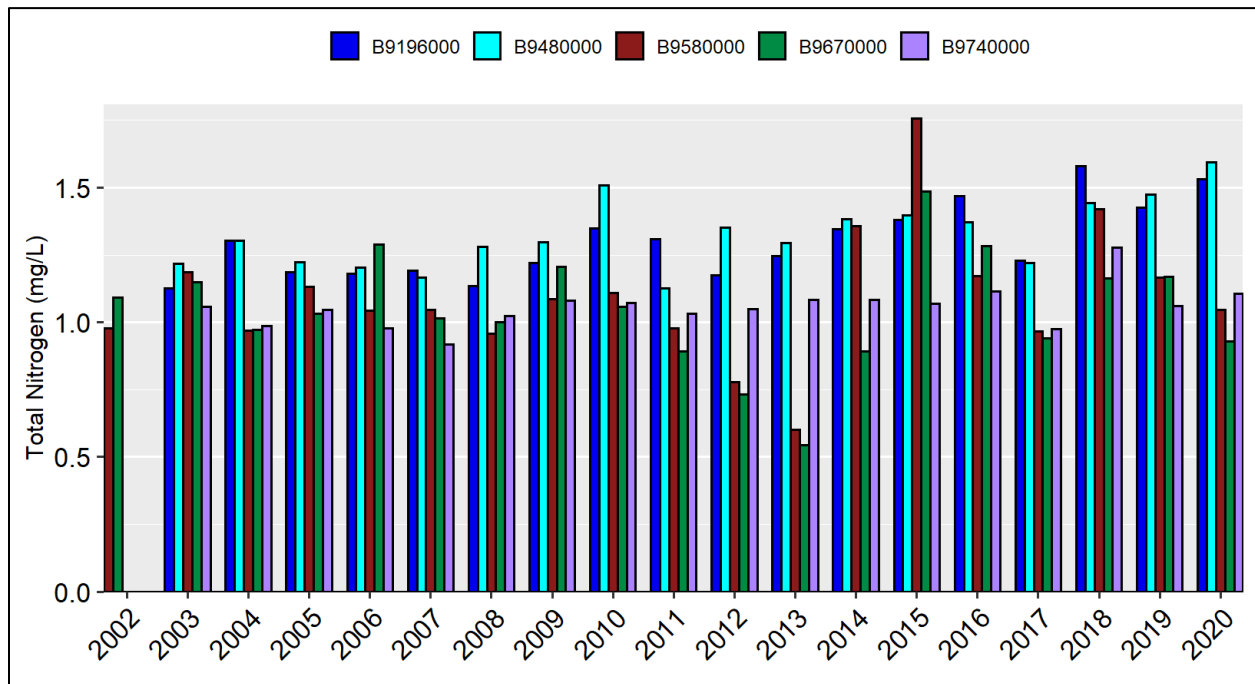


Figure 11-56: Annual Mean Total Phosphorus Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

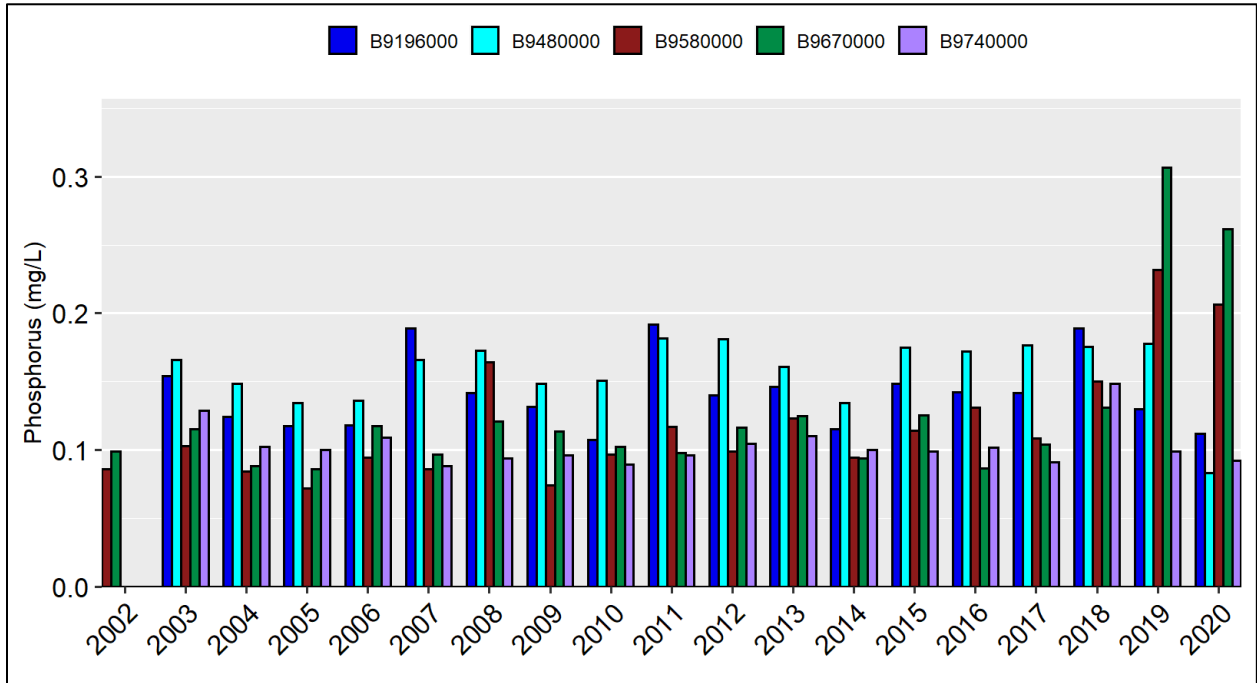


Figure 11-57: Annual Mean Total Ammonia Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

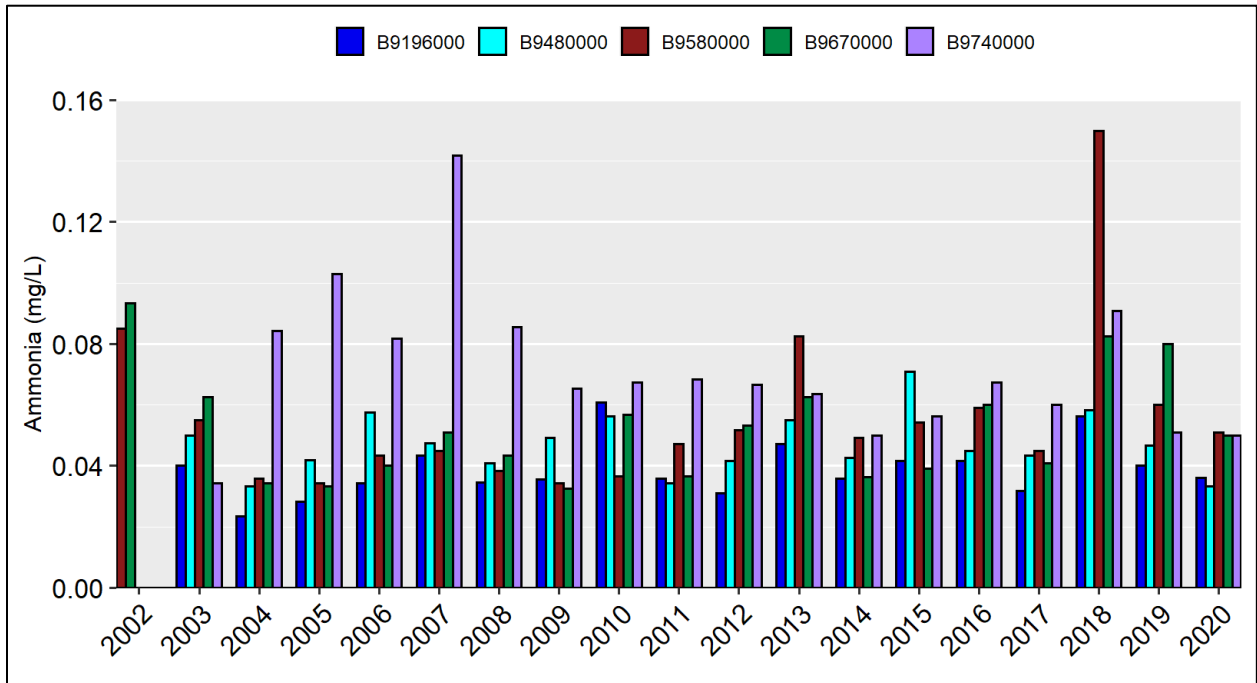


Figure 11-58: Annual Mean Nitrate+nitrite Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.

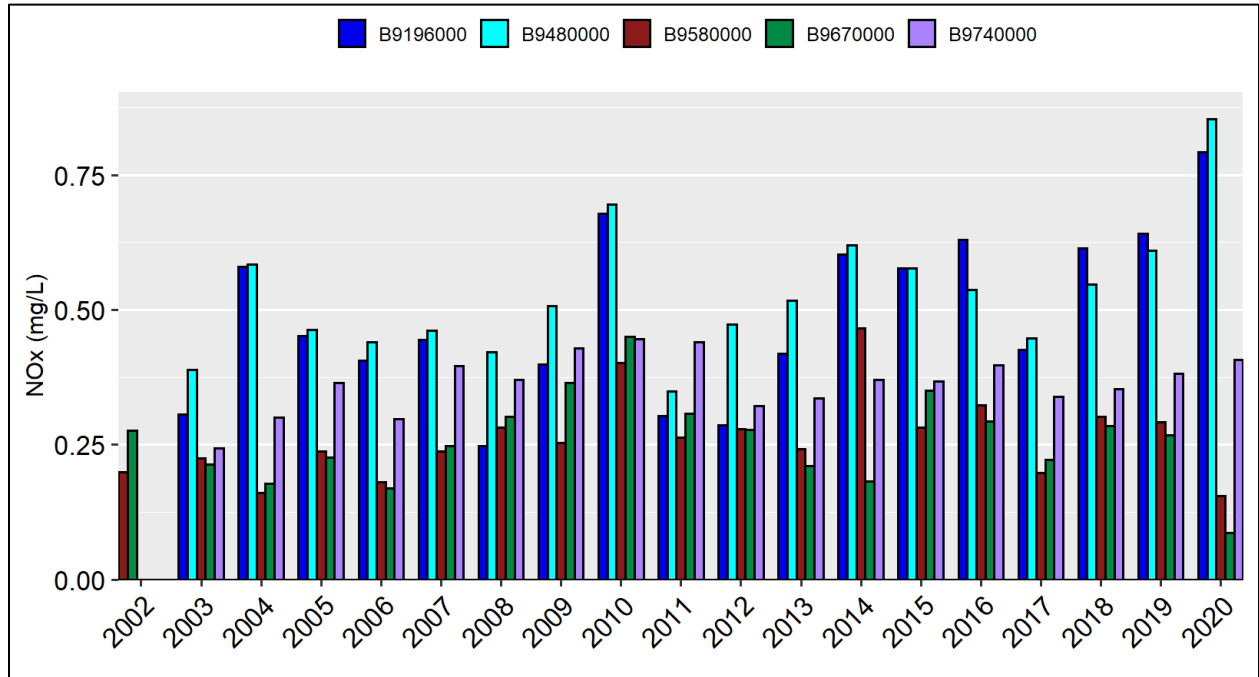
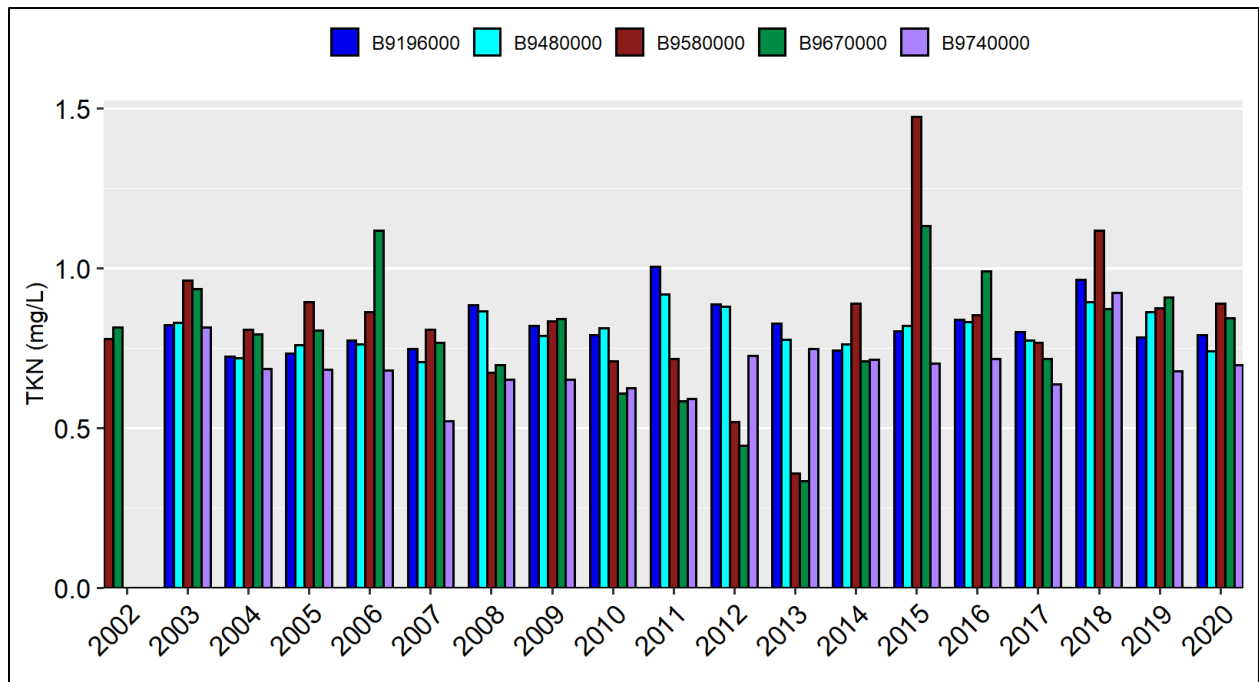


Figure 11-59: Annual Mean Total Kjeldahl Nitrogen Results for the Northeast Cape Fear River (B9196000, B9480000, B9580000, B9670000 and B9740000) between 2002 and 2020.



11.8.8.6 Harrison's Creek – Northeast Cape Fear River Watershed Summary

The water quality in Burgaw Creek, Smith Creek, Burnt Mill Creek, Prince George Creek and the Northeast Cape Fear River were/are impacted by both point and nonpoint sources of pollution. Burgaw Creek, Lillington Creek and Burnt Mill Creek are all on the impaired waters list for excursions of the aquatic life standards for benthos, copper and pH. Point sources in this watershed include major and minor NPDES-permitted facilities. Nonpoint sources of pollution in this watershed include swine feeding operations, agriculture practices, manure applications to cropland, urban development, stormwater, septic systems and/or straight pipes, domestic animals and wildlife.

The Harrison's Creek – Northeast Cape Fear River watershed receives drainage from all the upstream and adjacent watersheds; therefore, any pollution prevention measures installed in upstream watersheds will help protect the best uses downstream. This watershed contains the only section of Northeast Cape Fear River that is classified as primary recreational waters (Class B). This section overlaps with Primary Nursery Area-classified waters as well. Protecting the best uses of this waterway is necessary. Elevated nutrients and fecal coliform bacteria, as well as impaired benthic macroinvertebrate communities are concerns impacting waterways in this watershed.

Nutrient (total nitrogen and phosphorus) concentrations in Burgaw Creek, Smith Creek and the Northeast Cape Fear River are all elevated compared to the concentrations considered normal for minimally impacted streams. Harrison's Creek and Lillington Creek are two largely undeveloped waterways in this watershed with nutrient concentrations typically considered normal for minimally impacted streams. Notably, total nitrogen concentrations in all these waterways were primarily composed of organic nitrogen, possibly from the surrounding forested wetlands. The addition of the inorganic form of nitrogen from point and/or nonpoint sources contributes to elevated total nitrogen concentrations in Burgaw Creek, Smith Creek and the Northeast Cape Fear River. These sustained nutrient concentrations could show improvement if upstream watersheds are able to reduce their nutrient input to the Northeast Cape Fear River. Targeting nutrient-reducing best management practices in upstream watersheds, tributaries and adjoining lands can help lower these inputs and reduce the nutrient levels in this waterway.

The sources of these elevated fecal coliform bacteria concentrations in Burgaw Creek should be determined and preventative actions should be taken to prevent bacteria loads from entering this waterway. Burgaw Creek ultimately flows into the primary recreational waters of the Northeast Cape Fear River, potentially posing concerns for human health. While Burgaw Creek is the only monitored waterway in this watershed with sustained and elevated fecal coliform bacteria concentrations, elevated fecal coliform bacteria concentrations have been detected in and downstream of these primary recreational waters of Northeast Cape Fear River.

The New Hanover County water quality monitoring program should continue to conduct localized water quality monitoring and implementing best management practices to address the nutrients and fecal coliform bacteria levels to improve water quality in this watershed. The New Hanover County Local Watershed Plan was published in 2003. This planning document includes Smith Creek, Burnt Mill Creek and Prince George Creek project opportunities in these waterways. The plan is available for download on DEQ's Division of Mitigation Services website via: <https://deq.nc.gov/media/8071/download>.

Additional recommendations for the Harrisons Creek – Northeast Cape Fear River watershed include:

- Stream walking much of the watershed to assist in identifying sources of water quality problems.
- Reduction of nonpoint source pollution runoff through forested buffers alongside streams, wetland and stream restoration, erosion and sediment control best management practices and implementation of agriculture BMPs where needed (e.g., cover crops, grassed waterways, livestock exclusion, filter strips and field borders).
- As time and resources allow, DWR should pursue sampling of Burnt Mill Creek benthic macroinvertebrate community to update the rating.
- A natural conditions assessment should be considered to understand the cause of the low pH impairment in Lillington Creek.

11.9 Northeast Cape Fear River Subbasin Water Use

Water resources in the Cape Fear River Basin include surface and ground water, as well as water moving through built infrastructure. North Carolina has a diverse array of water users throughout the state including public and private water supply systems that supply drinking water to their customer base, industries such as food production, wood manufacturing and metal processing and energy production (hydroelectric and thermoelectric). Water is also used statewide for agricultural, mining and recreational purposes. The availability and continued use of water by all users is vital to the continued prosperity of the communities and ecosystems of this state.

There are several programs within DEQ that provide information about how much water is being used in North Carolina. These include the Water Withdrawal and Transfer Registration (WWATR) Program, the Local Water Supply Planning (LWSP) Program, the Central Coastal Plain Capacity Use Area (CCPCUA) and the Interbasin Transfer (IBT) Certification Program. Several programs are also in place to protect drinking water sources including the Source Water Assessment Program (SWAP), the Surface Water Protection Program (SWPP) and the Wellhead Protection Program (WHP). Additionally, the Groundwater Resources Branch (GWRB) oversees the assessment, monitoring and management of the state's groundwater resources. More information about these programs can be found in Chapter 3 and Chapter 5.

In addition to administering programs for water use and protection, DEQ plays a critical role in providing technical and managerial support for the development and use of surface water and groundwater resources and calculating the volume of water moving through a system. For agriculture water use, the North Carolina Department of Agriculture & Consumer Services (NCDACS) plays a critical role in collecting statewide water use data. Information included in this section is taken from the Water Quantity Assessment and Planning in the Cape Fear River Basin, Chapter 5.

11.9.1 Water Use and Availability Reported in Local Water Supply Plans

The information presented in this section quantifies water demand/use and available water supply on a subbasin scale based on public water supply systems that submitted local water supply plans in the Northeast Cape Fear River subbasin. Per North Carolina General Statutes §143-355(l), the Local Water

Supply Planning Program applies to units of local governments and community water systems that regularly serve 3,000 or more individuals or have 1,000 or more service connections. See Chapter 5 for more information on water use and availability along with data qualifications and methodologies.

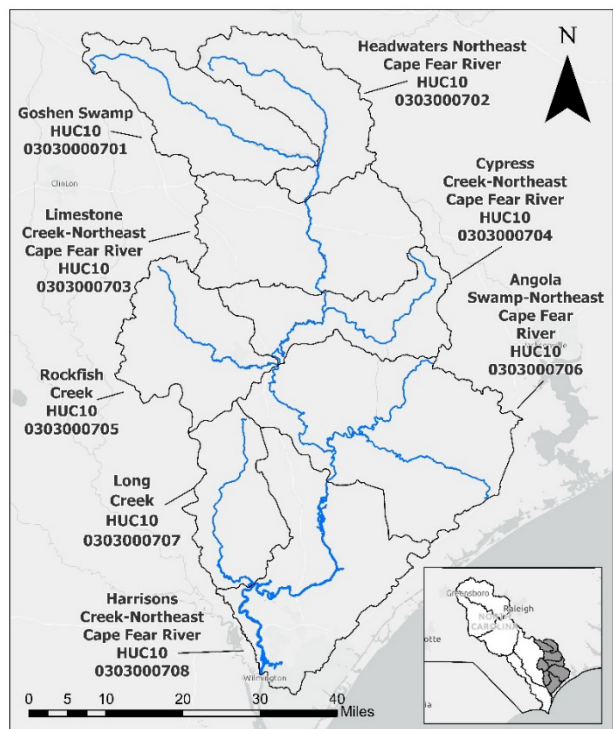
Fourteen (14) water systems are included in the Northeast Cape Fear River subbasin. Based on the information reported by users, not including ecological flow, domestic users, non-reporters and other unknown usages; there are no apparent water supply issues in the Northeast Cape Fear River subbasin. The Northeast Cape Fear River subbasin population served by public water supply systems was 64,006. The public water supply systems in this subbasin had a combined average daily water demand of 6.09 MGD in 2020. Comparing this to the total available supply reported by these 14 public water supply systems in 2020 of 16.5 MGD, the combined average daily demand of the public water supply systems in the Northeast Cape Fear River subbasin was approximately 37% of available supply. The Duplin County Water System and Pender County Utilities have the largest demands for water systems in the subbasin. Duplin County depends upon groundwater as its source and is within the Central Coastal Plain Capacity Use Area (CCPCUA). Pender County also has groundwater wells, but most of their raw water is purchased from LCFWASA, with a small amount purchased from the Town of Wallace. The average daily water demand for both Duplin County and Pender County Utilities in 2020 was approximately 3.26 MGD, combined this constitutes approximately 54% of the subbasin demand. A detailed description of the public water supply availability, demand and projections for the Northeast Cape Fear River subbasin is in Chapter 5.

11.10 Protecting Water Resources in the Northeast Cape Fear River Subbasin

The Basin Planning Branch (BPB) continually works with the Nonpoint Source Planning Branch (NPSPB), Soil and Water Conservation Districts (SWCD), Natural Resources Conservation Service (NRCS) and various stakeholders throughout the region to improve our understanding of point and nonpoint sources of pollution and encourage continued efforts to implement best management practices (BMPs) and restoration activities that reduce nutrients, bacteria, sediment loads and stormwater flow volume to the receiving waterbodies.

11.10.1 Fecal Coliform Bacteria in the Northeast Cape Fear River

The highest fecal coliform bacteria concentrations were identified in the Goshen Swamp, Headwater Northeast Cape Fear River, Limestone Creek-Northeast Cape Fear River and Rockfish Creek watersheds. Additionally, pulses of elevated fecal coliform bacteria have been observed in Angola Creek and Harrisons Creek-Northeast Cape Fear River



watersheds. A lack of surface water quality monitoring in the Cypress Creek-Northeast Cape Fear River and Long Creek watersheds prevents an understanding of fecal coliform bacteria in these regions of the Northeast Cape Fear River subbasin.

Water quality standards for fecal coliform bacteria are intended to ensure safe use of waters for recreation (Administrative Code Section 15A NCAC 2B .0200). The North Carolina fecal coliform standard for freshwater is 200 colonies/100ml based on the geometric mean of at least five consecutive samples taken during a 30-day period and not to exceed 400 colonies/100ml in more than 20% of the samples during the same period. This standard applies to all class B and C waters. Since many of the rivers, streams and creeks of the Northeast Cape Fear River subbasin are classified as secondary recreational waters (Class C) these waterways are not prioritized for fecal coliform 5-in-30 sampling due to DWR staff limitations to focus on primary recreational waters (Class B) waters.

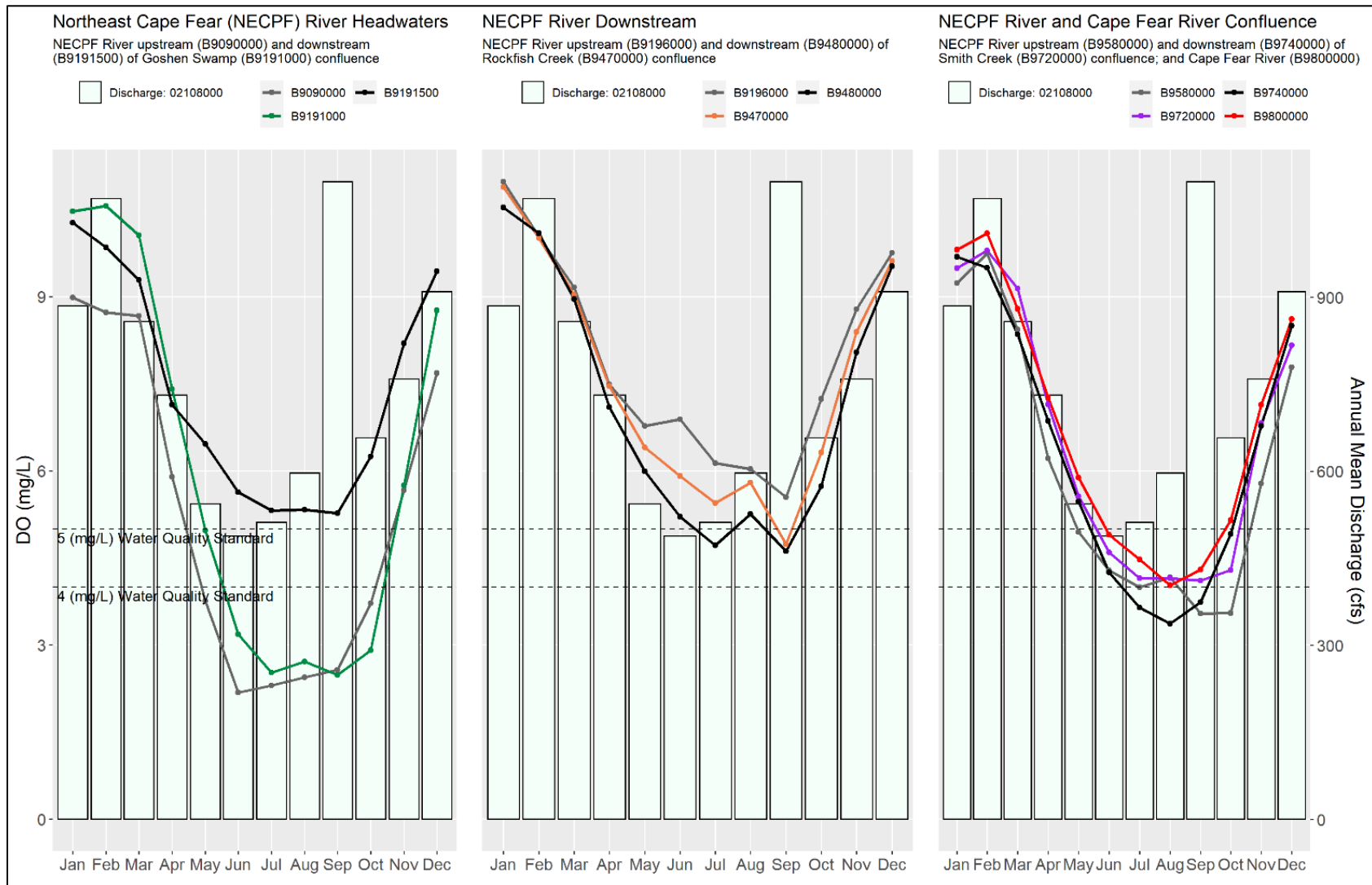
As time and resources allow, additional special studies should be conducted in the waters of the Northeast Cape Fear River subbasin to determine the sources of fecal coliform bacteria. These special studies could be led by state or federal government, local stakeholders, or any group with an interest in protecting the waters of this watershed. Identifying where people recreate in the Northeast Cape Fear River subbasin and the fecal coliform concentrations observed at these locations could help protect the health of citizens interacting with these waterways. Potential sources of fecal coliform include wastewater treatment dischargers, sanitary sewer lines, on-site wastewater management systems (septic systems), animal feeding operations and stormwater runoff.

Considerable efforts to conduct source identification in this subbasin have already occurred and were mentioned in this chapter, including Harden (2015) and Brown et al. (2020). *A Stocking Head Creek source identification study is recommended to provide additional information regarding the potential sources of elevated fecal coliform bacteria concentrations. Initiatives should be made to reduce the bacterial loading from all sources.*

11.10.2 Dissolved Oxygen in the Northeast Cape Fear River

The Northeast Cape Fear River flows 113 miles south from its origins south of Mount Olive to the estuary at Wilmington. Downstream from the confluence of the Northeast Cape Fear River and Goshen Swamp, there are a total of six monitoring stations collecting dissolved oxygen data on the Northeast Cape Fear River. The stations are described from upstream to downstream as follows: the Northeast Cape Fear River downstream from the Goshen Swamp and the Northeast Cape Fear River confluence as monitored by station B9191500; the Northeast Cape Fear River upstream of the confluence with Stocking Head Creek and Rockfish Creek as monitored by station B9196000; downstream of the confluence with Rockfish Creek as monitored by station B9480000; recreational waters (Class B) of the Northeast Cape Fear River as monitored by station B9580000; upstream of the City of Wilmington as monitored by station B9670000; and downstream of City of Wilmington as monitored by B9740000 prior the confluence with the Cape Fear River.

Figure 11-60: Mean Monthly Dissolved Oxygen Levels in the Northeast Cape Fear River.



Stations are examined from upstream to downstream based on data collected between 2002 and 2020 at surface water quality monitoring stations. Each panel in the graphic represents either the upstream (headwaters), downstream, or mouth of the Northeast Cape Fear River with one adjoining tributary per panel. Monthly mean discharge values are based on data collected between 2002 and 2020 from USGS gaging station 02108000 which is in the Northeast Cape Fear River. Discharge values were influenced by Hurricanes that occurred in September.

Northeast Cape Fear River is a swamp-classified river with observed low dissolved oxygen levels throughout much of the summer months when flows are at their lowest point in the year (*Figure 11-60*). The Northeast Cape Fear River dissolved oxygen is monitored from the headwaters to its mouth before the confluence with the Cape Fear River.

Dissolved oxygen levels monitored at these stations have recorded a river with progressively less dissolved oxygen as the river flows downstream. The graphs explore the average dissolved oxygen concentration for each month's average concentration based on surface water quality monitoring data from 2002 to 2020 (*Figure 11-60*). As displayed on *Figure 11-60*, the dissolved oxygen levels in the Northeast Cape Fear River headwaters at surface water quality monitoring station B9090000 and Goshen Swamp at station B9191000 are quite low with summer values less than 4 mg/L; however, other tributaries join Northeast Cape Fear River, appearing to contribute to improved dissolved oxygen in the river as recorded at station B9191500 with summer values above 5 mg/L.

Monitoring of Northeast Cape Fear River is continued at stations B9196000 and B9480000, which are above and below the confluence with Rockfish Creek. The summer dissolved oxygen levels progressively decline to reach summer values between 4 mg/L and 5 mg/L, possibly due to low dissolved oxygen contributions from Rockfish Creek (*Figure 11-60*). The furthest downstream station in Northeast Cape Fear River, B9740000, is located prior to the confluence with the Cape Fear River. This monitoring station maintains the lowest monthly average dissolved oxygen concentrations during the months of June through September based on data collected between 2002 and 2020 (*Figure 11-60*).

The contribution of low dissolved oxygen to the Cape Fear River can possibly contribute to lower dissolved oxygen levels found in the estuary. Analyzing water from the Black and Northeast Cape Fear rivers aids in understanding the low dissolved oxygen levels in the Northeast Cape Fear River. Researchers have worked to determine both photosynthetic and heterotrophic pathways for inorganic and organic fractions of nutrients (nitrogen and phosphorus) in blackwater systems.

11.10.3 Nutrient Research and Modeling in the Northeast Cape Fear River

The Northeast Cape Fear River receives nutrient runoff from both point and non-point sources of pollution. These nutrients include nitrogen and phosphorus that are transported from the land surface into the rivers and streams that dissect this subbasin. The highest total nitrogen concentrations were recorded in the Goshen Swamp, Headwaters Northeast Cape Fear River, Limestone Creek-Northeast Cape Fear River and Rockfish Creek watersheds (*Table 11-12* and *Figure 11-55*). Lesser values were observed in Angola Creek-Northeast Cape Fear River and Harrison's Creek-Northeast Cape Fear River. The highest total phosphorus concentrations were recorded in Rockfish Creek, Angola Creek and Goshen Swamp (*Table 11-12* and *Figure 11-56*). Lesser values were observed in Headwater Northeast Cape Fear River, Limestone Creek-Northeast Cape Fear River and Harrison Creek-Northeast Cape Fear River. A lack of surface water quality monitoring in Cypress Creek-Northeast Cape Fear River and Long Creek watersheds prevents an understanding of nutrient levels in these regions of the Northeast Cape Fear River subbasin. Notably, while total Kjeldahl nitrogen concentrations comprise a large portion of the total nitrogen concentrations found at many surface water quality monitoring stations, when many waterways in this subbasin receive additional inputs from nitrate+nitrite, either from point or nonpoint sources, the total nitrogen concentrations can exceed concentrations considered normal for minimally impacted streams.

Since the Northeast Cape Fear River Subbasin is a blackwater river system, it presents a unique challenge in understanding how contributing nutrients interact with these waterways. Mallin et al. 2004 concluded that additions of nitrogen and phosphorus into blackwater systems potentially increases biological oxygen demand by photosynthetic and heterotrophic activity which can subsequently reduce dissolved oxygen concentrations through increased biological oxygen demand.

Previous work by Mallin et al., 2002 support the above conclusion: “Based on field and experimental data, we [Mallin et al.] contend that algal blooms do occur in blackwater streams. These blooms occur only in spring or summer, primarily in shallow streams. However, these blooms die upon entering the deep, light-limited main channels and become a source of BOD [biological oxygen demand]. Thus, nutrient loading, through the photosynthetic pathway, can indirectly exacerbate low dissolved oxygen problems in blackwater rivers.” (Mallin et al., 2002). Their work in 2002 also found: “Significant stimulation of chlorophyll *a* and BOD occurred with additions of 0.2 - 0.5 mg nitrate-N/L, and significant stimulation of chlorophyll *a* and BOD also occurred in Great Coharie Creek with inputs of TN as low as 0.2 mg-N/L. Significant stimulation of BOD occurred with additions of either 0.5 or 1.0 mg-P/L as TP. Previous experiments conducted on water from the Black and Northeast Cape Fear Rivers using additions of 1.0 mg/L of N or P also showed significant stimulation of chlorophyll *a* (by N) and adenosine triphosphate (ATP) by P or N.” (Mallin et al., 2002).

Research by Mallin and Cahoon (2020) supported the heterotrophic pathway for phosphorus: “Significant positive field correlations between total P and BOD in a variety of Coastal Plain lotic and lentic systems suggest an influence of P on hypoxia in these aquatic ecosystems. Targeted nutrient addition experiments using water from several different Coastal Plain watercourses demonstrated significant P stimulation of bacterial growth and associated increases in BOD and ATP concentrations as ecosystem-level effects. From a management perspective, the findings indicate that in systems affected by low dissolved oxygen, the direct contribution of P enrichment to hypoxia must be considered when devising total maximum daily loads required for remediation of impaired waters.” (Mallin and Cahoon, 2020). Research by Mallin et al. (2004) supported the photosynthetic pathway that nitrogen stimulates biological oxygen demand through photosynthetic activity, meaning the growth and subsequent death and decay of algal blooms, followed by bacterial increase, then increased biological oxygen demand (Mallin et al., 2004). These two pathways increased biological oxygen demand that can then result in a decrease in dissolved oxygen (Mallin et al., 2004). Mallin et al. (2004) also states: “Without increased attention paid to controlling both nutrients, deterioration of water quality can be expected in the extensive blackwater systems characterizing the U.S. Coastal Plain, and likely other ecosystems as well.”

The Soil and Water Assessment Tool, a physically-based watershed model, was used in the Northeast Cape Fear River to assess the impact of point and nonpoint sources on total nitrogen, total phosphorus and dissolved oxygen. The main objectives of the study were to estimate total nitrogen and total phosphorus loads discharged from the Northeast Cape Fear River to the Lower Cape Fear River under varying land use and management conditions. A second objective was to support the hydrodynamic and nutrient response model that will be used as a tool to develop a dissolved oxygen Total Maximum Daily Load (TMDL) for the Lower Cape Fear Estuary. See Chapter 9 for more details on the Lower Cape Fear River Estuary TMDL. This tool used data collected between 1999 and 2005 for model calibration. Model results suggested that nonpoint sources contributed more than 90% of the nutrient loads to the Lower Cape Fear River. Among

the nonpoint sources, agricultural land and forested wetland contributed a major portion of the load. They respectively contributed approximately 30% and 40% of the total nitrogen load and 60% and 20% of the total phosphorus load during normal and dry years. It is observed that the nutrient load was high during March for dry period and during September for normal period.

It appears the forested wetlands in the Northeast Cape Fear River subbasin were not designed to trap nutrient loading coming from adjoining lands. The wetlands functioned as a passive source by transporting nutrients into streams in the natural environment. Several streams drain nutrients from wetlands as well as from adjoining lands. In addition, the wetlands receive pollution input from surrounding uplands, including agricultural land used for hog farming. Adoption of proper BMPs in the watershed would reduce the nutrient loads. In agricultural land, a significant portion of the phosphorus load was due to erosion. It accounts for 70% of the total load. This heavy amount of load can be reduced through additional adoption of agricultural BMPs (NCDENR, 2008).

Alongside this modeling effort the University of North Carolina at Charlotte developed a three-dimensional water quality model Environmental Fluid Dynamics Code (EFDC) (Bowen et al., 2009). “The model was used to investigate the effects of various organic matter and ammonia load reduction scenarios on the dissolved oxygen concentrations within the estuary. Various scenarios investigated the system response to reductions in wastewater and watershed loadings. Of the three primary constituents that contribute to oxygen depletion, only ammonia had a load that was contributed primarily from the wastewater sources. For organic matter loadings, the majority of the load was contributed by the incoming rivers and local tidal creeks and wetlands discharging directly to the estuary. Reducing these watershed loads had a significant impact on the dissolved concentrations within the estuary. Despite the sensitivity of the system to changes in these loadings, elimination of violations of the water quality standard for dissolved oxygen (5 mg/L) would require a 70% reduction both in riverine loadings but also a similar reduction in sediment oxygen demand.” (Bowen et al., 2009)

11.10.4 Northeast Cape Fear River Subbasin Recommendations

Recommendations and actions to improve and protect water quality are listed in detail throughout the Northeast Cape Fear River subbasin chapter. Some of the key recommendations include:

- Provide sufficient funding to existing state and federal cost share programs (urban, agriculture and forestry) for technical assistance and the voluntary implementation of BMPs. This includes cost share programs managed by the NCDA&CS Division of Soil & Water Conservation (DSWC) and NC Forest Service (NCFS) and federal programs managed by the USDA Natural Resources Conservation Service (NRCS). Programs should promote BMPs that reduce nutrients, turbidity and fecal coliform in waterways.
- Expand existing data collection (including source identification) to include agricultural watersheds with high concentrations of deemed permitted animal operations. DWR has little to no information on deemed permitted facilities making it difficult to determine if they are having an impact on water quality. Data could also be used by multiple local, state, and federal agencies to

review the existing regulatory framework as it relates to deemed permitted facilities and help target BMP implementation.

- Enhance coordination and provide financial and technical support to local governments to effectively manage and improve stormwater and wastewater infrastructure.
- Maintain existing, effective regulatory strategies, such as use of vegetated buffers and stormwater controls throughout the river basin, to reduce nonpoint pollution and minimize cumulative losses of fish habitat and impacts to water quality.
- There are multiple sources of pollutants in the Lower Cape Fear River subbasin that have the potential to contaminate fish and shellfish tissue. Additional fish tissue/consumption advisories are likely once more research is completed. It is recommended to evaluate the need for additional staff for DEQ and NC DHHS to increase fish tissue collection, testing, data analysis, and public education and outreach.
- Publicly Owned Treatment Works (POTWs) must work with DWR to determine if their Pretreatment Programs are sufficiently evaluating indirect dischargers to protect against accepting waste with potential emerging contaminants.

11.11 References

Griffith, G.E., Omernik, J.M., Comstock, J.A., Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.F., Glover, J.B., and Shelburne, V.B. (2002). *Ecoregions of North Carolina and South Carolina*, (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000). ftp://newftp.epa.gov/EPADDataCommons/ORD/Ecoregions/nc/nc_eco_pg.pdf. Accessed 3/23/21. Website lasted updated 2/9/2021. <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-4#pane-31>.

Eaton Scientific, LS and The Three Oaks Engineering. (2019). 2019 Benthic Macroinvertebrate Survey NPDES Wastewater Permit Application NC0001970 Bay Valle Foods LLC – Faison, NC. Accessed: <https://edocs.deq.nc.gov/WaterResources/DocView.aspx?id=876336&dbid=0&repo=WaterResources&earchid=df21aa32-6845-4b62-bb7a-e5b32cde96a>

Dubrovsky, N.M., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton P.A., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and Wilber, W.G. (2010). *The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004*: U.S. Geological Survey Circular 1350, 174 p. Additional information about this study is available at <http://water.usgs.gov/nawqa/nutrients/pubs/circ1350>

Esri Living Atlas. (2020). *USA Census 2020 Redistricting Blocks* (Version 11) [GIS Feature Service Layer]. Retrieved from: https://services.arcgis.com/P3ePLMys2RVChkXj/arcgis/rest/services/USA_Census_2020_Redistricting_Blocks/FeatureServer

Mallin M. A., Cahoon L. B., McIver M. R., Ensign S. H. (2002). *Seeking Science-Based Nutrient Standards for Coastal Blackwater Stream Systems*. *Water Resources Research Institute Project Nos. 70171 & 70177*.

Mallin M. A., Mclver M. R., Ensign S. H., Cahoon L. B. (2004). *Photosynthetic and Heterotrophic Impacts of Nutrient Loading to Blackwater Streams*. Ecological Applications.

Mallin M. A., Cahoon L. B. (2020). *The Hidden Impacts of Phosphorus Pollution to Streams and Rivers*. BioScience. Vol. 70, pg. 315-329. [biaa001.pdf \(silverchair.com\)](#)

Mallin M A., Mclver M. R., Brown C. N., Merritt J. F. (2022). *Environmental Assessment of the Lower Cape Fear River System*, 2021.

Multi-Resolution Land Characteristics. (n.d.). *NLCD Land Cover (CONUS) All Years* [NCLD Mapping Tool]. Retrieved from <https://www.mrlc.gov/data?f%5B0%5D=category%3ALand%20Cover> , Accessed 2022.

NCDEQ, Division of Water Resources, n.d. Draft and Approved TMDLs. <https://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/tmdls/draft-and-approved-tmdls>. Accessed May 13, 2021.

NC DWQ. Modeling and Assessment Unit. (2004). *Lower Cape Fear River / Estuary TMDL Study DENR/DWQ ISU Sampling Data July 7 – August 11, 2004*. [Microsoft Word - Cape Fear River Estuary Monitoring Study \(nc.gov\)](#)

North Carolina Department of Environmental Quality (NCDEQ). (2020). *Title VI: Increasing Equity, Transparency, and Environmental Protection in the Permitting of Swine Operations in North Carolina*. <https://deq.nc.gov/media/15659/download>

North Carolina Department of Environmental and Natural Resources (2008). *Application of Soil and Water Assessment Tool for Northeast Cape Fear River Watershed*. [Microsoft Word - Watershed modeling report draft2.doc \(nc.gov\)](#)

North Carolina Department of Environmental and Natural Resources (2004). *Assessment Report: Biological Impairment in the Burnt Mill Creek Watershed*. <https://deq.nc.gov/media/4725/download>

Rosov, B. (2022). *New Hanover County Water Quality Monitoring Program: 2021- 2022 Final Report*. New Hanover County, North Carolina: Coastal Protection Engineering of North Carolina, Inc.

Harden, S.L. (2015). *Surface-water quality in agricultural watersheds of the North Carolina Coastal Plain associated with concentrated animal feeding operations*: U.S. Geological Survey Scientific Investigations Report 2015–5080, 55 p., 7 apps. <http://dx.doi.org/10.3133/sir20155080>

Bowen, J. D., Negusse, S. J., Goodman, M. J., Duclaud B., Robin M., Williams J. (2009). *Development and Use of a Three-Dimensional Water Quality model to Predict Dissolved Oxygen Concentrations in the Lower Cape Fear River Estuary, North Carolina*. [AppendixA.xlsx \(nc.gov\)](#)