

**BASINWIDE WATEWAR 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 9 –  
Lower Cape Fear River Subbasin  
HUC 03030005**

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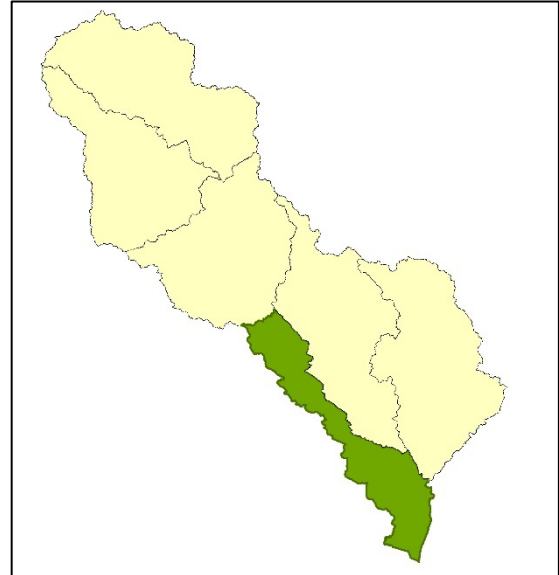
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# 1 Lower Cape Fear River Subbasin (HUC8 03030005)

## 1.1 General Description

The Lower Cape Fear River is a narrow linear-shaped subbasin with a northwest-southeast orientation that follows the direction of the Cape Fear River. This 8-digit hydrologic unit code (HUC) boundary (03030005) has the smallest land area of the Cape Fear River Basin's six subbasins, covering 1,061.5 square miles (mi<sup>2</sup>) or 679,338 acres. The Lower Cape Fear River subbasin encompasses the southern part of Cumberland County, the eastern sections of Bladen, Columbus, and Brunswick counties, and the southwestern section of New Hanover County. The largest municipalities include a portion of Wilmington in New Hanover County on the east side of the Cape Fear River and Leland on the west side of the river in Columbus County. Several smaller densely



populated coastal communities include Oak Island, Southport, Kure Beach, and Carolina Beach. Rural residential properties and smaller communities are also scattered throughout the subbasin. The Lower Cape Fear River subbasin is comprised of eight HUC10 watersheds. The Lower Cape Fear is primarily located in the Middle Atlantic Coastal Plain ecoregion, with the exception of a small section in the upper part of the subbasin found in the Southeastern Plains ecoregion. Over one-third of the land cover (35.3%) in this subbasin is wetlands, including many Carolina bays, which are concentrated between the Cape Fear River and South River located in the adjacent Black River subbasin. Several of the bays in this subbasin have formed shallow lakes, including White, Jones, Little Singletary, Bakers, Horseshoe, and Salters.

The Lower Cape Fear River mainstem flows southeast from the Upper Cape Fear subbasin toward the Atlantic, first merging with the Black River just to the east of the small community of Hooper Hill, then merging with Northeast Cape Fear River when it reaches Wilmington. From there it bends to the south then southeast finally flowing into the Atlantic Ocean between Fort Caswell and Baldhead Island. Other major tributaries from upstream to downstream include Harrison Creek and Turnbull Creek in the upper part of the subbasin, closer to Elizabethtown, Livingston Creek near the community of Riegelwood, Hood Creek near Cooper Hill and above the Black River confluence, Town Creek located below Wilmington and the Northeast River confluence, and Lilliput Creek, which drains Boiling Springs Lake. The lowest section of the river is characterized as an estuary with tidal creeks. The Lower Cape Fear River has three historic lock-and-dam (LD) structures that were once used by barges and large boats to navigate shallow waters. While no longer used for navigation, the water behind LD#3 and LD#1 are used by municipalities to provide drinking water within their service area.

There have been several concerning water resource-related issues and DEQ actions taken in the Lower Cape Fear River subbasin during the 2002 to 2020 timeframe of this plan:

- Rapid population growth and development of coastal areas in the Lower Cape Fear subbasin (Sections 9.2, 9.9.6, 9.9.7, 9.9.9, 9.10.3)
- The discovery of GenX, a type of PFAS and an Emerging Contaminant of Concern (see Chapter 2), in the Cape Fear River and the linkage to the Chemours Facility (formerly DuPont Fayetteville Works; Sections 9.9.1.1, 9.10.1).
- Intense storm events, sea level rise, storm surges, and drought combined with dredging threaten infrastructure in coastal areas and have altered wetlands, causing ghost forests to form (Section 9.10.3).
- Harmful Algal Blooms (HABs) and nutrient over enrichment in the Cape Fear mainstem (Sections 9.10.4).
- 2017 and 2021 fish tissue advisories for hexavalent chromium and arsenic in the Cape Fear River Estuary and Sturgeons Creek (Sections 9.6, 9.9.6, 9.10.3).
- The newest July 13, 2023, fish tissue advisory for PFOS (perfluorooctane sulfonic acid), a type of PFAS (per and polyfluoroalkyl substances) issued for over 90 miles of the Cape Fear River (Sections 9.6.1, 9.9.1.1, 9.10.1).
- High bacteria levels in the estuary and shellfish closures (Sections 9.5, 9.10.3).
- Increasing TKN levels throughout the Lower Cape Fear subbasin (Sections 9.9.3, 9.9.5.1, 9.9.6.1, , 9.10.1, 9.10.2, 9.10.3).
- Reduction in the number of biological (benthic) stations monitored in 2018 due to a lack of resources, compared to eight sites monitored in 2003. (Section 9.4).
- White Lake's eutrophication, algal blooms, and fish kill (Sections 9.9.1.2, 9.10.1).
- High fecal coliform bacteria levels in Brown (Section 9.9.2.1) and Hammond (Section 9.9.5.1) Creeks and high ammonia levels in Livingston Creek (Section 9.9.4.1).
- The need for ambient monitoring in tributaries along the mainstem to identify pollutant sources in places where monitoring was halted or never existed (Sections 9.9.4, 9.10.1, 9.10.2, 9.10.3).
- Increased total phosphorus levels in recent years below Natmore Creek, an unmonitored tributary that originates in the Black River subbasin (Sections 9.9.5.1, 9.10, 9.10.2).
- The coal ash basin overflow at the Sutton Lake Duke Energy facility, Sutton Lake Dam breach during Hurricane Florence and closure of coal ash pond (Sections 9.9.6.1, 9.10.3).
- Greenfield Lake's eutrophication, nutrient loading, high chlorophyll *a* levels, and algal blooms (Sections 9.9.6.1, 9.10.3).
- Impaired waters in the Cape Fear River Estuary due to Low DO and pH levels (Sections 9.9.6, 9.9.6.1, 9.10.3, 9.11).
- The failed dam and dewatering of Boiling Springs Lake during Hurricane Florence (Sections 9.9.7, 9.10.3).

*Figure 9-1 to Figure 9-5* show maps with permitted facilities, monitoring stations, and the 2022 Integrated Report (IR) for all classified streams. Most of the impairments occurred in the lower third of the subbasin

near and below Wilmington along the Cape Fear and Brunswick rivers and along the Intercoastal Waterway to the west of Southport (*Figure 9-1* to *Figure 9-5*). The 2022 IR for the Lower Cape Fear River subbasin is summarized in *Table 9-1* and categorized by parameter in *Table 9-2*. Monitoring data were available for 36% of the freshwater (FW) miles of rivers and streams, 53% of the FW acres of lakes and reservoirs, and almost all of the saltwater (SW) acres of the estuary. At the basin level, the Lower Cape Fear subbasin accounted for 100% of the SW acre impairments and just 2.3% of both the freshwater (FW) mile and FW acre impairments. FW acre impairments included Jones Lake near Elizabethtown (*Figure 9-3*), impaired for pH, and Greenfield Lake in Wilmington (*Figure 9-4*), impaired for chlorophyll *a*. For FW miles, 5.6 miles of Mill Creek in the Livingston Creek (HUC10 0303000503) watershed is impaired for pH (*Figure 9-1*), 3.8 miles of the Cape Fear River mainstem in the lower part of the Hood Creek-Cape Fear River (HUC10 0303000504) watershed is impaired for benthos (*Figure 9-4*), and 5.1 miles of Sturgeons Creek near Leland is impaired due to arsenic and hexavalent chromium Fish Tissue advisories (*Figure 9-4*) (also see *Table 9-2*). SW acre impairments were primarily due to copper (5,568 SW acres), dissolved oxygen (5,026 acres), and shellfish growing areas (2,408.6 SW acres), other impairments also included the arsenic and hexavalent chromium fish tissue advisories (350.6 acres) (*Figure 9-5*; *Table 9-2*)

There was an error identified during the development of the basin plan that found an additional 4,281.8 SW acres that should have been on the 2022 IR due to low pH levels (<6.8) in the Lower Cape Fear River (estuary), between Assessment Unit (AU)# 18-(71)a1, from Cartwheel Branch (upstream of Toomers Creek) to AU# 18-(71)a5, 1.9 miles downstream of Mott Creek (*Table 9-1* and *Table 9-2*). The standard applied was <4.3 instead of <6.8.

Also, see Chapter 2 for more information on the integrated report (IR) or the Chapter 2 Appendix for a full list of individual 2022 IR impairments.

The classified FW miles, FW acres, and SW acres for the Lower Cape Fear subbasin are summarized in *Table 9-3*. This subbasin contains just 10% of the Cape Fear River's classified FW miles (672 FW miles). The Lower Cape Fear also contains just 15% of the FW acres (3,784 FW acres), with close to 50% classified for primary contact recreation, Class B (i.e., swimming, etc). White, Singletary, Jones, and Boiling Springs lakes along with the upper section of Gray's Creek (9.6 FW miles) are all Class B waterbodies. Almost all of the Cape Fear River Basin's classified SW acres (24,236 SW acres) are found in this subbasin, with over a third (36.8%) classified as HQW. Most of the FW, in Columbus and Brunswick counties, are classified as Swamp Waters (Sw). A section of the lower part of Hood Creek-Cape Fear River watershed (HUC10 0303000504), including the mainstem Cape Fear and several tributaries, is classified as WS-IV. Statewide, 35 wetlands were reclassified to Unique Wetlands (UWL) [15 NCAC 02B .0311](#) (o) on November 1, 2007, 10 of these wetland sites are in the Cape Fear River Basin, including seven in the Lower Cape Fear River subbasin.

Figure 9-1: General map of monitoring stations and permitted facilities in the Lower Cape Fear River subbasin.

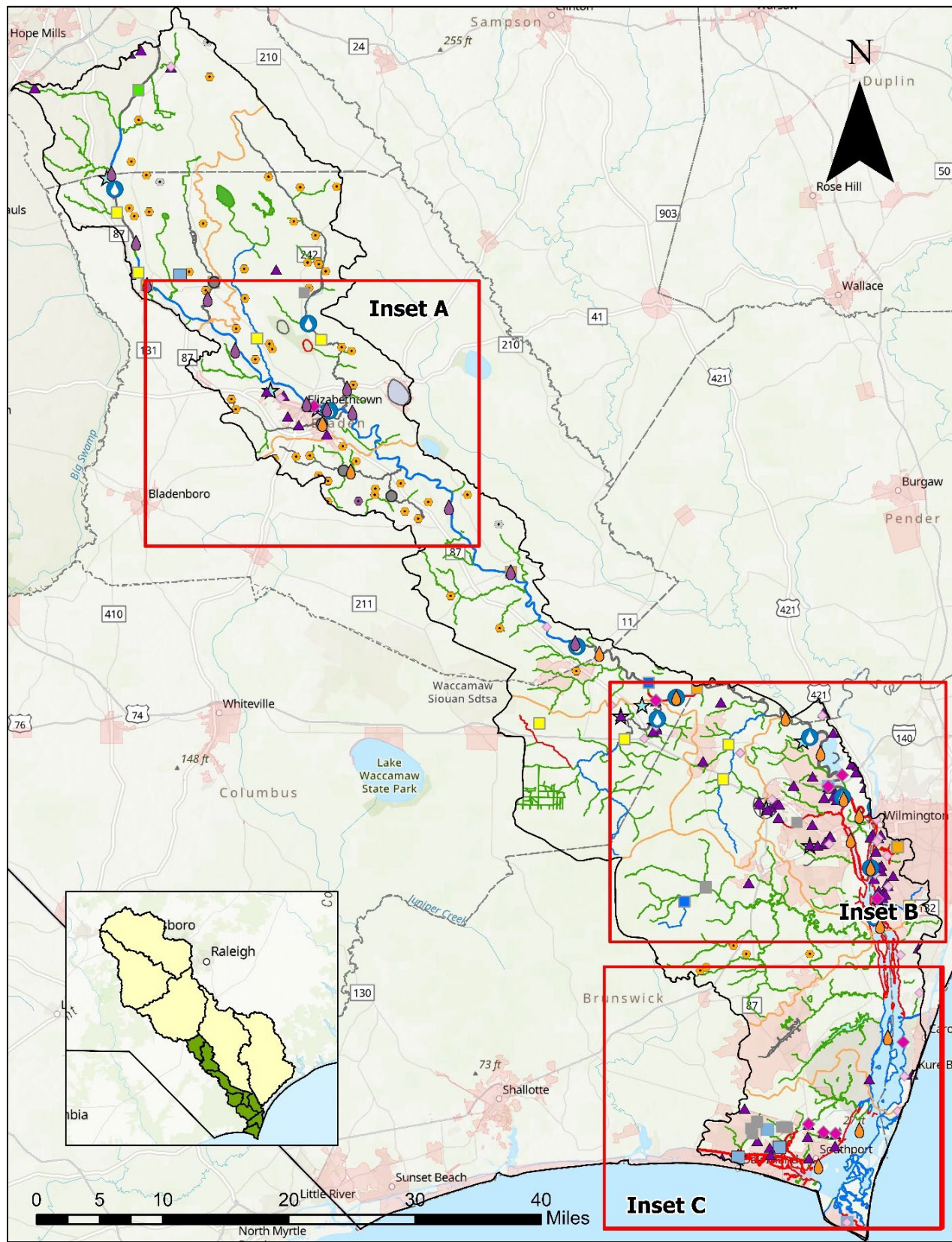


Figure 9-2: Lower Cape Fear Map Legend

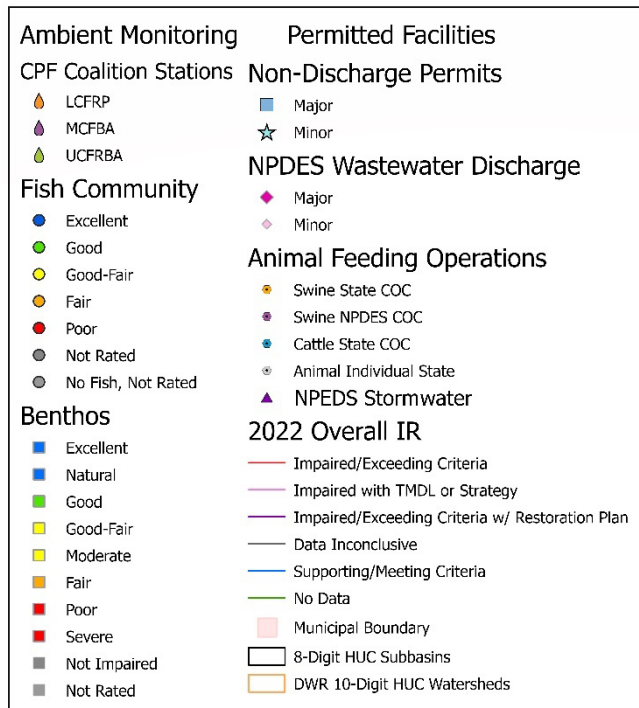


Figure 9-3: General map of monitoring stations and permitted facilities in the Lower Cape Fear River subbasin – Inset A

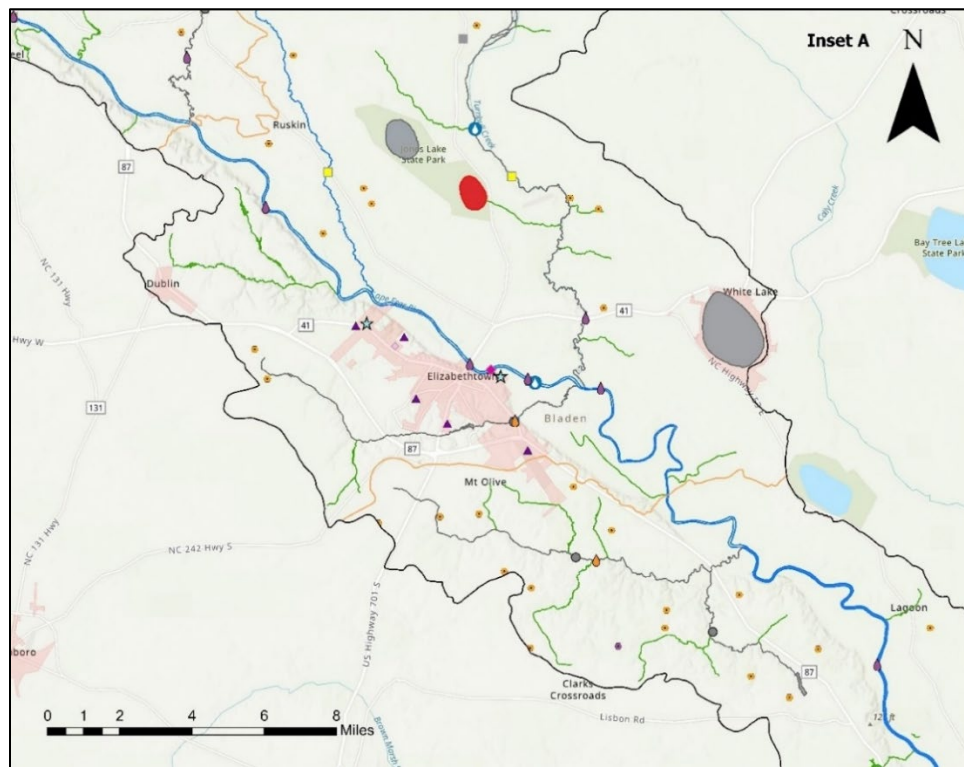


Figure 9-4: General map of monitoring stations and permitted facilities in the Lower Cape Fear River subbasin Insert B

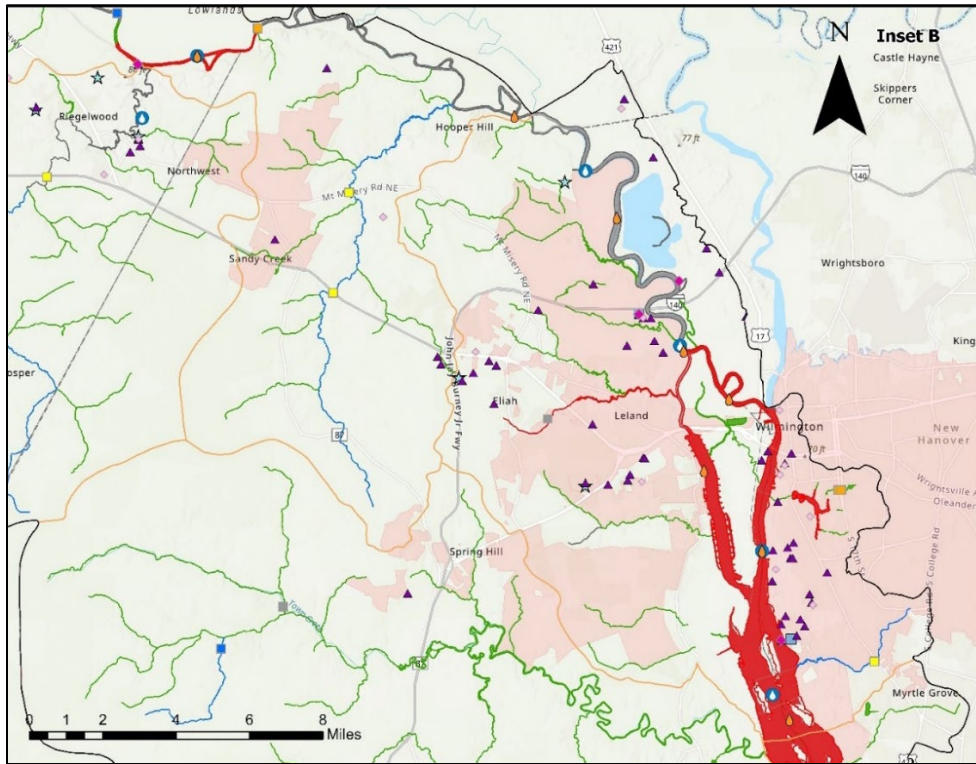


Figure 9-5: General map of monitoring stations and permitted facilities in the Lower Cape Fear River subbasin Insert C

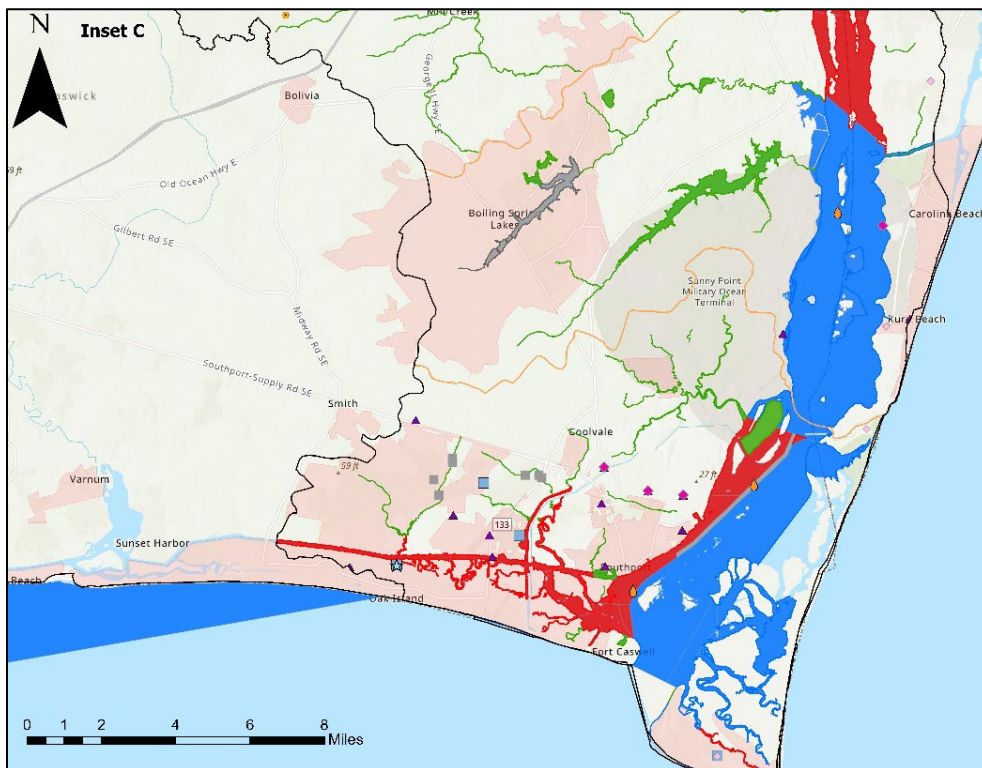


Table 9-1: Lower Cape Fear River Subbasin 2022 Integrated Summary

Assessment Unit <sup>1</sup>	Map Color	FW Miles <sup>2</sup>	FW Acres <sup>2</sup>	SW Acres <sup>2,3</sup>
Total	All Colors Combined	672.0	3,784.0	24,446.3
Total Monitored	Combined Blue, Gray, and Red	243.3	2,000.3	23,860.1
Not Monitored	Green	428.7	1,783.7	586.2
Meeting Criteria (Category 1)	Blue	98.4	0.0	14,316.8
Data Inconclusive (Category 3)	Gray	130.4	1,710.9	0.0
Exceeding Criteria 303(D) (Category 5) <sup>3</sup>	Red	14.5	289.4	9,543.3
% Exceeding of Monitored Exceeding	Red / Total	6.0%	14.5%	38.1%

<sup>1</sup> All waterbodies in North Carolina are impaired for Fish Tissue Mercury and were not included in Category 5 impairments on this table.

<sup>2</sup> FW - Freshwater, SW -Saltwater

<sup>3</sup> Added Brunswick River's (18-77a and 18-77b) 743.7 SW acres not originally captured on the 2022 IR category 5 list or total classified SW acres.

Table 9-2: Lower Cape Fear River Subbasin 2022 Impairments by Parameter (Category 5)

PARAMETER (Category 5) <sup>1,2</sup>	FW Miles <sup>3</sup>	FW Acres <sup>3</sup>	SW Acres <sup>3</sup>
Arsenic (10 µg/l, HH, NC)	0.0	0.0	715.1
Arsenic Fish Tissue Advisory (Advisory, FC, NC)	5.1	0.0	350.6
Benthos (Nar, AL, FW)	3.8	0.0	0.0
Chlorophyll <i>a</i> (40 µg/l, AL, NC)	0.0	75.3	0.0
Copper (3 µg/l, AL, SW)	0.0	0.0	5,567.7
Dissolved Oxygen (5 mg/l, AL, SW)	0.0	0.0	5,025.6
Hexavalent Chromium Fish Tissue Advisory (Advisory, FC, NC)	5.1	0.0	350.6
Nickel (8.3 µg/l, AL, SW)	0.0	0.0	715.1
pH (4.3 su, AL, Sw)	5.6	0.0	0.0
pH (6 su, AL, FW)	0.0	214.1	0.0
pH (6.8 su, AL, SW)	0.0	0.0	743.7
Shellfish Growing Area Status (Fecal, SH, SA)	0.0	0.0	2,408.6

<sup>1</sup> Waterbody Uses: HH – Human Health, AL – Aquatic Life, FC – Fish Consumption, SH - Shellfish Harvesting.

<sup>2</sup> Waterbody Type: FW – Freshwater, SW - Saltwater, Sw - Swamp Waters, SA - Shellfish Area, NC - All North Carolina waters.

<sup>3</sup> Added Brunswick River's (18-77a and 18-77b) 743.7 SW acres not originally captured on the 2022 IR category 5 list or total classified SW acres. 60.6 SW acres added to Arsenic Fish Tissue, 743.7 SW acres added to DO, 60.6 SW acres added to Hexavalent Chromium Fish Tissue, 743.7 SW acres added to pH (6.8).

Table 9-3: Lower Cape Fear River Surface Water Classifications

Classification*	Freshwater Miles	Freshwater Acres	Saltwater Acres
<b>C</b>	<b>671.9</b>	<b>3,783.9</b>	0.0
<b>B</b>	<b>9.6</b>	<b>1,737.4</b>	0.0
WS-IV	118.1	17.2	
WS-V	8.1	0.0	
<b>WS TOTAL</b>	<b>126.2</b>	<b>17.2</b>	
<b>CA</b>	<b>2.8</b>	<b>0.0</b>	0.0
<b>SC</b>	<b>0.0</b>	<b>0.0</b>	<b>24,235.7</b>
<b>SA</b>	<b>0.0</b>	<b>0.0</b>	<b>8,909.9</b>
<b>HQW</b>	<b>0.0</b>	<b>0.0</b>	<b>8,930.4</b>
<b>Sw</b>	<b>365.4</b>	<b>1,255.5</b>	<b>200.7</b>

\*Waterbody Classification C - Aquatic life propagation and secondary recreation, B - Primary contact recreation, SC - Tidal salt waters, SA - Tidal Salt Waters Commercial Shellfish Harvesting or Marketing, WS - Water Supply, CA - Water Supply Watershed Critical Area, NSW - Nutrient Sensitive Waters, HQW - High Quality Waters, ORW - Outstand Resource Waters, Sw - Swamp Waters

Most of the basin’s tidal salt waters (SC) are located in the Lower Cape Fear subbasin (24,236 acres). Primary Nursery Areas (PNA) “means tidal salt waters that provide essential habitat for the early development of commercially important fish and shellfish and are so designated by the Marine Fisheries Commission” [15A NCAC 02B .0202(47)]. The Lower Cape Fear River subbasin contains 14,767.4 acres of PNAs, over 60% of the PNAs in the Cape Fear River Basin. An [interactive map](#) is available online to see where common marine fisheries rules may apply and delineations can be found in [15A NCAC 03R .103](#). In addition, over a third (37%) of these tidal salt waters are classified for commercial shellfish harvesting or marketing (SA; 8,910 acres). See Section 9.5 for more information on Shellfish Growing Areas in the Lower Cape Fear River subbasin.

In 2016, a 15.8-mile segment of the Lower Cape Fear estuary was reclassified to swamp water due to a request to address the persistent low DO and pH impairments. However, in 2021 the US Environmental Protection Agency (EPA) declassified the same 15.8-mile segment as there were several tidal saltwater species found in this area including two that were federally endangered. See Section 9.11 for more details on low DO levels in the estuary and this reclassification/declassification process.

The water quality in the Cape Fear River is impacted by the changing landscape due to the growth in development throughout the basin, changes in the agricultural sector, increasing industrial uses (mega sites) as well as due to climate impacts. Protecting this critical water resource is essential in order to provide good quality drinking water, ensure sufficient supply, protect the aquatic ecosystem and to support economic development.

The mainstem Cape Fear River has a long history of algal blooms first reported in the 2000 basin plan. Severe Harmful Algal Blooms (HABs) occurred between 2009 and 2012 along the Cape Fear River

mainstem from the confluence with the Deep and Haw rivers downstream below Lock and Dam #1 (LD1) near Wilmington. Whalen and Dubbs (2005) reported that the Cape Fear River was nutrient replete, meaning the nitrogen and phosphorus concentrations are in excess and that diluting the concentration by 45% did not result in a reduction in algal growth. Therefore, when environmental conditions are sufficient, which include low flow, warm temperatures and increased clarity, algal blooms will likely develop. At one point in 2009, HABs covered a 75-mile stretch of the Cape Fear River. Press releases by NC DEQ and DHHS caution the public to avoid contact and/or recreating in areas with algal blooms. These blooms are also known to result in water supply taste and odor issues.

Current water quality analysis described throughout the subbasin indicates that the water quality in the Cape Fear River mainstem and many of its tributaries is of concern. The central portion of the Cape Fear River Basin (Jordan Lake and Randleman Lake dams down to LD1) has been recognized as nutrient over-enriched. As such, DWR has a permitting strategy that requires a no net increase in watershed loading for nitrogen and phosphorus while additional processes are underway that will assist DWR in understanding how best to protect the quality of the Cape Fear River for all uses. These actions include the development of watershed models for the central portion of the Cape Fear River Basin and working with the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) to develop potential instream nutrient criteria or a response variable that protects the most sensitive uses of the resource. These actions could lead to the need for future reductions in nutrient loading to this system from all point and nonpoint watershed sources. More information is available in the permitting strategy, Section 3.2.4 of Chapter 3, and the NCDP (2.14) and chlorophyll *a* (2.5.8 and 2.7) sections of Chapter 2.

## 1.2 Population and Land Use

Based on the 2020 Census data (*Table 9-4*), the population in the Lower Cape Fear River subbasin is estimated at 165,663 people, having grown by over 25% and more than 26,000 during the last 10-year census period. The Brunswick River–Cape Fear watershed, where Leland and parts of Wilmington are located, is the most densely populated watershed with the most population increase, over 14,000, during the last census period. The 2020 census tallied the total pollution of Wilmington at 115,500 and Leland at 23,000. The two coastal watersheds, Lilliput-Creek-Cape Fear (HUC10 0303000207) where Boiling Spring Lakes, Kure Beach, and parts of Carolina Beach are located, and the Walden Creek-Cape Fear River (HUC10 030300508), where Oak Island, Southport, Coolvale and St. James are located, are also densely populated watersheds with the fast growth (*Table 9-4*). The Walden Creek-Cape Fear River watershed had the most rapid-paced population growth, 41%, with development expanding around St. James, Southport, and Coolvale in Brunswick County. Statewide, growth in Brunswick County was a close second to Johnston County at 27% during the last census period (University of North Carolina n.d.) and listed as the fastest growing county in the state between 2021 and 2022, according to Census Bureau estimates, with a growth rate of 5.7%.

Table 9-4: Estimated population of the watershed boundary scale (HUC 10)

HUC10 Watershed Name	HUC10	Land Area (mi <sup>2</sup> )	Population 2010	Population 2020	Population Density 2020 (pop/mi <sup>2</sup> )	2010 - 2020 Pop. Change
Harrison Creek-Cape Fear River	0303000501	163	13,760	15,308	94	+1,548
Turnbull Creek-Cape Fear River	0303000502	193	10,841	9,315	48	-1,526
Livingston Creek	0303000503	101	3,886	3,441	34	-445
Hood Creek-Cape Fear River	0303000504	215	8,567	10,341	48	+1,774
Brunswick River-Cape Fear River	0303000505	95	51,255	65,509	690	+14,254
Town Creek	0303000506	126	6,786	7,054	56	+268
Lilliput Creek-Cape Fear River	0303000507	89	30,002	34,747	390	+4,745
Walden Creek- Cape Fear River	0303000508	79	14,176	19,948	253	+5,772
<b>Total</b>	<b>03030005</b>	<b>1,061.5</b>	<b>139,273</b>	<b>165,663</b>	<b>156</b>	<b>+26,390</b>

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.

The National Land Cover Dataset (NLCD) analyzed for the Lower Cape Fear River subbasin showed land cover is 10.2% agriculture, 10% developed, 28.7% forested, 10% grassland/shrub, 5.4% open water, and 35.3% wetlands in 2019 (Table 9-5). This land cover provides a perspective from which to view the water quality in this subbasin. Developed lands, agricultural lands, forest lands, and grass/shrub-covered lands all engage with the environment to influence the water quality. Figure 9-6 displays the spatial distribution of land cover as of 2019 in the Lower Cape Fear River subbasin. Development patterns mirror population patterns with the most developed areas in the lower part of the subbasin near Wilmington and closer to the coast. Between 2001 and 2019 development increased by 16.8 mi<sup>2</sup> while 15.7 mi<sup>2</sup> of forested land was lost (Table 9-5). Wetlands are predominant throughout the subbasin with freshwater riverine wetlands occurring along the Cape Fear River mainstem and its tributaries and coastal marshes occurring in estuarine areas in the lowest part of the subbasin. Many Carolina bays are found in the upper portion of the subbasin to the east of the Cape Fear River mainstem, particularly in Bladen County. In the lower part of the subbasin, to the west of the Cape Fear River in the upper parts of the watersheds, the interstream divide, there are several large sections of wetland that have been converted to managed pine plantations through ditching and raised beds. Pocosin wetlands have also formed in these interstream divide areas, primarily in Brunswick County near Boiling Springs Lake (Table 9-6; Figure 9-6). A comparison of 2019 land cover at the HUC10 watershed scale is shown in Table 9-6. Development patterns follow population

patterns with the Brunswick River-Cape Fear River being the most developed watershed (30.2%) followed by the Cape Fear River (19.5%) and Lilliput Creek-Cape Fear River (18%) watersheds (*Table 9-6*).

*Table 9-5: Land cover of the Lower Cape Fear River subbasin*

Land Cover <sup>1</sup>	2001	2011	2019	% Change 2001-2019	mi <sup>2</sup> Change 2001-2019	Total mi <sup>2</sup> 2019
<b>Agriculture</b>	10.27%	10.09%	10.18%	<b>-0.87%</b>	<b>-0.95</b>	<b>108.10</b>
<b>Barren Land<sup>2</sup></b>	0.40%	0.41%	0.38%	<b>-3.49%</b>	<b>-0.15</b>	<b>4.06</b>
<b>Developed</b>	8.40%	9.37%	9.99%	<b>18.88%</b>	<b>16.84</b>	<b>106.04</b>
<b>Forest</b>	30.21%	30.14%	28.73%	<b>-4.90%</b>	<b>-15.71</b>	<b>304.97</b>
<b>Grassland/Shrub</b>	9.87%	9.18%	9.97%	<b>1.01%</b>	<b>1.06</b>	<b>105.78</b>
<b>Open Water</b>	5.45%	5.56%	5.40%	<b>-0.79%</b>	<b>-0.46</b>	<b>57.36</b>
<b>Wetlands</b>	35.40%	35.24%	35.34%	<b>-0.17%</b>	<b>-0.62</b>	<b>375.17</b>
<b>Total mi<sup>2</sup></b>						<b>1,061.47</b>

<sup>1</sup>Data was downloaded from the Multi-Resolution Land Characteristics NLCD website and processed for each Cape Fear River Basin HUC8s in 2022.

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

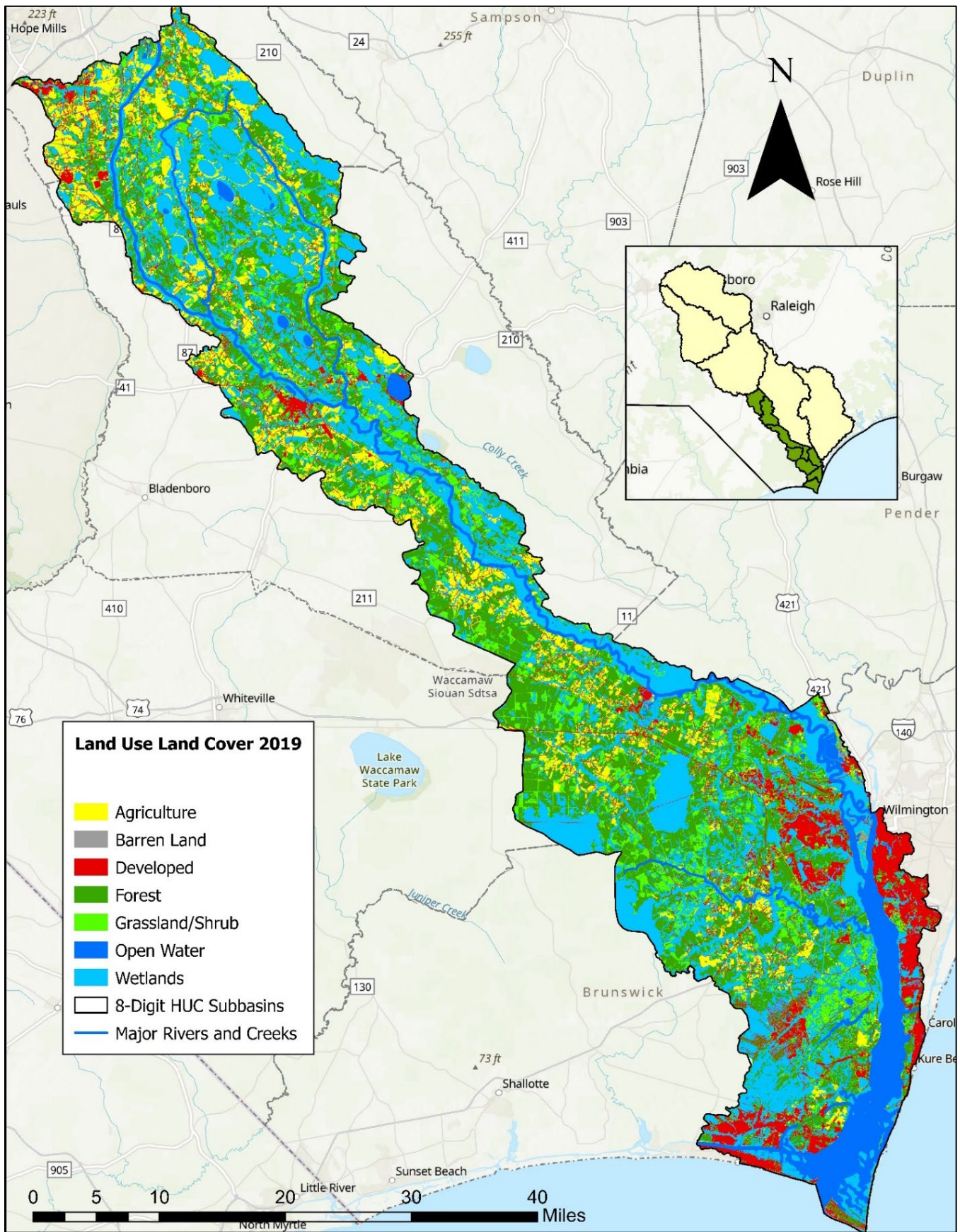
*Table 9-6: Land Cover in the HUC10 Watersheds of the Lower Cape Fear River Subbasin*

Watershed	Land Area (mi <sup>2</sup> )	Agriculture	Barren Land	Developed	Forest	Grassland Shrub	Open Water	Wetlands
Harrison Creek-Cape Fear River	163	22.7%	0.0%	7.7%	25.4%	7.8%	1.2%	35.2%
Turnbull Creek-Cape Fear River	193	11.3%	0.0%	5.9%	28.5%	9.3%	2.7%	42.3%
Livingston Creek	101	9.5%	0.1%	4.8%	42.2%	11.9%	0.3%	31.2%
Hood Creek-Cape Fear River	215	12.5%	0.1%	5.0%	35.4%	12.5%	1.4%	33.2%
Brunswick River-Cape Fear River	95	1.3%	1.3%	30.2%	18.0%	7.2%	9.7%	32.2%
Town Creek	126	6.8%	0.1%	5.2%	37.3%	13.5%	0.5%	36.7%
Lilliput Creek-Cape Fear River	89	1.4%	0.5%	18.0%	16.9%	11.0%	20.4%	31.7%
Cape Fear River	79	2.2%	2.3%	19.5%	13.5%	2.9%	23.9%	35.8%

<sup>1</sup>Data was downloaded from the Multi-Resolution Land Characteristics NLCD website and processed for each Cape Fear River Basin HUC8s in 2022.

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

Figure 9-6: Land cover in the Lower Cape Fear River Subbasin



The US Department of Agriculture (USDA) 2022 [Census of Agriculture](#) data indicate there are poultry operations in the Lower Cape Fear River subbasin counties in addition to permitted animal operations (AFOS) described in the next section. Since these facilities are “deemed permitted”, DWR has minimal information on the location of poultry operations and the locations where their manure is transported and applied. Only Bladen County was chosen for the Census data evaluation of poultry operations within the Lower Cape Fear River subbasin as just this county has >50% land area within the subbasin boundary (*Table 9-7*). Between the 2007 and 2022 census years, Bladen County increased notably by close to 21% from 3 to 3.6 million for poultry inventory and 70% from 14.7 to 24.9 million for production contracts (*Table 9-7*). Chapter 1 and the Chapter 1 Appendix have more information on the USDA Census data. At the basin level, USDA data was also evaluated for Brunswick County (Chapter 1), which has very few poultry operations and was not included in the Lower Cape Fear River evaluation. The total number of chickens reported as inventory for Brunswick County in 2022 was 2,637, approximately 0.004% of the 2022 chicken inventory population reported for all counties in the Cape Fear River Basin (76 million) (Chapter 1, appendix table 1).

*Table 9-7: USDA Census data for Chicken/Poultry in Lower Cape Fear River Subbasin Counties*

USDA Data	Bladen
<b>2007</b>	
Inventory <sup>1</sup>	2,980,133
Contract <sup>2</sup>	14,686,500
<b>2012</b>	
Inventory <sup>1</sup>	1,583,952
Contract <sup>2</sup>	11,061,500
<b>2017</b>	
Inventory <sup>1</sup>	3,715,557
Contract <sup>2</sup>	21,605,729
<b>2022</b>	
Inventory <sup>1</sup>	3,610,003
Contract <sup>2</sup>	24,926,534

<sup>1</sup>USDA Inventory numbers represent a point in time (End of December) when the census data was collected for chickens only.

<sup>2</sup>USDA Production Contract numbers are “totals for the portion of agriculture production raised and delivered under production contract” (USDA, 2017) for chickens only. Production Contract and Inventory are not additive. They each represent different data items.

<sup>3</sup>Counties included in this table had >50% land area within the Lower Cape Fear River Subbasin.

### 1.3 Permits

As of May 2022, there were 38 NPDES wastewater, 18 non-discharge and land application, 76 NPDES stormwater, 1,516 state stormwater, and 59 animal feeding operation (AFO) permits issued in the Lower Cape Fear River subbasin (*Table 9-8*).

*Figure 9-7* shows the location of the permitted facilities in the Lower Cape Fear River subbasin. More information about the permitting programs can be found in Chapter 3, including a map of state stormwater facilities. A complete list of permits is also available in the Chapter 3 Appendix.

The Lower Cape Fear River subbasin accounts for close to 20% of the total permitted as-built discharge (425.47 MGD) in the Cape Fear River Basin. There are 12 major NPDES permits for municipal and industrial wastewater treatment plants (WWTPs) and 26 minor NPDES wastewater permits in the subbasin with a total permitted as-built flow of 78.8 MGD (*Table 9-8*). Facilities designated as major are permitted to discharge more than one million gallons per day (1 MGD). Ten major permits are for discharge directly to the Cape Fear River, including the Riegelwood Mill and the Chemours Company-Fayetteville Works industrial facilities. The Riegelwood Mill (NC0003298), run by International Paper, has the second highest permitted as-built flow in the entire basin, 50 MGD. The Chemours Company-Fayetteville Works, formerly owned by Dupont, has three NPDES discharge permits, NC0089915 with a permitted as-built discharge of 1.58 MGD of treated groundwater, stormwater and surface water, NC009042 with a permitted as-built discharge of 2.38 MGD of treated groundwater, stormwater and surface water from seeps and extractions wells and NC0003573 for processed wastewater discharged from Chemours tenants, Dupont and Kuraray. Since 2017, Chemours has not been permitted to discharge process wastewater from its facility. More information about the Chemours facility can be found in Section 9.9.1.1. Three of the NPDES major permits in the Lower Cape Fear are held by power plants that pass water through and have no permitted flow requirement; these include the Sutton Steam Electric Plant (NC0001422) and Brunswick Steam Electric Plant (NC0007064) owned by Duke Energy Progress and the Southport Power Plant (NC0065099) owned by CPI USA North Carolina LLC. The Sutton Steam Electric Plant discharges water to the Cape Fear River and Catfish Creek and the other two facilities discharge water to the Atlantic Ocean.

The Lower Cape Fear River subbasin also accounts for close to 10% of the total permitted field acreage (21,771 acres) for non-discharge and residual land application permits in the basin. Permitted fields are primarily used for land application of residual solids (see Chapter 3 and its Appendix).

There are 59 AFOs permitted in the Lower Cape Fear River subbasin, far fewer than the Black River or Northeast Cape Fear River subbasins to the east. Permitted AFOs include one Swine NPDES Certificate of Coverage (COC), 54 swine state COCs, and four individual state permits. The state COCs and individual permits are all non-discharge. Overall basin maps and summary tables are available in Chapter 1, section 1.5.1, Chapter 1 appendix and Chapter 3, section 3.6.

Some of the NPDES stormwater facilities and many state stormwater facilities are concentrated near Wilmington and the coast in the lower part of the subbasin (see Chapter 3). Seven of the Cape Fear River Basin's 32 NPDES MS4 (Municipal Separate Stormwater Sewer Systems) stormwater permits are located in this subbasin. NPDES MS4 permits are required for every owner/operator of facilities in areas that the US Census Bureau has designated as Urbanized Areas (see Chapter 3). MS4 stormwater permits are held by Carolina Beach, Hope Mills, Kure Beach, Leland, Navassa, Oak Island, and Wilmington.

Table 9-8: Total Number of Permits Found in the Lower Cape Fear River Subbasin

Number of Permits <sup>1</sup>		Permit Information <sup>1</sup>	
<b>NPDES Wastewater Discharge<sup>2</sup></b>			
<b>Major<sup>3</sup></b>	<b>Minor</b>	<b>Permitted As-Built (MGD)</b>	
12	26	78.8	
<b>Non-Discharge and Land Application<sup>4</sup></b>			
<b>Major</b>	<b>Minor</b>	<b>Field Number</b>	<b>Field Acres</b>
8	10	145	2,081.2
<b>Stormwater</b>			
<b>State</b>	<b>NPDES</b>	<b>NPDES Outfalls</b>	
1,516	76	133	
<b>Animal Feeding Operations</b>			
<b>Number of Permits</b>		<b>Allowable Headcount</b>	<b>Allowable Weight (Lb.)</b>
59		292,652	46,710,606

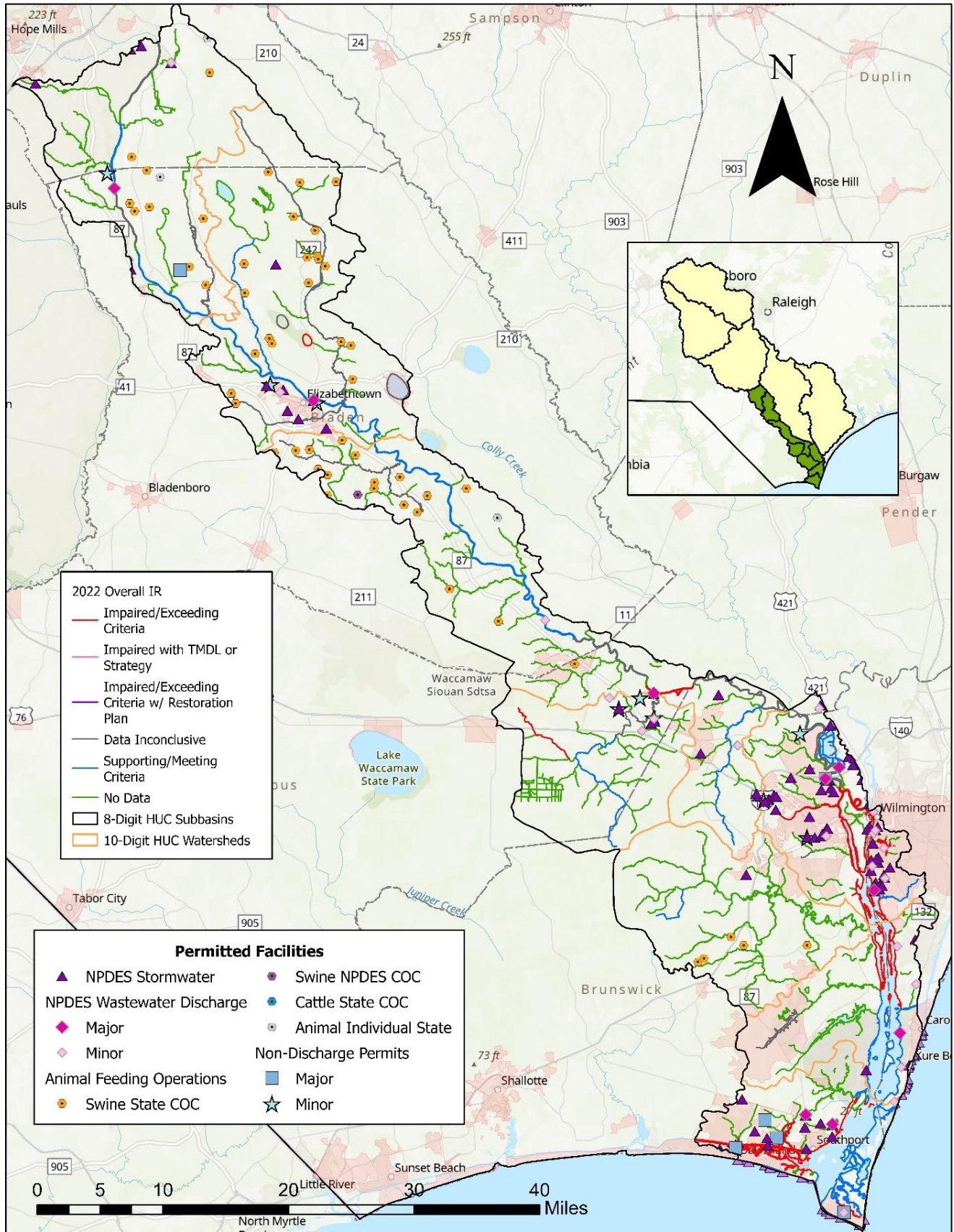
<sup>1</sup>Active and expired permitted facilities and associated permit data were queried by the DWR Basinwide Information Management System (BIMS) in May 2022. All permits are associated with active facilities.

<sup>2</sup> Permitted NPDES Discharge facility numbers are based on the number of facilities and as-built totals that discharge to the Cape Fear River Basin except NC0078344 (Tar Heel Plant) and NCG590020 (Bladen Bluffs Regional Surface WTP). These facilities discharge to the Lower Cape Fear subbasin but have facilities located in the Lumber River Basin. Both facilities were counted in the Lower Cape Fear River subbasin.

<sup>3</sup>Three of the major facilities are power plants that pass through water and have no permitted as-built requirements. The Chemours Fayetteville Works facility has two NPDES permits, one for Chemours (NC0089915) and one for tenants (NC0003573). Chemours added a third NPDES permit (NC0090042; September 2022) after the BIMS for the basin plan. These numbers are not included in the table values.

<sup>4</sup>Some permitted fields are associated with facilities located outside of the Cape Fear River Basin.

Figure 9-7: NPDES Wastewater, NPDES Non-Discharge, NPDES Stormwater, and Animal Operations Permits in the Lower Cape Fear River subbasin.



The United State Geological Survey (USGS), with financial support from an EPA 319 grant, conducted a study and published a report in 2015 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 animal feeding operations or streams receiving primarily inorganic fertilizers inputs (Harden, 2015). This study provided 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 [here](#). This study identified waterways with “measurable concentrated animal feeding operations manure effects” (Harden, 2015). As this chapter focuses on the Lower Cape Fear River subbasin, we will briefly highlight the waterways that were identified in this subbasin by stream name and stream index, and associated site number used in the USGS report in *Table 9-9*.

*Table 9-9: USGS stations with measurable concentrated animal feeding operations manure effects.*

Stream name	Stream Index	USGS Site Name	Watershed
Davis Creek	18-50-5-2	SP-06	Hood Creek-Cape Fear River
Hammonds Creek	18-50	SP-07	Hood Creek-Cape Fear River

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

Their 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 percent) had results similar to background (non-animal agricultural) conditions, and 21 of the sites (58 percent) 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). It is also important to note that the background conditions in this study do not represent pristine reference conditions but represent non-animal agricultural watershed conditions. Animal waste could have been applied to these areas which made distinguishing between these watersheds challenging.

“Five of the SW and SP sites (14 percent) 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).

Another study conducted by 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. Brown et al. (2020) is available online [here](#).

## 1.4 Biological Health

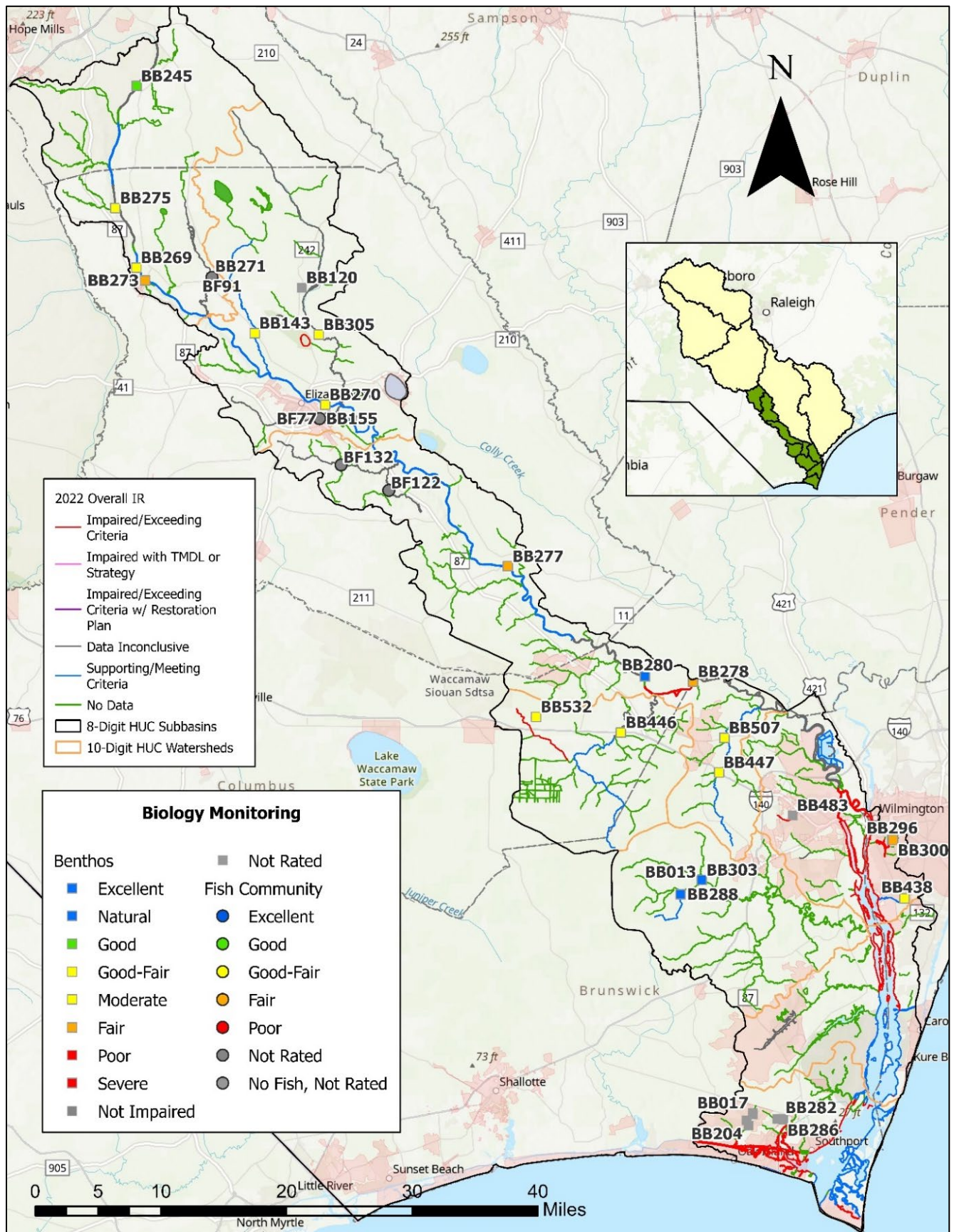
Biological communities are highly sensitive to changes in both water quality and water quantity and can reflect both long- and short-term environmental conditions. Benthos and fish community survey information are collected on species richness (i.e., diversity), abundance, and composition, as well as 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 Lower Cape Fear River subbasin, four assessment methodologies were used: Swamp (primarily), EPT, Full Scale, and Qual 4. Fish community IBIs have not been developed for the Coastal Plain ecoregion where most of the Lower Cape Fear subbasin is located although four non-rated fish community assessments were conducted in the upper half of the subbasin in 2008. 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’s update. The results of the previous monitoring cycle, completed in 2003, were evaluated as a point of comparison.

### 1.4.1 Benthic Macroinvertebrates

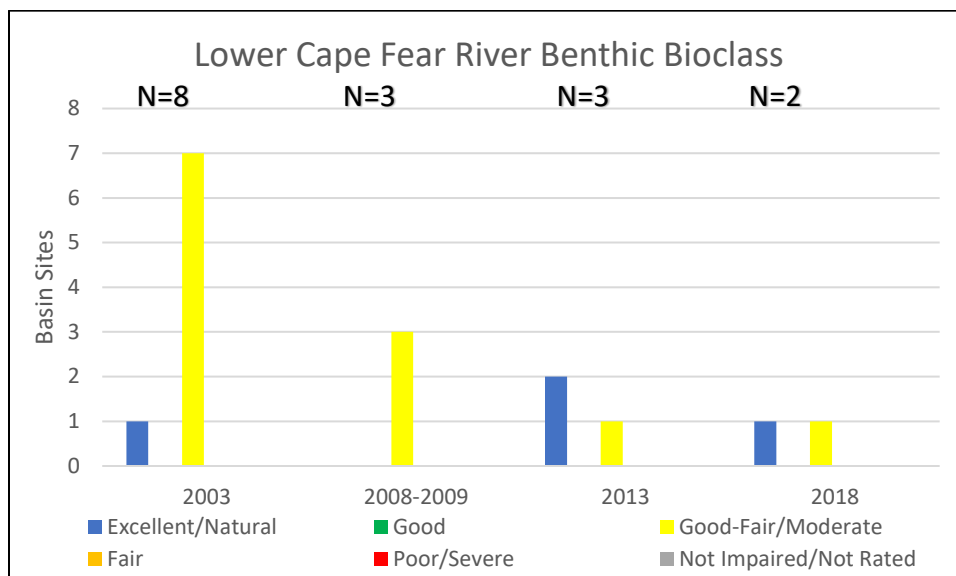
Map [Figure 9-8](#) displays all of the Lower Cape Fear River’s current benthic site ratings. A total of 10 benthic stations, including nine basin sites and one special study, have been sampled for benthos in the Lower Cape Fear River subbasin between 2003 and 2018, over 17 sampling events. Most sample types used the Swamp methodology with all results being Natural or Moderate. EPT and Full Scale were used on several stations with Good-Fair results. One special study station, sampled in 2008 used the Qual 4 method and was not rated.

Figure 9-8: Biological community monitoring stations for benthos and fish in the Lower Cape Fear River subbasin



The Lower Cape Fear River benthos monitoring results for the four-cycle years are displayed in *Figure 9-9*. Basin site monitoring results for 2009 were also combined with 2008 as some stations were sampled (or resampled) in 2009 due to drought in 2008. Eight stations were monitored in the Lower Cape Fear River Basin in 2003 and just two stations in 2018 due to reduced resources. All benthos station results from 2002 to 2021 are available in Chapter 2 Appendix.

*Figure 9-9: 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 in *Figure 9-8*.

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.

## 1.5 Shellfish Growing Areas

The [Shellfish Sanitation and Recreational Water Quality Section](#) of DEQ's [Division of Marine Fisheries \(DMF\)](#) is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting for human consumption. Shellfish growing areas (SGAs) 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. The Shellfish Sanitation Section maintains a [map](#) that shows which shellfish growing areas are currently open or closed. Lower Cape Fear River subbasin SGAs and their Harvest Area (HA) classification and open/closed status are shown in [Table](#)

9-10, [Figure 9-11](#), and [Figure 9-12](#). As of 2022, the Lower Cape Fear subbasin has seven Shellfish Growing Areas (SGA) with one that is entirely open, [B3](#), The Basin, located in the Fort Fisher State Recreation Area; two that are partially open, [B2](#), on Baldhead Island, and [B4](#) which includes the Cape Fear River and its tributaries south of Snow Cut; and four that are entirely closed, [A3](#), [B1](#), [B5](#), and B10 ([Table 9-10](#)). The SGAs are primarily located in the Lower Cape Fear subbasin; however, the upper portion of the B10 SGA covers some areas in the Black (HUC8 03030006) and Northeast Cape Fear (HUC8 03030007) subbasins. [Table 9-10](#) also provides information on the SGA size and a link to the most current Sanitary Report. Most of the [A3](#) SGA is located in the Lumber River basin and most of the [B5](#) SGA is located in the White Oak River basin ([Table 9-10](#) also see [Shellfish Sanitation Map](#)).

The Shellfish Sanitation Section completes a Sanitary Survey for each shellfish growing area every three years that includes a shoreline survey of all existing or potential pollution sources, a hydrographic and meteorological survey, and a bacteriological survey of the shellfish growing waters. Shoreline surveys assess the impacts of potential pollution sources like marinas, multi-slip docks, agricultural areas, subdivisions, septic tanks, wastewater treatment plants, or ditching on surrounding water quality. The hydrographic and meteorological survey is used to evaluate the factors that may affect the distribution of pollutants within a growing area, such as prevailing winds, tidal amplitude and type, water circulation patterns, and the amount of freshwater. Rainfall patterns and intensity can also affect the distribution of pollutants by increasing the volume and duration of pollutant delivery and flooding.

For water quality assessment purposes, shellfish growing areas that are Conditionally Approved (open or closed), Restricted, or Prohibited are considered impaired and not meeting their designated use. To target resources and the development of watershed action plans, conditionally approved (open) shellfish growing areas and the waterbodies associated with each are included in this subbasin chapter. For a complete list of water quality assessments for shellfish growing areas, refer to the Integrated Reports.

All the sanitary surveys conducted in the subbasin reported that the county health departments were notified before the surveys were conducted. Each county health department agreed to provide corrective action and follow-up for any malfunctioning septic systems or illegal on-site wastewater discharges discovered during the survey. Copies of the sanitary survey are available in the [NC Digital Collections Library](#). Current, or more recent, surveys are available upon request from DMF.

The Sanitary Survey Reports indicated that stormwater, marinas, subdivisions, golf courses, on-site wastewater, subdivisions, and domestic animals and wildlife are all potential nonpoint pollution sources for the SGAs in the Lower Cape Fear River subbasin (NC DMF, 2020-a, 2020-b, and 2020-c). The 4,092-acre B1 SGA is located within the Beaverdam Creek, Dutchman Creek, and Elizabeth River portions of the Intracoastal Waterway near Southport. Specific facilities identified as potential nonpoint pollution sources included the Southeast Brunswick Sanitary District (WQ0013200), which sprays treated effluent on golf courses at the St. James Plantation and has an average flow of 260,000 GPD; the Oak Island Fish Factory Road Wastewater Reclamation Facility (WQ0005790) with an average summertime flow of 250,000 GPD, that discharges reclaimed water to an infiltration pond and spray fields; the Oak Island Satellite Wastewater Reclamation Facility (WQ0031857) used to irrigate golf courses; and the Archer Daniels Midland Plant (NC0027065), located in B4, which has redirected domestic waste to the Town of Southport. Historically, a small package wastewater treatment plant provided some treatment to the domestic

sewage generated from the Archer Daniels Midland facility before combining the effluent with the industrial process wastewater flow for discharge into the river. After the package plant was decommissioned in 2016, the domestic sewage was sent to the Brunswick County sewage collection system in Southport. The Archer Daniels Midland facility also made other adjustments to its industrial wastewater treatment processes to reduce bacterial concentrations. However, despite these efforts, the overall industrial waste stream that discharges directly to the Cape Fear River continues to have frequent high bacteria counts in recent years (NC DMF, 2020-a).

The B2 and B3 SGAs were combined into one Sanitary Survey Report which described the 7,758-acre combined SGAs as having several creeks, bays, and sloughs between Bald Head Island and Federal Point in Brunswick and New Hanover Counties near the Cape Fear River inlet. One specific facility was identified as a potential nonpoint pollution source in B2 and B3, the Baldhead Island Non-Discharge treatment plant (WQ0000193). The flow from this facility ranges from less than 50,000 GPD during the winter to greater than 350,000 GPD during the summer. Reclaimed water from this facility is discharged to two infiltration ponds and the Baldhead Island golf course. Stormwater issues of note include a ditch that drains from the golf course to Baldhead Creek in B2. Although typically dry, this ditch has been used for emergency stormwater drainage in recent years which has caused the temporary closures of harvests within the Baldhead Creek harvest area (NC DMF, 2020-b).

The 15,527-acre B4 SGA is the largest in the basin and includes drainage from portions of Carolina Beach, Kure Beach, and the eastern side of Southport. The pollution source assessment conducted for B4 did include an inventory of some potential sources higher up in the watershed where B10 is located. However, a source assessment was not conducted for B10 as the entire SGA is prohibited (pers. comm. Andrew Haines, July 21, 2022). The Duke Energy Nuclear plant, Sunny Point Military Ocean Terminal, and Archer Daniels Midland manufacturing facility are located in the watershed that drains to B4. Five NPDES WWTPs that discharge treated effluent to the Cape Fear River either directly in B4 or upriver in B10 were evaluated for the Sanitary Survey Report. These facilities include: The Beau River Plantation Package (NC0065480), located in B10 off River Road with an average daily flow of 100,000 GPD and 200,000 GPD as-built, the Cape package WWTP (NC0057703) with an average daily flow of 140,000 GPD and 260,000 GPD as-built, the Carolina Beach WWTP (NC0023256) with an average daily flow of 1.2 MGD and 3 MGD as-built, the Kure Beach WWTP (NC0025763) with 285,000 GPD as-built, and the Archer Daniels Midland manufacturing facility (NC0027065) with a 3.51 MGD as-built. Two other large facilities, owned by the Cape Fear Public Utility Authority, located further away in B10, were also evaluated due to their size. The Wilmington Southside WWTP (NC0023973), approximately 15 miles from B4 with an average daily flow of 9 MGD and a 12 MGD as-built, and the Northside Plant (NC0023965) in Wilmington adjacent to Smith Creek, with an average daily flow of 8.3 MGD and 16 MGD as-built. Both facilities discharge directly to the Cape Fear River (NC DMF, 2020-c).

A discussion of specific facilities affecting pollution sources in the A3 and B5 SGAs is not included since they are primarily located in the adjacent river basins. For A3, only approximately 165 acres of the 4,429-acre SGA, on the eastern portion of Intercoastal Waterway near Long Beach on Oak Island is located within the Cape Fear River Basin. Only approximately 115 of the 3,053-acres of SGA B5 is located within the Cape Fear River Basin along Snow Cut Creek to the west of the Lake Park Boulevard bridge and the lower section of Telfairs Creek tributary.

In 2010, a No Discharge Zone (NDZ) was approved for the Cape Fear Estuary to protect shellfish, PNAs, and recreational use of the water. An NDZ designation prohibits discharging of sewage from marine sanitation devices into coastal waters. In the Cape Fear River Estuary, this applies to all commercial and pleasure vessels operating in the waterways of New Hanover, Brunswick, and Pender counties (*Figure 9-10*). Boaters must secure Type I, Type II, and Type III marine sanitation devices when operating in a NDZ and must use a sewage pump-out facility to empty their waste. This does not apply to gray water from showers or sinks and does not prohibit the use of porta-potties. For additional information please go to the [NDZ webpage](#). New Hanover County has a brochure on their program available [here](#).



*Figure 9-10: No Discharge Zones for Brunswick, New Hanover, and Pender counties North Carolina*

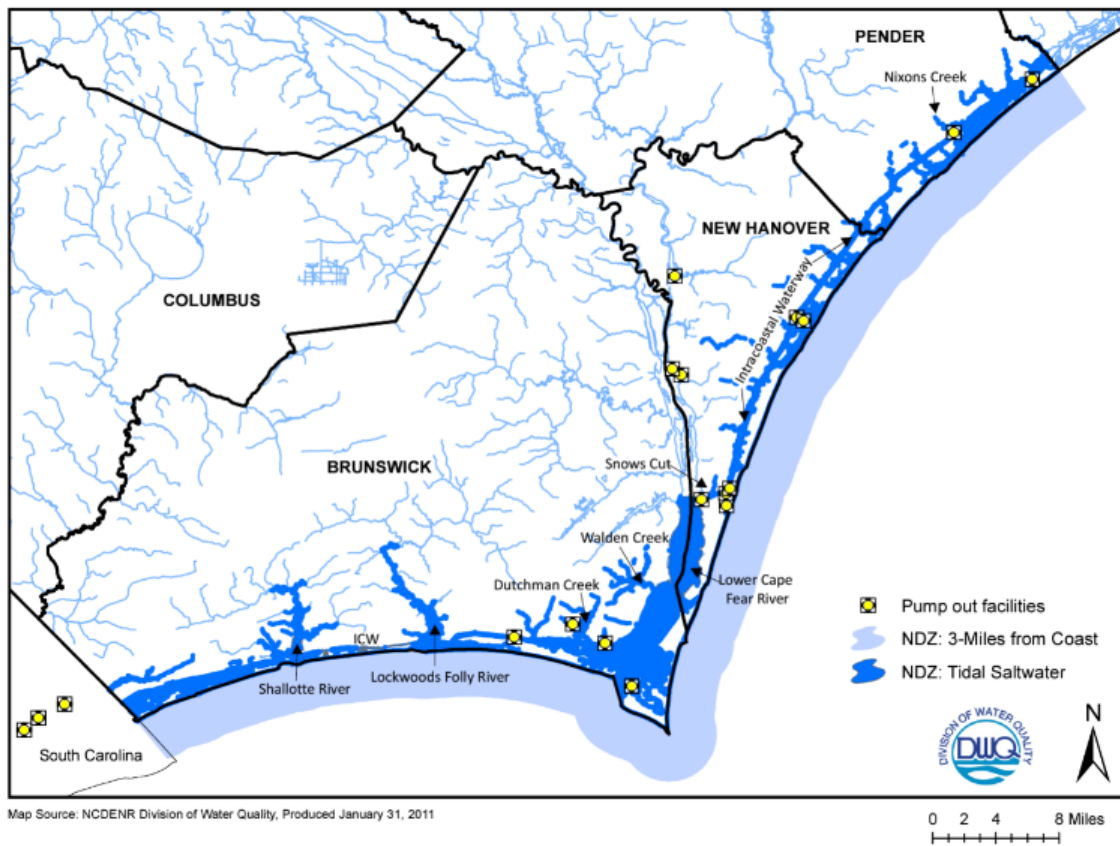


Table 9-10: Lower Cape Fear Subbasin Shellfish Growing Areas

Grow Area	Harvest Area Name	Harvest Area Classification	Harvest Area Status	Water Acres	Sanitary Report Link <sup>4</sup>	Dates
<a href="#">A3</a>	Intracoastal Waterway <sup>1</sup>	CSHA - Prohibited	Closed	4,429	<a href="#">Sanitary Survey Report, A-3</a>	Jan 2017 to May 2022
<a href="#">B1</a>	Southport/Elizabeth River/IWW	CSHA - Prohibited	Closed	4,092	<a href="#">Sanitary Survey Report, B-1</a>	May 2015 to July 2020
<a href="#">B2</a>	Baldhead Creek	Conditionally Approved - Closed	Closed	7,758	<a href="#">Sanitary Survey Report, B2 &amp; B3</a>	June 2015 to Sept 2020
<a href="#">B2</a>	Baldhead Island	Approved	Open		<a href="#">Sanitary Survey Report, B2 &amp; B3</a>	June 2015 to Sept 2020
<a href="#">B2</a>	Bald Head Island Marina	CSHA - Prohibited	Closed		<a href="#">Sanitary Survey Report, B2 &amp; B3</a>	June 2015 to Sept 2020
<a href="#">B3</a>	The Basin	Approved	Open		<a href="#">Sanitary Survey Report, B2 &amp; B3</a>	June 2015 to Sept 2020
<a href="#">B3</a>	Wildlife Boat Ramp	CSHA - Prohibited	Closed		<a href="#">Sanitary Survey Report, B2 &amp; B3</a>	July 2015 to Oct 2020
<a href="#">B4</a>	Cape Fear River	Approved	Open	15,527	<a href="#">Sanitary Survey Report, B-4</a>	July 2015 to Oct 2020
<a href="#">B4</a>	Cape Fear River	CSHA - Prohibited	Closed		<a href="#">Sanitary Survey Report, B-4</a>	July 2015 to Oct 2020

Grow Area	Harvest Area Name	Harvest Area Classification	Harvest Area Status	Water Acres	Sanitary Report Link <sup>4</sup>	Dates
<a href="#">B5</a>	Carolina Beach Harbor and Snow Cut <sup>2</sup>	CSHA - Prohibited	Closed	3,053	<a href="#">Sanitary Survey Report, B-5</a>	Jan 2015 to Nov 2019
B10	Cape Fear River <sup>3</sup>	CSHA - Prohibited	Closed		None were found in the library	N/A

<sup>1</sup>The Intracoastal Waterway SGA (A3) is primarily located in the Lumber River Basin, approximately 175 of the easter Intercoastal Waterway is in the Cape Fear River Basin

<sup>2</sup>The Carolina Beach Harbor and Snow Cut SGA (B5) is primarily located in the White Oak River Basin, approximately 115 acres of Snow Cut Creek and Telfairs Creek is located in the Cape Fear River Basin

<sup>3</sup>The Cape Fear SGA (B10) is partially located in the Black River (HUC8 03030006) and Northeast Cape Fear (HUC8 03030007) subbasins.

<sup>4</sup>Shellfish Sanitary Reports are from NC Digital Collections Library.

Figure 9-11: Shellfish Growing Areas (SGAs) in the Lower Cape Fear River Subbasin

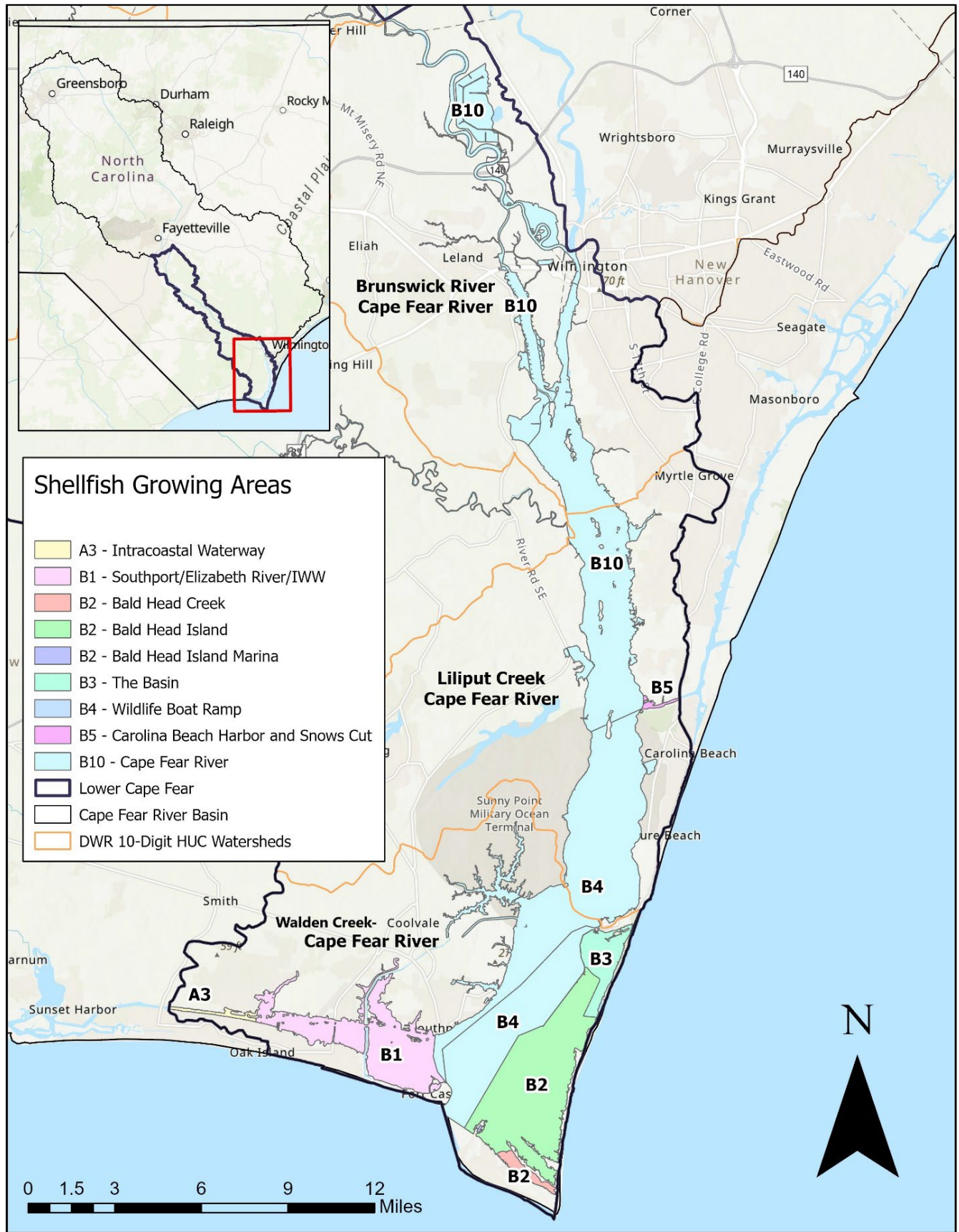
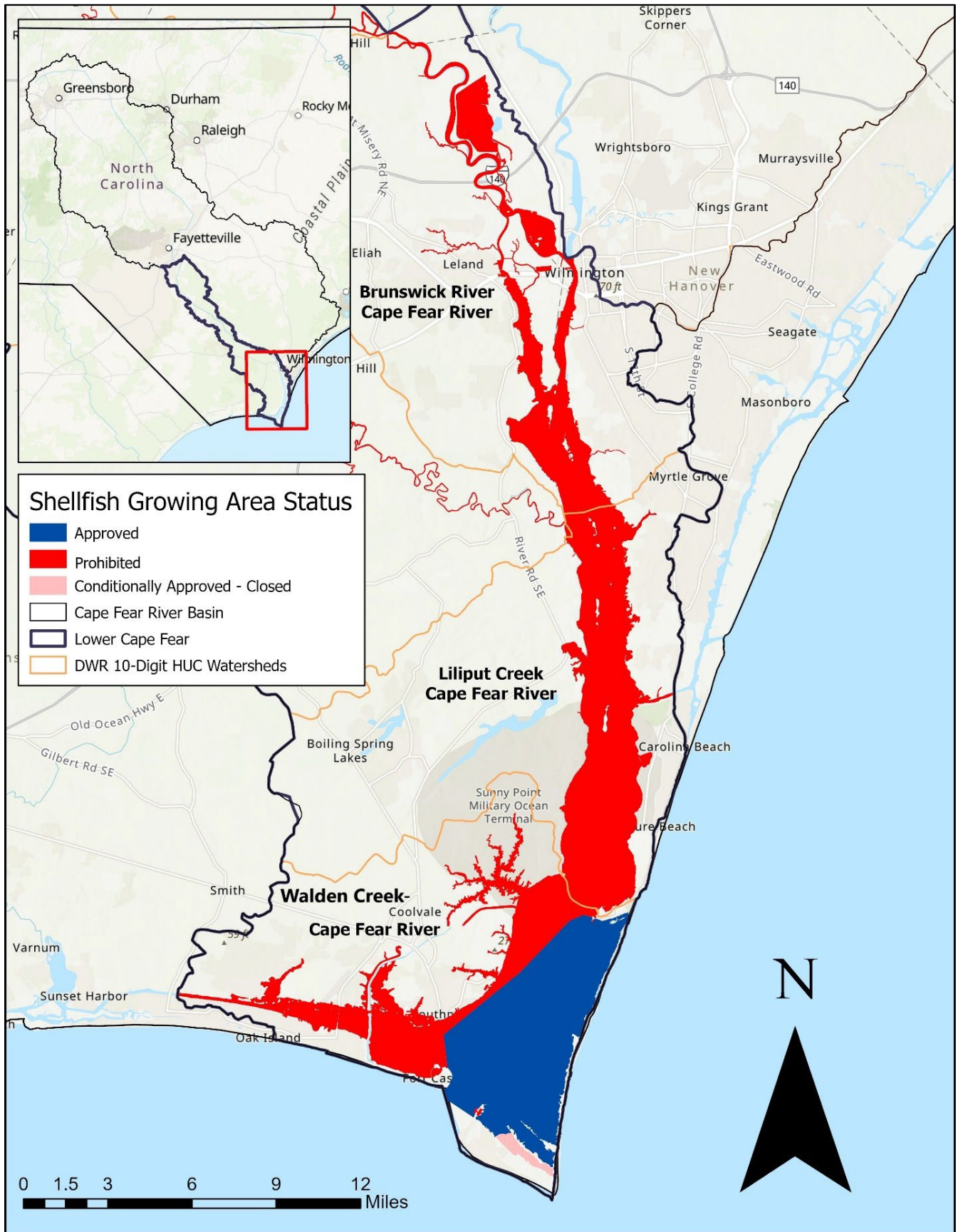


Figure 9-12: Lower Cape Fear River Shellfish Growing Areas (SGA) Status (2022)



Nonpoint source (NPS) pollution is defined as “any source of water pollution that does not meet the legal definition of ‘point source’ in Section 502(14) of the Clean Water Act (CWA)” (US EPA, 2020). NPS can result from any number of activities and land uses. Construction and land clearing activities, agriculture, golf courses, mining operations, solid waste disposal sites, urban landscapes, and on-site wastewater treatment systems (septic systems) all contribute to NPS and can add sediment, nutrients, bacteria, heavy metals, oil, and grease to a waterbody.

Marinas and boating activities are also considered a NPS of pollution. Chemicals used to maintain and repair boats and poorly maintained sanitary waste systems or pump-out stations can contribute chemical and biological contaminants to surface waterbodies (NOAA, n.d.). In North Carolina, marinas are defined as “any water area with a structure (dock, basin, floating dock, etc.) which is utilized for docking or otherwise mooring vessels and constructed to provide temporary or permanent docking space for more than 10 boats” (15A NCAC 18A .0901). Marinas are evaluated as part of the shoreline survey because of their potential to affect the suitability of adjacent shellfish areas for harvesting. Consequently, waters enclosed by a marina are classified as Prohibited for shellfish harvesting. An additional area beyond the marina may also be classified as Prohibited depending on the number of boat slips that are present.

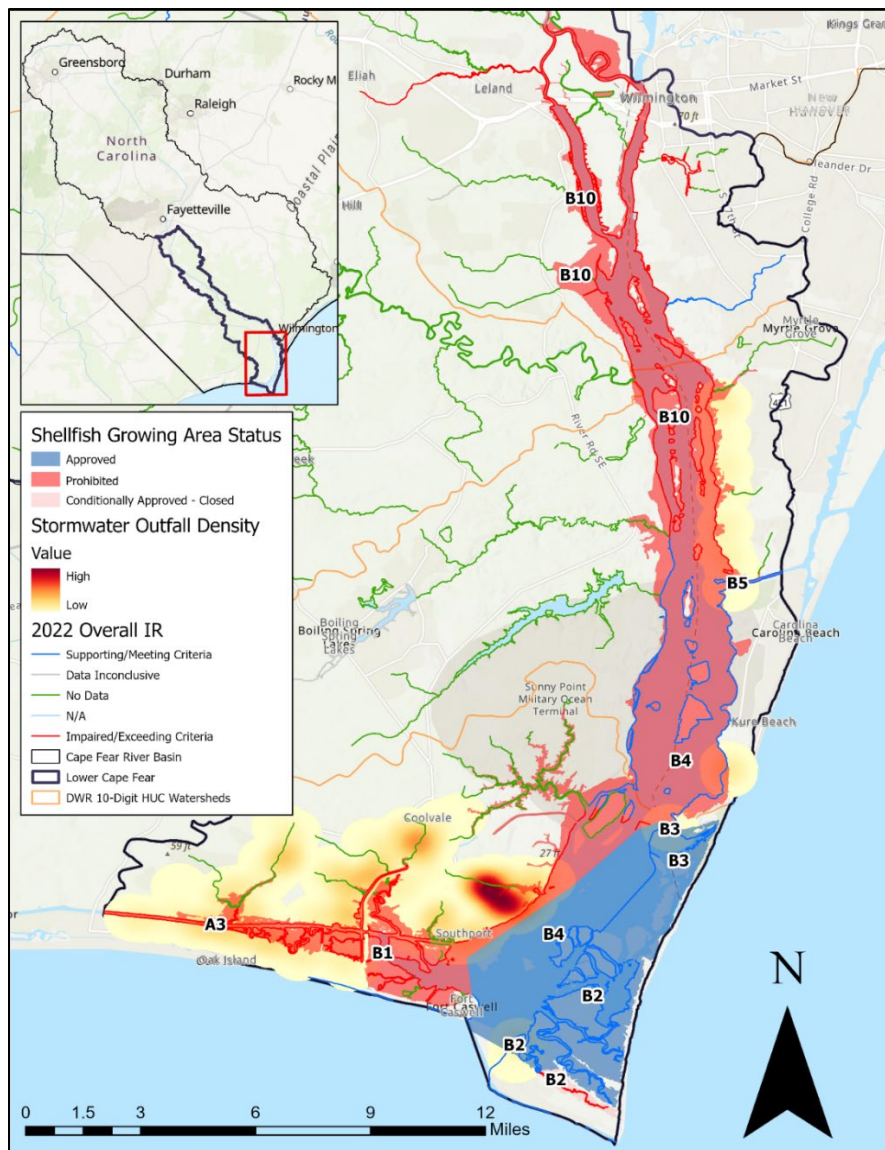
It is difficult to monitor and identify sources of NPS. The DWR works with several state and local agencies to identify potential NPS pollution and the types of activities that may be impacting water quality in the area, but data gaps exist. These unknowns include, but are not limited to, the amount of fertilizers, pesticides, herbicides, and animal waste applied to land, as well as the level at which these same pollutants may be reaching surface waters through groundwater seepage and atmospheric deposition. Seepage from septic drain fields and leaky wastewater pipes can contribute bacteria and other pollutants to ground and surface waters.

To identify areas of higher concentration of potential sources of pollution relative to the shellfish growing areas, a spatial analysis was conducted using data provided by DMF and tools available in ArcGIS Pro. Point data were available for the following categories of concern: animals, dockage, golf courses, stormwater, subdivisions, and wastewater. Stormwater points were separated from the rest of the data for three reasons: (1) a larger number of stormwater outfalls are in the basin when compared to the other point data provided by DMF; (2) stormwater is a constant concern in coastal basins due to topography and growing urban areas; and (3) the stormwater data could be weighted based on the overall relative contribution of a stormwater conveyance to the total bacterial load within the shellfish growing area.

The [Kernel Density](#) tool was used for the spatial analysis and to determine areas of high concentration of potential pollution sources in shellfish growing areas of the Lower Cape Fear subbasin. This method is commonly used in analyzing the density of occurrences and calculates the density of features in a set radius around the identified features. For all pollution source density maps, the analysis used a 1,000-meter radius to obtain greater detail of localized areas where pollution may be occurring. For the stormwater maps, each outfall was weighted based on its relative contribution. This information was pulled from the Shellfish Sanitary Survey Reports and was initially described as a low, medium, or high contribution. These were then changed to numerical values (low = 1, medium = 2, high = 3) that were then used to weight stormwater outfall points and allow for the density layer to be calculated.

Figure 9-13 displays the Kernel Density tool spatial analysis. The color gradients represent densities, with darker colors indicating areas of higher density of pollution sources and lighter colors indicating a lower density of pollution sources. This map is intended to provide a general idea of areas within the subbasin that may be impacted greater by pollution sources and does not provide quantitative values of pollution or indicate that an area is polluted. Figure 9-13 indicates that the most concentrated areas of pollution sources are on the north side of Southport along Price Creek, which drains to B4. Other areas of note are Cottage Creek on the west side of Southport, Dutchman’s Creek which originates in Coolvale and drains to B1, and Beaverdam Creek, which drains the growing St. James development to B1 as well as the Intercoastal waterway where A3 is located. All of these harvest areas are Prohibited.

Figure 9-13: Shellfish Growing Areas (SGA) and Stormwater Outfall Densities (High to Low) in the Lower Cape Fear Subbasin.



## 1.6 Health Advisories

### 1.6.1 Fish Consumption Advisories

Fish consumption advisories are based on human health advisory decisions from the North Carolina Department of Health and Human Services (NC DHHS), 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 NC DHHS [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 Lower Cape Fear River subbasin are impaired due to arsenic and hexavalent chromium concentrations occurring above the DPH levels of concern in fish and shellfish tissue samples (*Table 9-2* and *Table 9-11*). Arsenic and hexavalent chromium fish tissue advisories were issued for the first time in 2017 by DHHS and added to the 2020IR. Additional arsenic and hexavalent chromium fish tissue were issued in 2021 (*Table 9-11*) and will be included on the 2024IR.

The [NCDHHS Recommends Limiting Fish Consumption from the Middle and Lower Cape Fear River Due to Contamination With “Forever Chemicals”](#) press release came on June 13, 2023, for the newest fish tissue advisory for perfluorooctane sulfonic acid (PFOS; *Table 9-11*). PFOS is a type of per- and polyfluoroalkyl substance (PFAS), a Contaminant of Emerging Concern, designated a “forever chemical” due to its persistence in the environment. This most recent 2023 advisory will also be added to the 2026 IR and will ultimately impair most of the Lower Cape Fear mainstem. See Chapter 2 for more information on Contaminants of Emerging Concern.

*Table 9-11: NC Fish Consumption Advisories as of January 2023 in the Lower 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 <a href="#">Website</a> & <a href="#">Flyer</a>
Brunswick River	Brunswick	*Near US Hwy 74/US Hwy17 Bridge	Arsenic, Hexavalent Chromium	red drum
	Brunswick, New Hanover	^From its confluence with the Cape Fear River downstream to the US-17 bridge	Arsenic, Hexavalent Chromium	striped bass, striped mullet, blue crab
Cape Fear River*	Columbus, Pender, Brunswick	*Between Riegelwood Landing and the confluence of Livingston Creek and Cape Fear R.	Arsenic, Hexavalent Chromium	bowfin, bluegill, flathead catfish
	Brunswick, New Hanover	^Upstream of the confluence with the Brunswick River downstream to the US 17 bridge	Arsenic, Hexavalent Chromium	striped bass, striped mullet, blue crab

River	Counties	Location Of Advisory*^	Pollutant	Species
Davis Creek	Brunswick	*Downstream of Cartwheel Branch, upstream of the confluence of Davis Creek and Cape Fear River in Navassa	Arsenic, Hexavalent Chromium	bowfin, bluegill
Sturgeon Creek	Brunswick, New Hanover	^Just upstream of the confluence with the Brunswick River downstream of the US 17 bridge	Arsenic, Hexavalent Chromium	striped bass, striped mullet, blue crab
Cape Fear River	Bladen, Brunswick, Cumberland, Columbus, New Hanover, Pender	+Fayetteville Boat Ramp, near the I-95 overpass, to the bluffs on the Cape Fear, near the I-140 overpass	PFOS, one type of PFAS chemical	Blue Gill, Flathead Catfish, Largemouth Bass, Redear, Blue Catfish, American Shad, and Striped Bass

NC DHHS Website: <https://epi.dph.ncdhhs.gov/oeefish/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/oeemercury/safefish.pdf>

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

### Arsenic and Hexavalent Chromium Fish Tissue Advisories

The Kerr-McGee Chemical Corporation site in Navassa, North Carolina was placed on the US EPA’s Superfund National Priorities List (NPL) in 2010 ([Kerr-McGee Chemical Corp-Navassa Superfund website](#)). In 2011 and 2013, NC DEQ and the EPA collected and analyzed fish and shellfish from the waters near the site: Sturgeon Creek, the Brunswick River, and the Cape Fear River (*Table 9-11*). DPH reviewed these data and issued additional fish consumption advisories in 2017 for arsenic and hexavalent chromium (NC DHHS 2018).

Kerr-McGee operated as a creosote-based wood-treating facility from 1936 to 1974, and was dismantled in 1980. Dried lumber was pressure treated on site with creosote solution and stored outside to dry. Runoff from the site that flows into Sturgeon Creek, a tributary of the Brunswick River, had sediment contaminated with polycyclic aromatic hydrocarbons (PAHs) from the creosote. PAHs can move from the sediment to the aquatic food chain, including fish and shellfish. Fish and shellfish samples collected in 2011 were analyzed for PAHs, as well as semivolatile organic compounds, polychlorinated biphenyl (PCB) congeners, and metals. Samples collected in 2013 were only analyzed for metals. PAHs, from creosote, are the only contaminant of concern found in fish and shellfish known to be definitively associated with the Kerr-McGee NPL site. Other contaminants of concern may be from man-made activities such as coal burning, manufacturing or pesticide use or from natural sources, such as rock or soil. The environmental fate, human exposure, and health effects of some target pollutants collected in the Lower Cape Fear are summarized in *Figure 9-14*, based on Shapiro-Garza et al. (2022). Pollution to aquatic environments by metals is a serious public health hazard due to their bioaccumulative and non-biodegradable properties (Venkatrabreddy 2009). Both hexavalent chromium and arsenic are classified as carcinogens (Venkatrabreddy 2009; Shankar 2014). Arsenic and chromium are both naturally occurring in the

environment, but anthropogenic activities have caused toxic levels to enter some water sources. The burning of coal has had a profound effect on the contamination of arsenic in the environment (Shankar 2014). Hexavalent chromium, a pure metallic form of chromium, in most known circumstances, has entered the environment through industrial processes (Venkatrabreddy 2009).

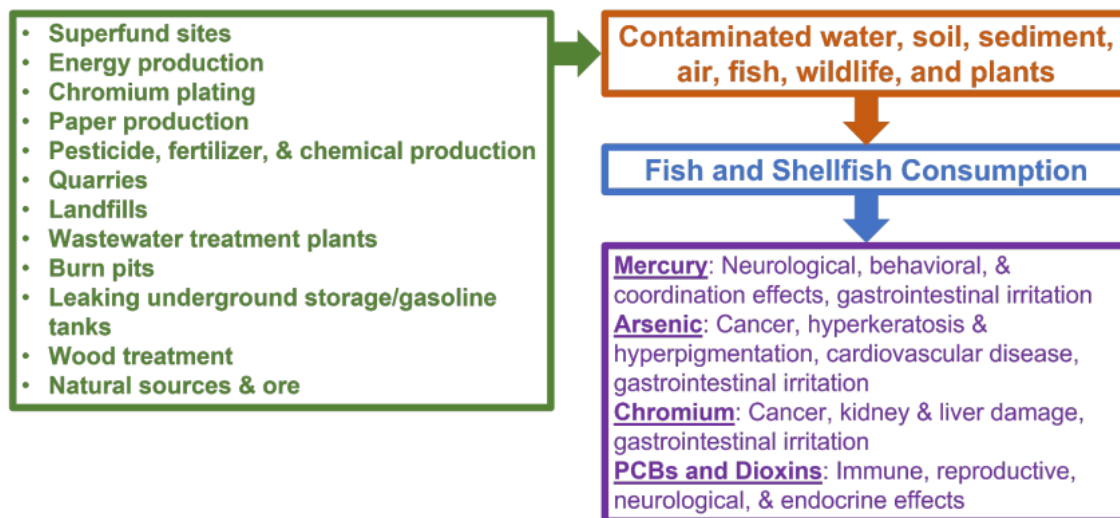
PAHs, PCBs, arsenic, hexavalent chromium, mercury, and copper were all detected in fish tissue at concentrations above DPH levels of concern, indicating the potential for cancer and non-cancer health effects. More stringent fish tissue advisories were issued just for arsenic and hexavalent chromium for striped bass, striped mullet, and blue crab since the existing statewide fish consumption advisory for mercury was already stricter for other species (*Table 9-11*). Due to the toxicity of hexavalent chromium, and to be highly health protective, all chromium in fish and shellfish was assumed to be hexavalent chromium. Contaminant levels were high enough for NC DHHS to issue site-specific fish tissue advisories in 2017 for arsenic, hexavalent chromium, and mercury for striped bass, striped mullet, and blue crab (NC DHHS 2018). Mercury Fish Tissue Advisories already existed statewide in 2017.

The Duke University Superfund Research Center and the School of Health Sciences at Oakland University conducted a follow-up study in the Lower Cape Fear from 2016 to 2022 with support from a coalition of individuals and organizations, including the Cape Fear River Watch, New Hanover NAACP, New Hanover County Department of Health, and Wake Forest School of Medicine. This collaborative study conducted household and bankside surveys to better understand which communities subsistence fish in the Lower Cape Fear; held focus groups to aid the development of appropriate messaging; organized a [Fish Forum](#) to discuss challenges and opportunities to create a more effective fish consumption advisory process in North Carolina; and collected and analyzed fish and shellfish tissue samples at locations in the Lower Cape Fear and North East Cape Fear subbasins (Shapiro-Garza et al. 2022).

The household (2016-2017) and bankside (2019-2020) surveys, combined with key actor interviews, found those eating fish from the river for subsistence tended to be low-income and/or food-insecure individuals and families. The key actor interviews included a bait and tackle shop owner, a local city council member, staff at a local non-profit focused on food security, and county health department employees. The surveys and interviews suggested that some people who eat fish from the Lower Cape Fear River are consuming types and quantities of fish that likely pose health risks, particularly for children and pregnant women, and that preferred species were red drum, black drum, trout, and catfish (Shapiro-Garza et al. 2022). Focus group (2017-2018) results led to the development of the [“Stop, Check, Enjoy!”](#) public outreach campaign. The goal of the campaign was to limit exposure by selecting safer fish and using preparation and cooking methods to reduce contaminant levels. Duke University organized a [Fish Forum](#) with relevant stakeholders in 2019 to discuss challenges and opportunities to create a more effective fish consumption advisory process. The major takeaway was that resource constraints limit all phases: tissue collection, testing, data analysis, and outreach. North Carolina must invest more in setting and communicating fish consumption advisories (Shapiro-Garza et al. 2022). The responsibility of posting local notifications falls to the local health department, which, similar to the state, has limited resources, although NC DHHS does offer language assistance (DHHS 2019). Due to resource limitations, at that time fish tissue samples had not been collected in the Lower Cape Fear since 2013 by DWR or DMF, although samples had been collected more recently in the upper parts of the basin.

Duke and Oakland universities worked with officials from DMF and NC Wildlife Resource Commission (WRC) to collect fish and shellfish tissue samples from multiple sites in the lower part of the basin near the 2011 and 2013 site locations, including Brunswick River, Burnt Mill Creek, Davis Creek (Cartwheel Creek), Northeast Cape Fear and the mainstem Cape Fear River (*Table 9-11*). All samples were tested for total metals (mercury, chromium, and arsenic) and a small subset was tested for PCBs and dioxins/furans to determine if more extensive testing would be necessary. All of the samples exceeded NC DHHS DPH cancer screening levels for arsenic and chromium and all but one sample exceeded the DPH screening levels for non-cancer effects for mercury. Dioxins and furans were not detected in any of the subset samples. Some PCBs were detected in all subset samples, but concentrations were 10 times lower than DPH screening levels (Shapiro-Garza et al. 2022).

*Figure 9-14: Examples sources, environmental fate, human exposure, and health effects of target pollutants (Shapiro-Garza et al. 2022)*



### PFOS Fish Tissue Advisory

DEQ and the NC Wildlife Resource Commission (WRC) conducted a large-scale fish and water collection study of the Middle and Lower Cape Fear River to better understand the levels of PFAS in commonly caught and consumed fish species (NCDHHS 2023a). Scientific studies have shown that exposure to these compounds may be linked to harmful health effects in humans and animals. More information about health effects can be found on the [NCDHHS Clinical Memo](#) and PFAS Factsheet. During the summer of 2022, over 250 samples of 14 types of migratory and non-migratory freshwater and marine fish species were collected from the Fayetteville Boat Ramp, near the I-95 overpass, to the Atlantic Ocean (NCDEQ 2023; *Figure 9-15*). A WRC survey was used to identify which species are most commonly caught and consumed in the Cape Fear region (NCDEQ 2023). The goals of the study were:

- To examine the extent of the PFAS contamination.
- To better understand the bioaccumulation of PFAS.

- To collect fish tissue data for the development of fish consumption advisories.

The freshwater fish analysis for the eight species collected from the portion of the river above the bluffs near the I-140 overpass is complete and the marine species analysis for six species collected in the estuary is currently underway. Freshwater fish fillet samples were analyzed for 56 different types of PFAS along with in situ water samples from eight 20-km freshwater river sections (*Figure 9-15*) (NCDEQ 2023a). The freshwater fish analysis found there was no significant statistical difference in PFAS concentrations between each collection site and that fish species were the only significant variable. Of all PFAS measured, PFOS was the leading compound in fish tissue across all analyzed species collected from the Cape Fear River (NCDHHS 2023a). The consistently elevated concentrations of PFOS in combination with the new and lower reference dose for PFOS released by the EPA in March 2023 informed the decision for the PFOS fish tissue advisories in the Middle and Lower Cape Fear River (*Figure 9-16*) (NCDHHS 2023b). Both cancer and non-cancer toxicological information published by the EPA was considered in issuing this advisory (NCDHHS 2023b).

*Figure 9-15: NCDEQ and NCWRC 2022 Fish and Surface Water Collection Project Map (NCDEQ 2023).*

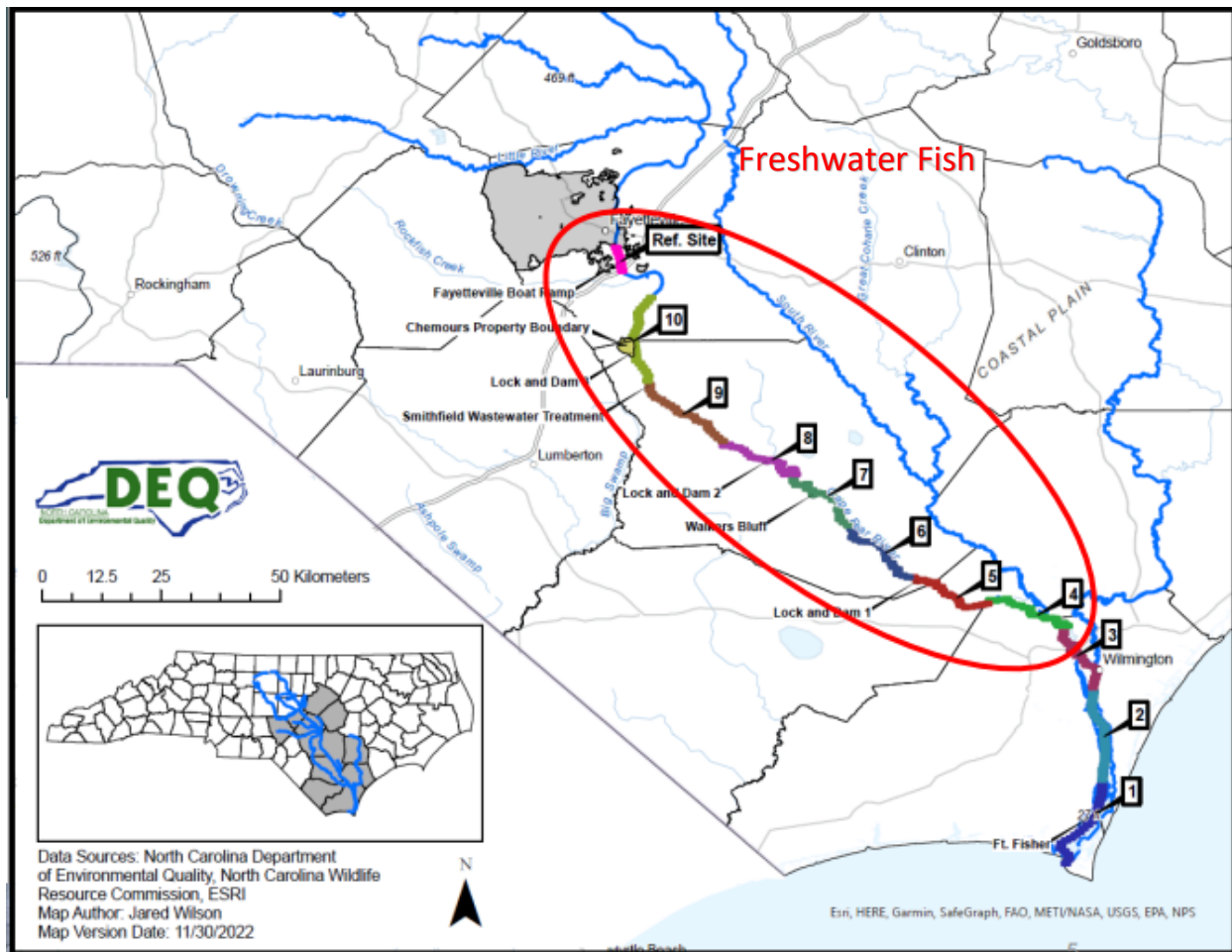
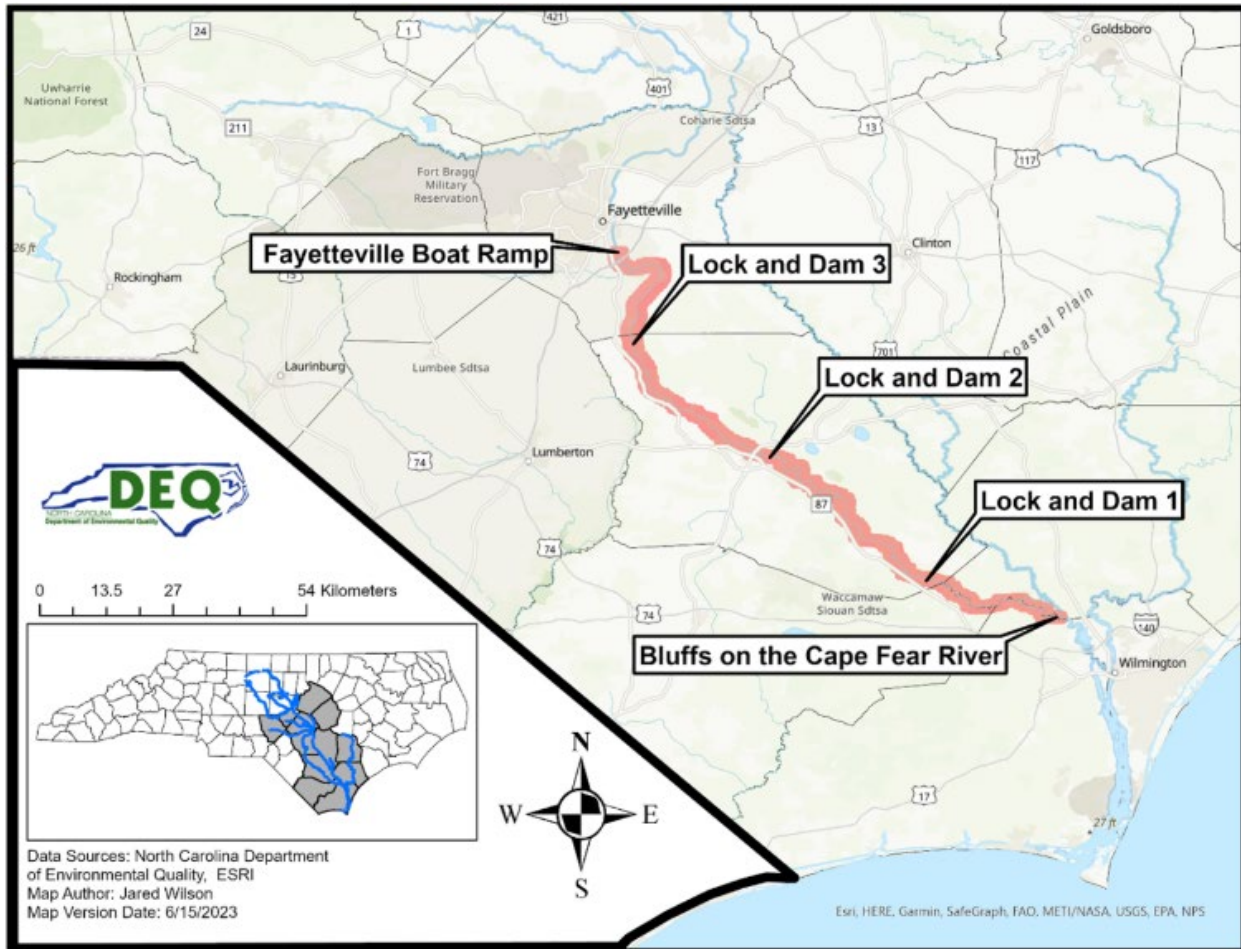


Figure 9-16: Fish Tissue Advisory for the Middle and Lower Cape Fear, June 13, 2023



### 1.6.2 Vibrio Bacteria Advisory

In July 2023, NC DHHS issued a press release encouraging North Carolinians to be aware of the potential dangers of having open wounds or cuts exposed to saltwater or brackish water following reports of three deaths due to Vibrio infections in North Carolina residents.

**NCDHHS Urges Caution After Three Deaths Due to Vibrio this Summer**

**NCDHHS insta a la precaución después de tres muertes debido a Vibrio este Verano**

Ver enlace para traducción al Español

<https://www.ncdhhs.gov/news/press-releases/2023/07/28/ncdhhs-urges-caution-after-three-deaths-due-vibrio-summer>

Vibrio are bacteria that normally live in warm seawater or brackish water (mixed salt and fresh water, as is found in an estuary or salt marsh) and can be found worldwide. Since they are naturally found in warm waters, people with open wounds, cuts or scratches can be exposed to these bacteria through direct contact with seawater or brackish water. Vibrio can also cause disease in those who eat raw or undercooked oysters and shellfish.

Vibrio cases in North Carolina are rare, with most cases being reported in the warmest months — June through September. However, Vibrio infections can cause severe illness. Since 2019, eight of the 47 reported cases among North Carolina residents have been fatal. The three most recent fatalities occurred in July 2023. Two of the three cases had scratches that were exposed to brackish water in North Carolina and another east coast state. The third case also had brackish water exposure in North Carolina; however, the individual also consumed personally caught seafood that was not shared nor commercially distributed.

While healthy individuals typically develop mild illness, Vibrio infections can be severe or life threatening for people with weakened immune systems or chronic liver disease. If you start to see signs of a skin infection after contact with brackish waters or seawater, you should contact your health care provider. Other symptoms can include diarrhea, stomach pain, vomiting, nausea, fever and chills.

Following these recommendations will help reduce your likelihood of exposure and infection:

- If you have a wound (including from a recent surgery, piercing or tattoo), stay out of saltwater or brackish water, if possible. This includes wading at the beach.
- Cover your wound with a waterproof bandage if it could come into contact with saltwater, brackish water or raw or undercooked seafood.
- If you sustain any type of wound while in salt or brackish water (e.g., cutting your hand on a boat propeller or crab pot) immediately get out of the water and wash with soap and water.
- Wash wounds and cuts thoroughly with soap and water after contact with saltwater, brackish water or raw seafood.
- Thoroughly cook all shellfish to an internal temperature of at least 145 degrees Fahrenheit, [according to the U.S. Department of Agriculture](#).

Reports of Vibrio infections associated with brackish water contact have been increasing over the past several decades, and the geographic range of waters associated with infection is spreading north along the East Coast of the U.S. due to increasing water temperatures. As climate change increases water temperatures, more Vibrio cases can be expected, and they are likely to be identified in previously unaffected areas.

More information on Vibrio can be found on the [CDC website](#) and the NCDHHS-[Division of Public Health website](#).

### 1.6.3 Swimming Advisory

The Division of Marine Fisheries Shellfish Sanitation and Recreational Water Quality Program began monitoring the state's coastal recreational waters in 1997. The coastal waters monitored include ocean beaches, sounds, bays and estuarine rivers. This program does not test inland waterways.

The primary purpose is to protect public health by monitoring the quality of North Carolina's coastal recreational waters and notifying the public when bacteria levels exceed state and federal standards for swimming and water play. This is done by testing waters for the bacteria enterococci. Enterococci are not known to be harmful themselves, but they are present at the same time as other organisms that can cause illness. Swimming notifications may be issued on a temporary basis if a single sample exceeds the standard for an area but must also maintain an acceptable running monthly average.

The Recreational Water Quality program tests 213 swimming sites throughout the state's coastal region, most of them on a weekly basis during the swimming season, which runs from April through September. All ocean beaches and high-use sound-side beaches are tested weekly from April through September; lower-use beaches are tested twice a month. All sites are tested twice a month in October and monthly from November through March. Water quality sampling results for all locations are posted [here](#) along with information about archived swimming advisories. In most cases, swimming advisories will not be issued during the non-swimming season from Nov. 1 to March 31.

For more information on the N.C. Recreational Water Quality Program or to view a map of testing sites and see swimming advisories visit the [program's website](#). [NC Recreational Water Quality Monitoring Program Brochure](#)

#### 1.6.4 Harmful Algal Bloom (HAB) Advisory

Algal blooms that cause adverse effects are known as Harmful Algal Blooms (HABs). When favorable environmental conditions exist, algae can reproduce rapidly and form blooms that appear as surface scums, water discoloration, or both. Blooms also cause major changes in water chemistry, including high pH and dramatic swings in dissolved oxygen. Lack of oxygen created by decomposing algal blooms sometimes results in fish kills and other aquatic life impacts.

Some algae, especially blue-green algae (cyanobacteria), can produce toxins. These toxins have been linked to adverse health effects in wildlife, domestic pets, and humans. DWR currently tests samples for microcystin, one of the most common and well-studied algal toxins. Link to DWR [Identifying Cyanobacteria \(Bluegreen\) Algal Blooms](#) Brochure.

When public health concerns arise from algae blooms, local health departments and NCDHHS determine an appropriate response with technical support from DWR. Common actions include swimming closures, contact advisories, and the issuance of public notifications.

NCDHHS-DPH routinely encourages the public to avoid contact with large accumulations of algae and to prevent children and pets from swimming or ingesting water in an algal bloom.

DPH suggests the following steps to safeguard against harmful algal blooms:

- Keep children and pets away from water that appears bright green, blue, discolored, or scummy.
- Do not handle or touch large mats of algae.
- Avoid handling, cooking, or eating dead fish that may be present.
- If you come into contact with an algal bloom, wash thoroughly.
- Use clean water to rinse off pets that may have come into contact with an algal bloom.

- If your child appears ill after being in waters containing an algal bloom, seek medical care immediately.
- If your pet appears to stumble, stagger, or collapse after being in a pond, lake, or river, seek veterinary care immediately.

To report an algal bloom, contact the nearest DEQ [regional office](#) or submit a report [online](#). To view reported algal bloom events, visit DWR's [Fish Kill & Algal Bloom Dashboard](#).

To learn more about algal blooms, visit the [DWR website](#). For more information on the potential health effects from algal blooms, visit the [DPH website](#).

## 1.7 Ambient Water Quality

Monthly chemical and physical samples are taken by DWR through the Ambient Monitoring System (AMS) stations coalitions of NPDES permit holders that are active in the Cape Fear River Basin. Both the Middle Cape Fear Basin Association (MCFBA) and Lower Cape Fear River Program (LCFRP) collect ambient samples in the Lower Cape Fear 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 20 AMS, 12 MCFBA, and 14 LCFRP stations being monitored in the Lower Cape Fear River subbasin with two stations co-located for the AMS and LCFRP programs (B9800000 and B4500000) (*Figure 9-17*). *Table 9-12* shows the ambient stations used in the 2022 IR. A complete list of all ambient monitoring stations from 2000 to 2020 is available in Chapter 2 Appendix. Ambient monitoring station sampling results are discussed in detail in Section 9.9.

While the MCFBA and LCFRP primarily collect instream monitoring information in waterways with point source dischargers, they also maintain several voluntary instream monitoring stations in the Lower 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 MCFBA voluntary monitoring stations are sampled quarterly and the LCFRP are sampled monthly in this subbasin. DWR recognizes the importance of this work and encourages continued monitoring of these stations.

Table 9-12: Ambient Monitoring Stations in the Lower Cape Fear River subbasin.

Station ID	Station Location	Level III Ecoregion	Assessment Unit Number	Classification
B8290000	CAPE FEAR RIV AT DUPONT WATER INTAKE UPS LOCK AND DAM 3	Southeastern Plains	18-(26.25)b	WS-IV
B8300000	CAPE FEAR RIV AT WO HUSKE LOCK NR TAR HEEL	Southeastern Plains	18-(26.25)c	WS-IV
B8302000	CAPE FEAR RIV AT POWER LINES NR TOLARVILLE	Southeastern Plains	18-(26.75)a	WS-IV
B8305000	CAPE FEAR RIV AT SR 1316 AT TAR HEEL	Southeastern Plains	18-(26.75)a	C
B8306000	CAPE FEAR RIV AT RM 80 NR RUSKIN	Southeastern Plains	18-(26.75)a	C
B8315000	HARRISON CRK AT SR 1320 AT BURNEY	Middle Atlantic Coastal Plain	18-42b	C
B8320000	CAPE FEAR RIV AT US 701 AT ELIZABETHTOWN	Southeastern Plains	18-(26.75)a	C
B8321000	TURNBULL CRK AT SR 1509 NR JOHNSONTOWN	Middle Atlantic Coastal Plain	18-46	C
B8339000	CAPE FEAR RIV ABOVE LOCK AND DAM 2	Southeastern Plains	18-(26.75)b	C
B8340000	CAPE FEAR RIV AT LOCK 2 NR ELIZABETHTOWN	Southeastern Plains	18-(26.75)b	C
B8340050	BROWNS CRK AT NC 87 NR ELIZABETHTOWN	Southeastern Plains	18-45	C
B8340100	TURNBULL CRK AT US 701 NC 53 AND NC 41 NR ELIZABETHTOWN	Middle Atlantic Coastal Plain	18-46	C
B8340130	CAPE FEAR RIV AT RM 70 NR ELIZABETHTOWN	Southeastern Plains	18-(26.75)c	C
B8340200	HAMMOND CRK AT SR 1704 NR MOUNT OLIVE	Southeastern Plains	18-50	C
B8340300	WHITES CRK AT SR 1715 NR BLADEN SPRINGS	Southeastern Plains	18-50-5	C
B8340650	CAPE FEAR RIV AT RM 55 NR BLADEN SPRINGS	Middle Atlantic Coastal Plain	18-(49)	WS-V
B8348000	CAPE FEAR RIV AT SR 1730 ELWELL FERRY RD NR CARVERS	Middle Atlantic Coastal Plain	18-(53.5)	WS-IV
B8349000	CAPE FEAR RIV ABOVE LOCK AND DAM 1 NR EAST ARCADIA	Middle Atlantic Coastal Plain	18-(58.5)	WS-IV;CA
B8350000	CAPE FEAR RIV AT LOCK 1 NR KELLY	Middle Atlantic Coastal Plain	18-(59)	WS-IV;Sw

Station ID	Station Location	Level III Ecoregion	Assessment Unit Number	Classification
B8360000	CAPE FEAR RIV AT NC 11 NR EAST ARCADIA	Middle Atlantic Coastal Plain	18-(59)	WS-IV;Sw
B8441000	LIVINGSTON CRK AT WRIGHT CORPORATION WALKWAY NR ACME	Middle Atlantic Coastal Plain	18-64b	C;Sw
B8450000	CAPE FEAR RIV AT NEILS EDDY LANDING NR ACME	Middle Atlantic Coastal Plain	18-(63)a	C;Sw
B8465000	CAPE FEAR RIV AT INTAKE NR HOOPER HILL	Middle Atlantic Coastal Plain	18-(63)b	C;Sw
B9017000	BULLDOG CUT BELOW BLACK RIVER NR NAVASSA	Middle Atlantic Coastal Plain	18-68-23	C;Sw
B9020000	CAPE FEAR RIV DNS HALE PT LANDING NR PHOENIX	Middle Atlantic Coastal Plain	18-(63)b	C;Sw
B9030000	CAPE FEAR RIV UPS INDIAN CREEK NR PHOENIX	Middle Atlantic Coastal Plain	18-(63)b	C;Sw
B9050000	CAPE FEAR RIV AT NAVASSA	Middle Atlantic Coastal Plain	18-(71)a1	SC
B9050025	CAPE FEAR RIVER NDN RR BRIDGE AT NAVASSA	Middle Atlantic Coastal Plain	18-(71)a2a	SC
B9050100	CAPE FEAR RIVER AT HORSESHOE BEND NEAR WILMINGTON	Middle Atlantic Coastal Plain	18-(71)a2a	SC
B9790500	PINEY BRANCH AT WIRE RD NR BELVILLE	Middle Atlantic Coastal Plain	18-77-3-1	C;Sw
B9795000	CAPE FEAR RIV AT CM 54	Middle Atlantic Coastal Plain	18-(71)a5	SC
B9800000	CAPE FEAR RIV AT CM 61 AT WILMINGTON	Middle Atlantic Coastal Plain	18-(71)a3	SC
B9820000	CAPE FEAR RIV AT CM 56 NR WILMINGTON	Middle Atlantic Coastal Plain	18-(71)a4	SC
B9850100	CAPE FEAR RIV AT CM 35	Middle Atlantic Coastal Plain	18-(71)b	SC
B9910000	CAPE FEAR RIV AT CM 23	Middle Atlantic Coastal Plain	18-(87.5)a	SC
B9921000	CAPE FEAR RIV AT CM 18	Middle Atlantic Coastal Plain	18-88-3.5	SC

An overall comparison of the Lower Cape Fear River’s HUC10 watershed scale ambient water quality results for samples collected in the basin from 2016 to 2020 (2022 IR) is shown in *Table 9-13*. 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 9-13* also shows the HUC8 mean levels for these parameters from 2016 to 2020 in the Lower Cape Fear River subbasin, and for comparison purposes, the highest HUC8 and HUC10 mean levels basinwide for conductivity, nutrients, turbidity, TSS, and fecal coliform. 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 Total Kjeldahl Nitrogen (TKN) while the Haw River subbasin (HUC8 03030002) had the highest mean five-year results for turbidity, TSS, total nitrogen (TN) and nitrate+nitrite (NOx). The Lower Cape Fear River subbasin had comparatively lower five-year means relative to the Northeast Cape Fear and Haw River subbasin highest HUC8 mean levels. The highest basinwide HUC10 values included in the *Table 9-13* are described in-depth in their respective watershed chapters (Chapters 6 through 11) of this report.

In the Lower Cape Fear River subbasin, at the HUC10 scale, Harrison Creek-Cape Fear River (0303000501) had the highest five-year mean levels for TKN, NOx, TN, and turbidity, Brunswick-Cape Fear River (0303000505) had the highest five-year mean levels for conductivity and TP, and Cape Fear River (0303000508) had the highest five-year mean levels for ammonia.

Water quality was evaluated along the entire Cape Fear River mainstem at 32 AMS, coalition, and co-located stations. The river was divided into five segments based primarily on HUC8 and HUC10 boundary lines. The lowest three estuarine stations were also evaluated separately. Twenty-five stations were evaluated in the Lower Cape Fear River within four segments: Harrison and Turnbull Creeks (Section 9.9.3), Hood Creek (Section 9.9.5.1), Brunswick River (Section 9.9.6.1), and the estuary (Section 9.9.10). An overall summary is provided in Section 9.10. The most upstream Upper Cape Fear River subbasin segment evaluation of seven stations is discussed in Chapter 8.

**Cape Fear River Mainstem Ambient Water Quality Evaluation**

Cape Fear River Mainstem Segment	Number of Stations
Upper Cape Fear	7
LCF - Harrison and Turnbull Creeks	8
LCF - Hood Creek	7
LCF - Brunswick River	7
LCF - Estuary	3

Figure 9-17: Ambient Monitoring System and Coalition Stations in the Lower Cape Fear River Basin

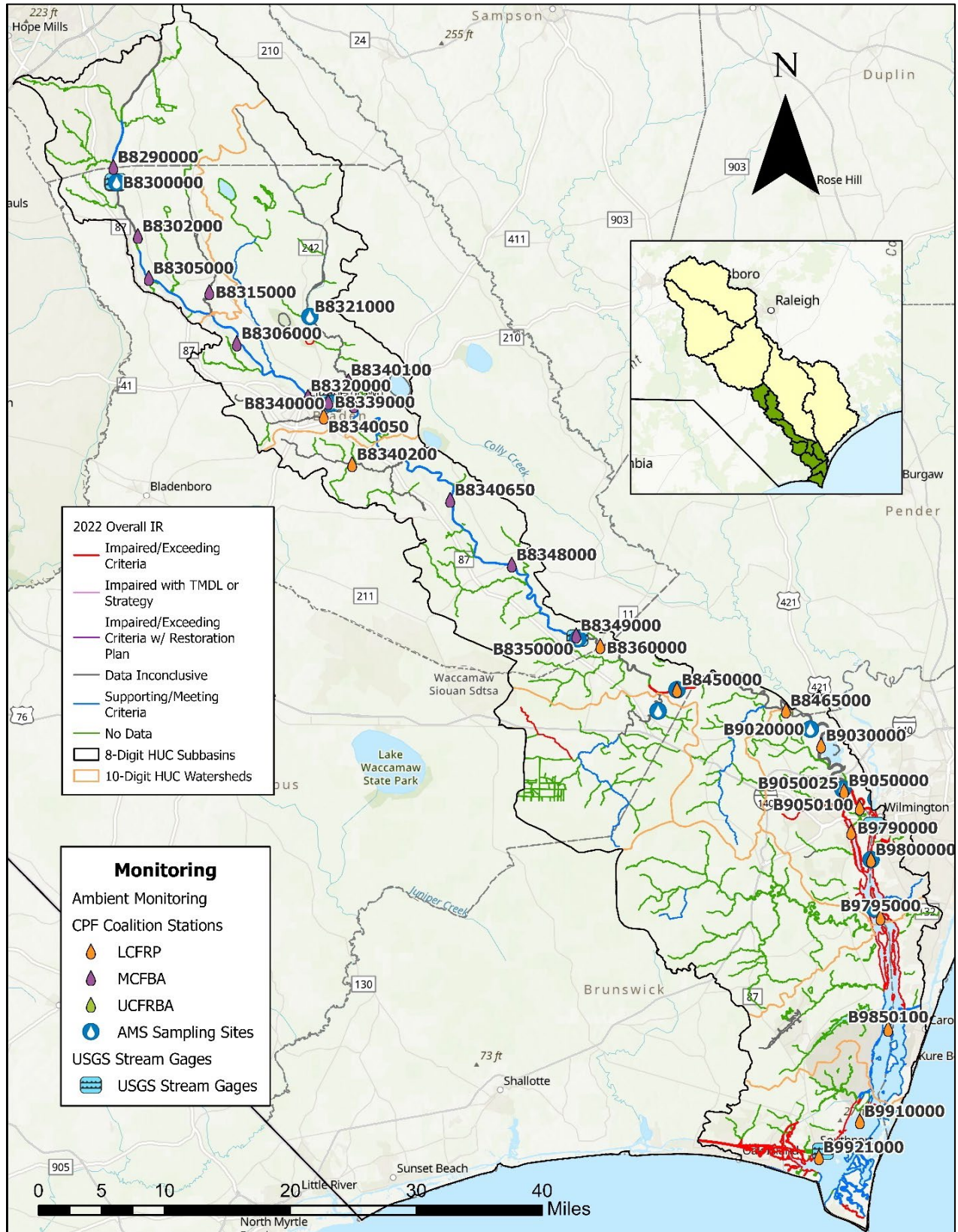


Table 9-13: Lower Cape Fear River Subbasin HUC10 Watershed Ambient Water Quality Means for 2016-2020

Watershed HUC 10 <sup>x</sup>	Watershed Name	Number of Stations <sup>^</sup>	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)
<b>Highest HUC 8 in Cape Fear River Basin</b>		$\bar{x}$			711	0.09	0.92	1.34	2.10	0.21	20.19	22.90	1,093
<b>Highest HUC 10 in Cape Fear River Basin</b>		$\bar{x}$			1,413	0.27	1.44	2.62	3.48	0.38	26.63	26.64	2,478
<b>03030005</b>	HUC8 Lower CPF Watershed	30	6.74	7.20	117	0.06	0.75	0.53	1.29	0.15	13.64		423
0303000501	Harrison Creek-CPF	3	6.72	7.57	109	0.03	0.88	0.73	1.61	0.13	18.52		294
0303000502	Turnbull Creek-CPF	7	6.36	7.47	104	0.05	0.84	0.72	1.56	0.14	13.86		466
0303000504	Hood Creek-CPF	8	6.59	7.36	121	0.06	0.75	0.60	1.35	0.16	14.94		603
0303000505	Brunswick -CPF*	9	6.88	6.48	201	0.07	0.72	0.38	1.09	0.17	10.05		289
0303000507	Lilliput Creek-CPF**	1	7.56	7.12		0.06	0.64	0.20	0.84	0.16			
0303000508	Cape Fear***	2	7.86	7.27		0.08	0.53	0.12	0.65	0.15	6.39		32
Minimally Impacted Streams <sup>o</sup>													
EPA Nutrient Criteria - Coastal Plain <sup>+</sup>													
						<0.05	<0.5	<0.3	<0.8	<0.05			

<sup>x</sup>Livingston Creek (0303000503), Town Creek (0303000506) had ambient data collected from 2016 to 2020.

<sup>^</sup>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.

<sup>\*</sup>HUC10 Brunswick River CPF River watershed (0303000505) includes six Estuary stations and three River/Stream stations, <sup>\*\*</sup>HUC10 Lilliput Creek - CPF River watershed (0303000507) includes one estuary station, <sup>\*\*\*</sup>HUC10 Cape Fear River watershed (0303000508) includes two Estuary stations, all other stations in the HUC8 Lower Cape Fear River subbasin (03030005) are River/Stream stations. NOTE: Conductivity was not collected at estuary stations.

<sup>o</sup>DWQ ESS- ISU Special Study. March 14, 2005, Lower Cape Fear River/Estuary TMDL Study. (This branch is now called DWR WSS-ISB (Water Sciences Section – Intensive Survey Branch)).

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

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.

Graphs for the river segments were developed to show the yearly standard exceedance rates and means for parameters of interest collected between 2002 and 2020. It should be noted that the method used to identify an impaired waterbody for the IR is based on the exceedance rate of a standard and percent confidence (90%) for a set of data generally collected over a five-year period and not based on individual yearly statistic as represented in the graphs in this chapter (see Chapter 2 for more information on the IR). The parameters of interest and statistics shown for each river segment set of graphs includes yearly means and exceedance rates for turbidity, fecal coliform, DO, and pH, just means for specific conductivity and nutrients. Yearly geomeans graphs were also developed for fecal coliform bacteria. The yearly average discharge, or streamflow, was overlaid on the Lower Cape Fear River water quality graphs using data from the USGS gage at Lock and Dam #1 near Kelly (02105769) on the Cape Fear River. The yearly discharge values were computed by calculating the yearly mean value of the mean daily discharge values. These yearly discharge values are representative of the mean daily streamflow volume flowing through a particular area of a stream throughout the period of one year. [Table 9-14](#) lists stations by hydrologic order in each river segment with the sampling organization (AMS, MCFBA, and LCFRP), sample years by parameter, location descriptions, ecoregion, and stream classification.

Most of the water quality stations on the mainstem Cape Fear River are collected from a boat. At boat stations, the physical parameters are monitored using a calibrated *in situ* data probe/sonde that is lowered through the water column to record a reading at approximately 0.1 m (surface reading) and then at various depths. The data from the water column was averaged to get a daily average value that was used to determine the remaining statistical summaries found throughout this chapter except for the stations in the Cape Fear River Estuary where the DO and pH impairments were identified as part of the 303(d)/Integrated Report process. The water quality standards generally apply to the readings collected at the surface and not the average water column readings. For the stations in the Cape Fear River Estuary, only the surface readings were used for water quality assessment purposes. All other non-lake stations collect surface readings only so daily averaging was not necessary.

[Figure 9-18](#) and [Figure 9-19](#) provide a spatial display of the 25 stations on the Lower Cape Fear River used in the mainstem evaluation with the four river segments identified. The sampling agency for each station is also identified as AMS, coalition, or co-located, and the location of the USGS gage at Lock and Dam #1 near Kelly is also shown. This gage is located just above Lock and Dam #1, downstream from MCFBA station B8349000 and upstream from AMS station B8360000, which is located below the Lock and Dam. [Figure 9-18](#) is overlaid on the 2019 land cover and [Figure 9-19](#) shows permitted facilities for NPDES stormwater, NPDES dischargers, and AFOs, and the location of non-discharge and residual solids fields. Stations in [Figure 9-18](#) and [Figure 9-19](#) are color-coded by hydrologic order and match the color coding in [Table 9-14](#).

Table 9-14: Lower Cape Fear River Mainstem Segments and Water Quality Stations for Evaluation

Station Order	Station ID	AMS	MCFBA	LCFRP	AU Description	AU#	Class
<b>Lower Cape Fear - Harrison and Turnbull Creeks</b>							
1	B8290000		2002-2020 - All		Grays Creek to Lock and Dam #3	18-(26.25)b	WS-IV
2	B8300000	2019-2020 - nutrients and turbidity, 2002-2011, 2013-2014, 2017-2020 - physical field parameters			From Lock and Dam #3 to a point approximately 0.5 miles upstream of Smithfield Packing Company's intake	18-(26.25)c	WS-IV
3	B8302000		2002-2020 - All		From Lock and Dam #3 to a point approximately 0.5 miles upstream of Smithfield Packing Company's intake	18-(26.25)c	WS-IV
4	B8305000	2002-2006 - turbidity, FCB, physical field parameters	2002-2020 - All		From Smithfield Packing Company's intake (approximately 2 miles upstream of County Road 1316) to NC 701	18-(26.75)a	C
5	B8306000		2002-2020 - All	C			
6	B8320000		2002-2020 - All	C			
7	B8339000		2002-2020 - All		NC 701 to Browns Creek	18-(26.75)b	C
8	B8340130		2002-2020 - All		From Browns Creek to Hammond Creek	18-(26.75)c	C
<b>Lower Cape Fear - Hood Creek</b>							
1	B8340650		2002-2020 - All		From the mouth of Hammond Creek to the mouth of Drunken Run (near mile 53)	18-(49)	WS-V
2	B8348000		2002-2020 - All		From the mouth of Drunken Run (near mile 53) to a point 0.6 mile upstream of Lock #1 near Acme	18-(53.5)	WS-IV

Station Order	Station ID	AMS	MCFBA	LCFRP	AU Description	AU#	Class
3	B8349000		2002-2020 - All		From a point 0.6 mile upstream of Lock #1 near Acme to Lock #1 (City of Wilmington water supply intake)	18-(58.5)	WS-IV;CA
4	B8350000	2002-2020 -All			From Lock #1 near Acme to a point 0.5 mile upstream of raw WSI at Fed. Paper Board Corp. (Riegelwood)	18-(59)	WS-IV;Sw
5	B8360000	2002-2006 - turbidity, FCB, physical field parameters, 2003-2006 - nutrients		2002-2020 - All			WS-IV;Sw
6	B8450000	2002-2020 - turbidity, FCB, physical field parameters, 2004 and 2010-2012 - nutrients		2002-2020 - FCB, physical parameters, nutrients	From raw water supply intake at Federal Paper Board corporation (Riegelwood) to Bryant Mill Creek	18-(63)a	C;Sw
7	B8465000			2002-2020 - FCB, physical parameters, nutrients	From Bryant Mill Creek to the upstream mouth of Toomers Creek	18-(63)b	C;Sw
<b>Lower Cape Fear - Brunswick River</b>							
1	B9020000	2002-2020 - turbidity and physical field, 2002-2019 - FCB, 2004-2019 - nutrients			From Bryant Mill Creek to the upstream mouth of Toomers Creek	18-(63)b	C;Sw
2	B9030000			2002-2020 - FCB, physical parameters, nutrients			
3	B9050025			2002-2020 – All but specific conductivity	From Railroad bridge to Hwy 17 bridge.	18-(71)a2a	SC
4	B9050100			2002-2020 – physical parameters (pH and DO only), nutrients, FCB			
5	B9800000	2002-2020 - turbidity, physical field parameters (pH and DO only), nutrients 2010, 2011, 2015), 2002-2019 -FCB		2002-2020 – physical parameters (pH and DO only) and nutrients, 2002 to 2011 FCB	From Greenfield Creek to Barnards Creek	18-(71)a3	SC

Station Order	Station ID	AMS	MCFBA	LCFRP	AU Description	AU#	Class
6	B9820000	2002-2020 - turbidity, and physical field parameters (pH and DO only), 2002-2019 -FCB, 2003-2019 - nutrients			From Barnards Creek to 0.6 miles downstream of Barnards Creek	18-(71)a4	SC
7	B9795000			2002-2020 - physical parameters (pH and DO only) and nutrients, 2002-2011 - FCB	From 0.6 miles downstream of Barnards Creek to 1.9 miles downstream of Mott Creek	18-(71)a5	SC
<b>Lower Cape Fear - Estuary</b>							
1	B9850100			2002-2020 - physical field parameter, nutrients, 2002-2011 - FCB	From a line across the river btw Lilliput Creek and Snows Cut to a line across the river from Walden Creek to the basin	18-(71)b	SC
2	B9910000			2002-2020 - physical field parameters, nutrients, 2002-2011 and 2016-2019 - FCB	Prohibited area north of Southport Restricted Area and west of Inter-Coastal Waterway (ICWW) in Cape Fear River	18-(87.5)a	SC
3	B9921000			2002-2020 - physical field parameters, nutrients, 2002-2011 and 2016-2020 - FCB	Beginning at a point on the west bank of the Cape Fear River 1000 yards upstream of Price Creek, thence in an easterly direction to the eastern border of the Lower Cape Fear River	18-88-3.5	SC

Note - This table lists Ambient Monitoring System (AMS) and Coalition - Middle Cape Fear Basin Association (MCFBA) parameters collected each year at Cape Fear River mainstem stations. Physical field parameters include temperature, pH, and specific conductivity and nutrients include ammonia, TKN, NOx, and TP. AMS and Coalition average day data were combined for the mainstem Upper Cape Fear River graphics. Overall station parameter data with < 8 average day records in a year was not included in the graphical images but is shown in this table.

Figure 9-18: Lower Cape Fear River Mainstem Segments and Water Quality Stations for Evaluation with 2019 Land Cover

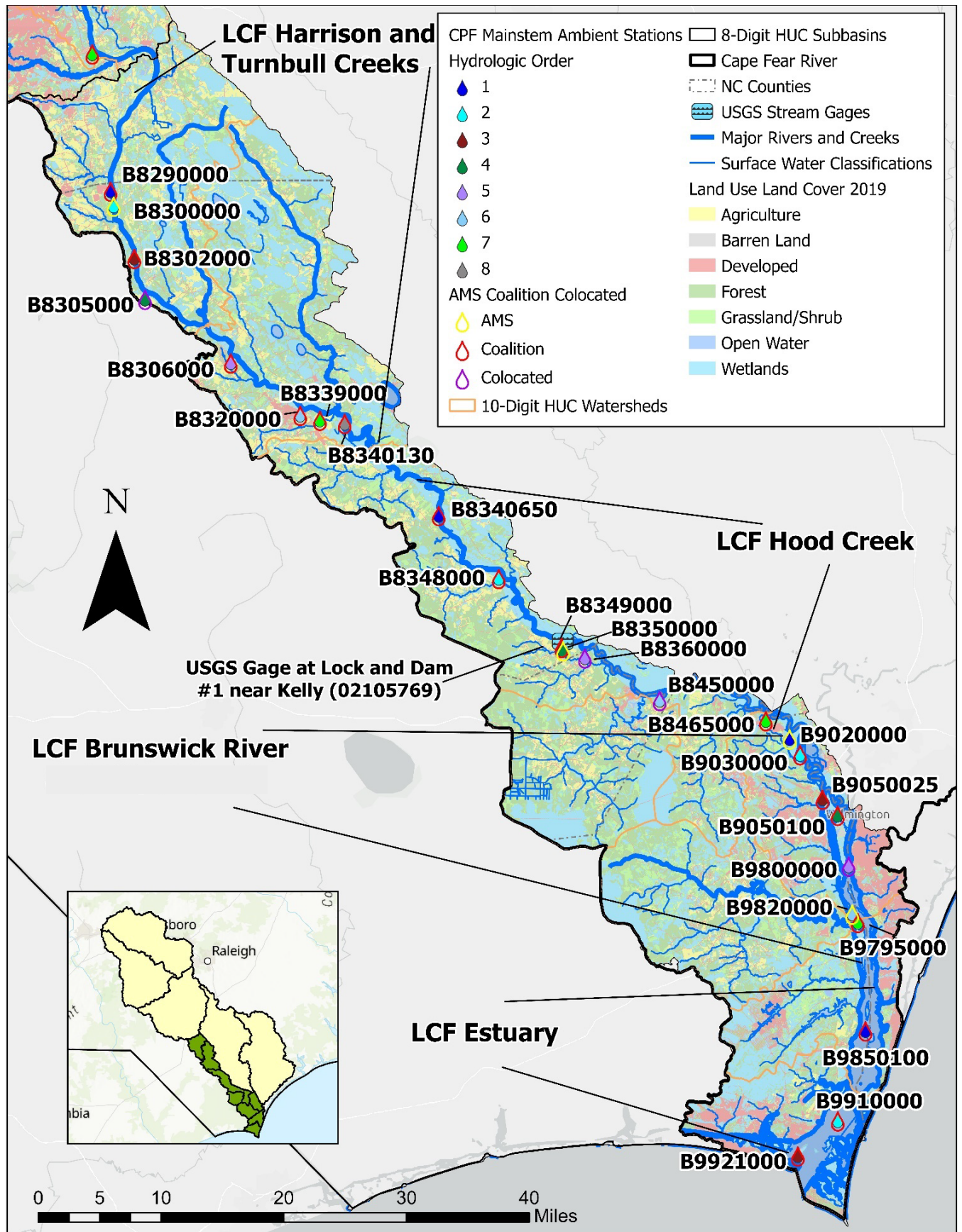
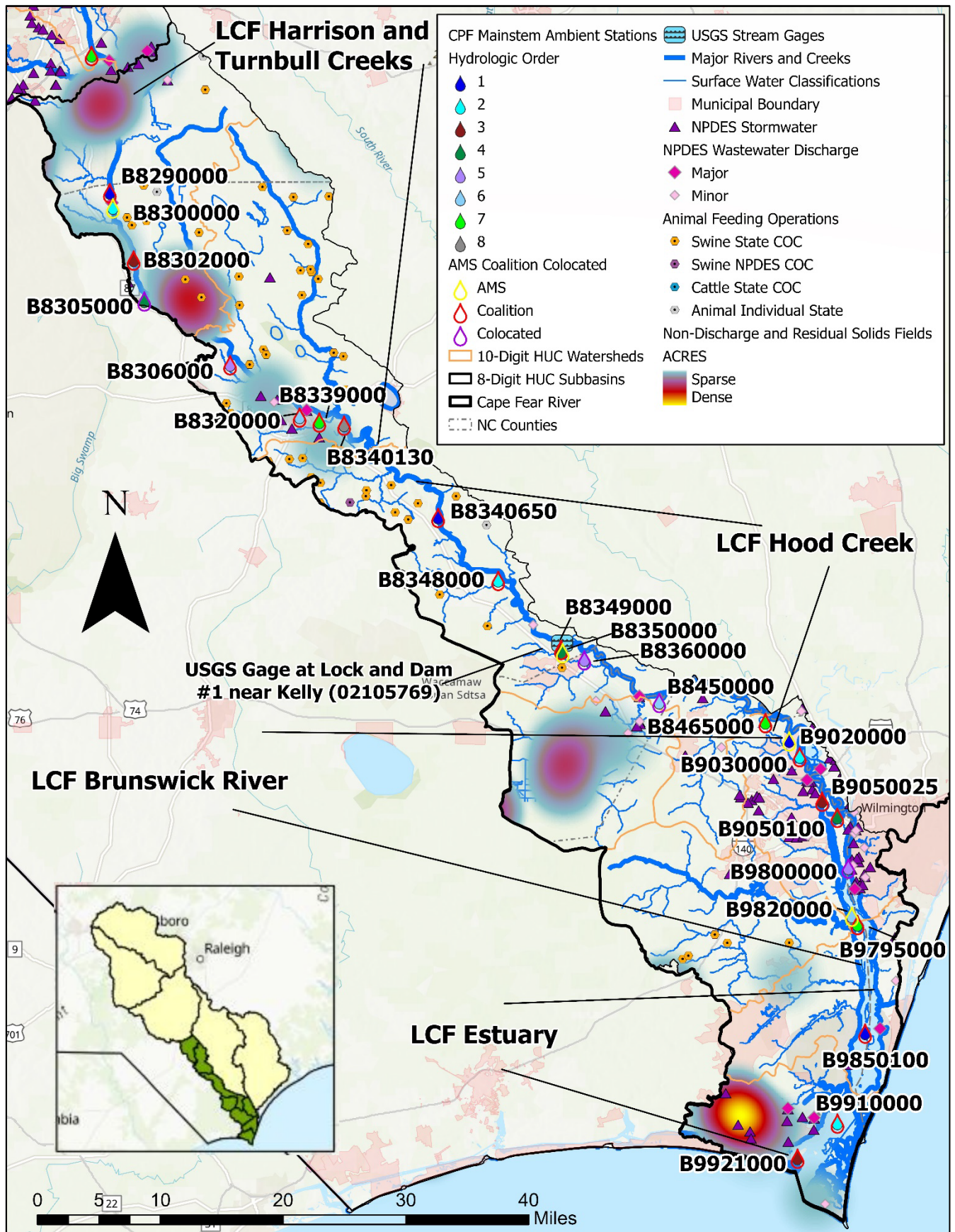






Figure 9-19: Lower Cape Fear River Mainstem Segments and Water Quality Stations for Evaluation with Permit Facilities and Non-Discharge and Residual Solids Fields



To better understand how water quality interacts with stream flow along the Lower Cape Fear River mainstem, flow-separated graphics were developed that show overall mean and median water quality concentrations for three flow bins by parameter for 2002 to 2020 (Figure 9-20 to Figure 9-29). The daily average water quality data for five mainstem stations were correlated with the daily average discharge from two USGS gages. The USGS gage Cape Fear River at William O Huske Dam (Lock and Dam #3) near Tarheel, NC (02105500) was used to evaluate water quality at stations B8300000, which is co-located with this gage, and B82900000, which is one mile upriver. The USGS gage Cape Fear River at Lock and Dam #1, NC (02105769) was used to evaluate water quality at the other three water quality stations, B3490000, B8350000, and B360000. The Lock and Dam #1 gage is located just below the dam, within 200 feet of B8350000, also located below the dam, and 600 feet from B8490000, located above the dam. B8360000 is two miles downriver from the Lock and Dam #1 gage. Water quality stations chosen for this analysis needed to be within three river miles of the correlating gage and have a comparable watershed size (<10% larger or smaller). Flow bins were determined using daily average discharge calculated from the 30+ years of discharge data (1985 – 2020) that was available for both gages. The average daily discharge that matched the ambient data collected on the same day based on the day, month, and year combination was used to calculate the mean and median values for the different flow bins. Flow and the corresponding water quality data were divided into low, mid, and high (upper) flow bins based on quartile ranges:

**Flow Separated Stations**

Station	Cape Fear River
B82900000	Upstream LD3
B83000000	Downstream LD3
B83490000	Upstream LD1
B83500000	Downstream LD1
B83600000	~2 miles Downstream LD1

-  Lower Quartile Range of Flows ( $\leq 25\%$ )
-  Mid Quartile Range of Flows (26%-74%)
-  Upper Quartile Range of Flows ( $\geq 75\%$ )
-  Median Concentration

Water quality field parameters are displayed in Figure 9-20 to Figure 9-23. The graphics indicate pH (Figure 9-20), specific conductivity (Figure 9-21), and temperature (Figure 9-23) are negatively correlated, meaning higher concentrations or levels tended to occur during lower flows. However, DO is positively correlated with flow, meaning higher concentrations tended to occur during higher flows. Turbidity (Figure 9-24) and fecal coliform bacteria (Figure 9-25) are also positively correlated with the flow, suggesting both of these parameters are primarily stormwater driven in the Lower Cape Fear River. Nutrients are displayed in Figure 9-26 to Figure 9-29. NO<sub>x</sub> (Figure 9-28) is negatively correlated with the flow, having higher concentrations during lower flows, a signature that indicates this parameter is primarily point-source driven. Nutrient correlations were less distinct for the other three parameters. Overall, all of the records that had the highest mean and median concentrations for TKN (Figure 9-26) occurred during the highest flow bin, suggesting TKN is more stormwater-driven during high-flow rain events. However, there was inconsistency on whether higher concentrations occurred during mid or low-flow bins. Phosphorus (Figure 9-29) had the highest mean and median concentrations for the low-flow bin at four of the five stations, only B8300000 did not fit this pattern. This suggests phosphorus is more point-source driven during low flows, but potentially more surface-water driven during high or medium flows. No clear pattern was evident for ammonia (Figure 9-27).

Figure 9-20: Mean pH (s.u.) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations

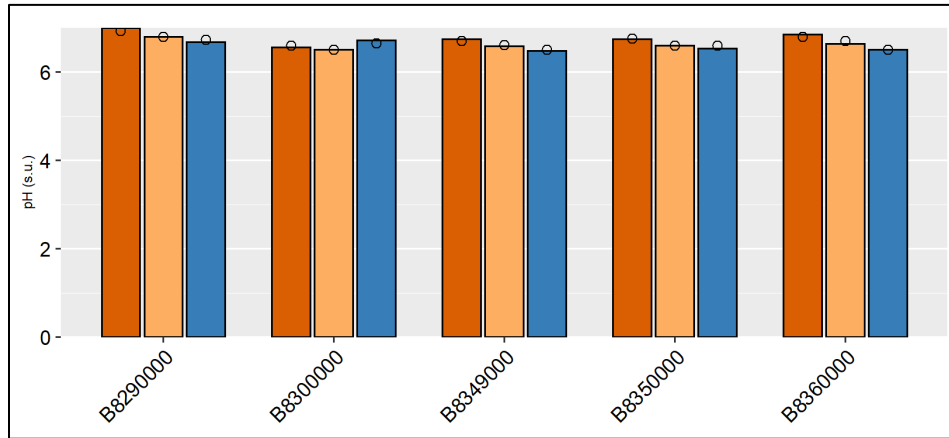
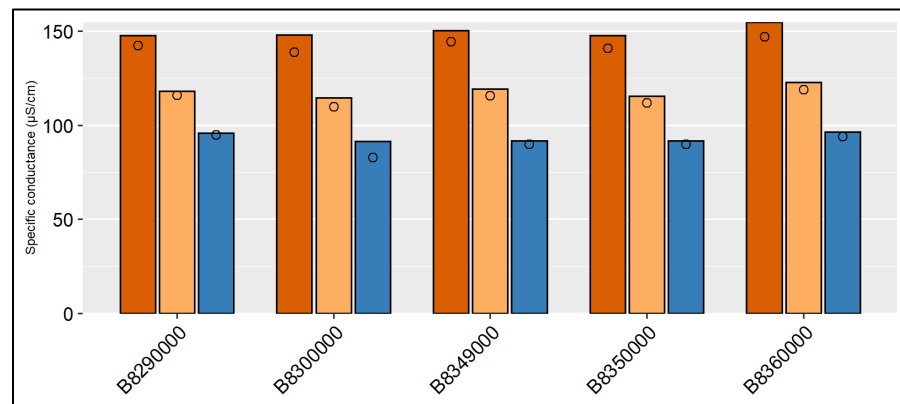


Figure 9-21 Mean Specific Conductivity ( $\mu\text{S}/\text{cm}$ ) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations



- Lower Quartile Range of Flows ( $\leq 25\%$ )
- Mid Quartile Range of Flows (26%-74%)
- Upper Quartile Range of Flows ( $\geq 75\%$ )
- Median Concentration

Figure 9-22: Mean DO (mg/L) for 2002-2020s and Flow Bins at Five Lower Cape Fear Mainstem Stations

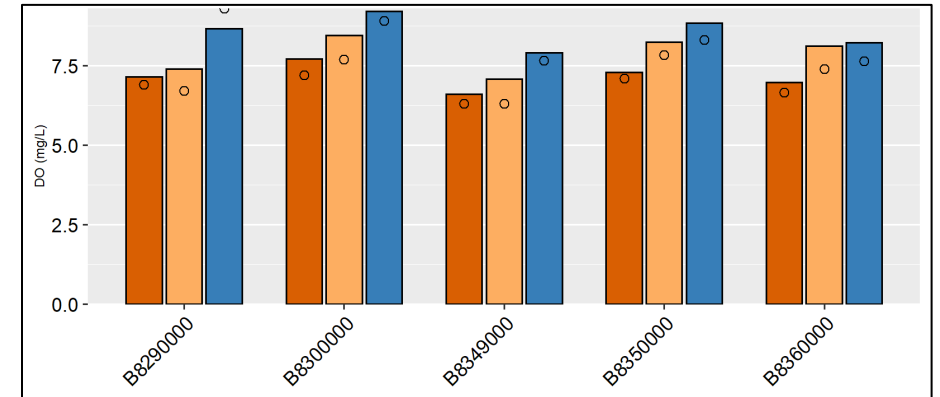
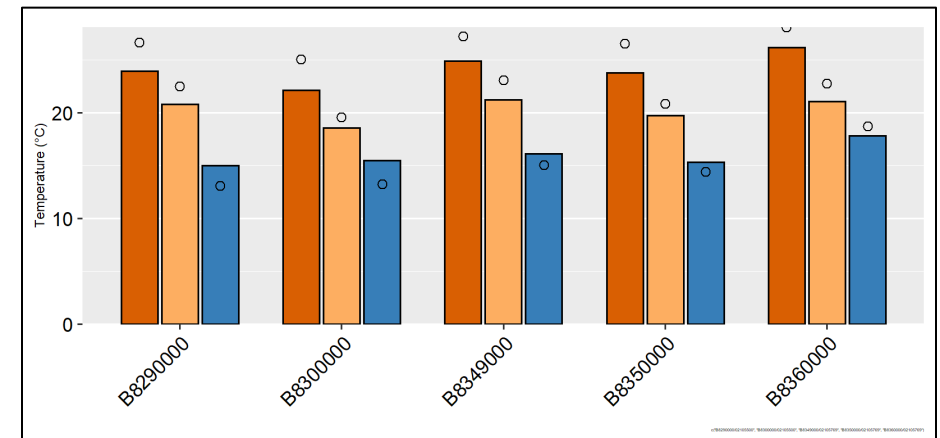


Figure 9-23: Mean Temperature ( $^{\circ}\text{C}$ ) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations



Stations B8290000 and B8300000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS gage Cape Fear River at Wilm O Huske Lock Nr Tarheel (Lock and Dam #3), NC (02105500) discharge from 1985-2020. Stations B3490000, B8350000, and B3600000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS Cape Fear River at Lock and Dam #1 Nr Kelly, NC (02105769) discharge from 1985-2020.

Figure 9-24: Mean Turbidity (NTU) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations

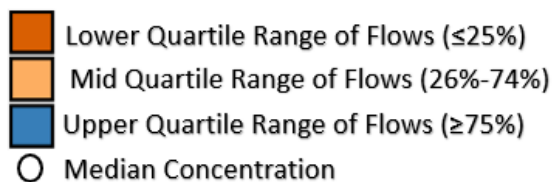
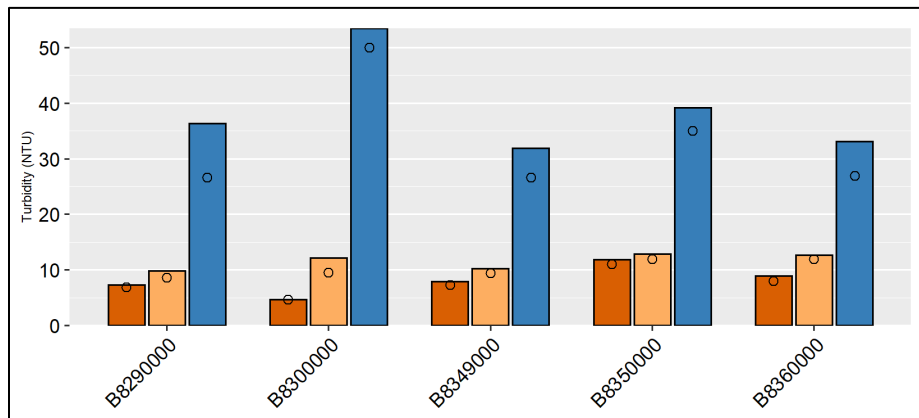
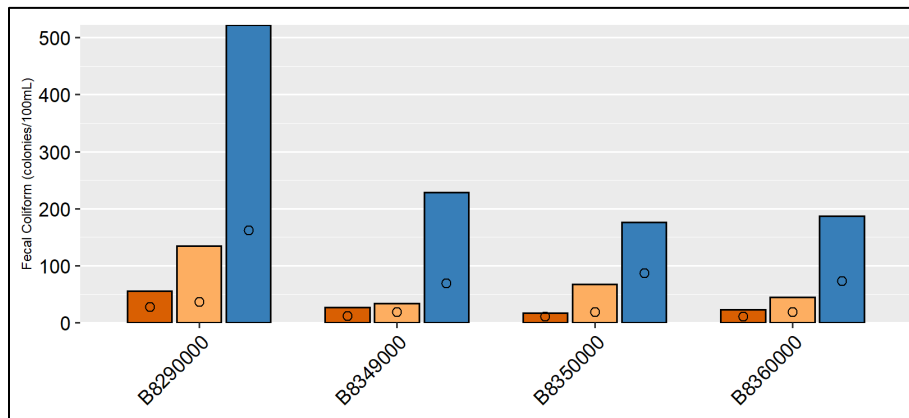


Figure 9-25: Mean Fecal Coliform (colonies/100mL) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations



Stations B8290000 and B8300000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS gage Cape Fear River at Wilm O Huske Lock Nr Tarheel (Lock and Dam #3), NC (02105500) discharge from 1985-2020. Stations B3490000, B8350000, and B3600000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS Cape Fear River at Lock and Dam #1 Nr Kelly, NC (02105769) discharge from 1985-2020.

Figure 9-26: Mean TKN (mg/L) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations

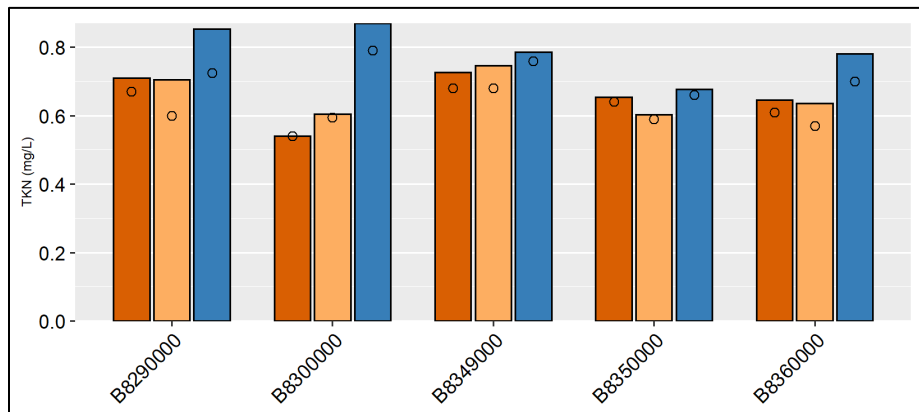


Figure 9-28: Mean NOx (mg/L) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations

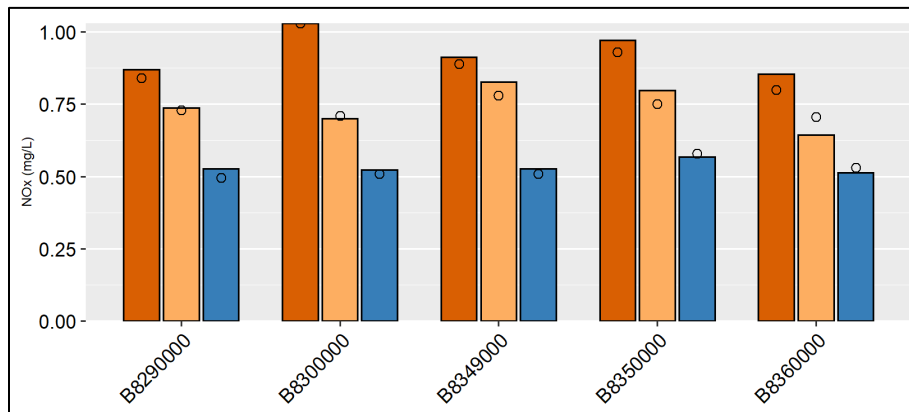


Figure 9-27: Mean Ammonia (mg/L) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations

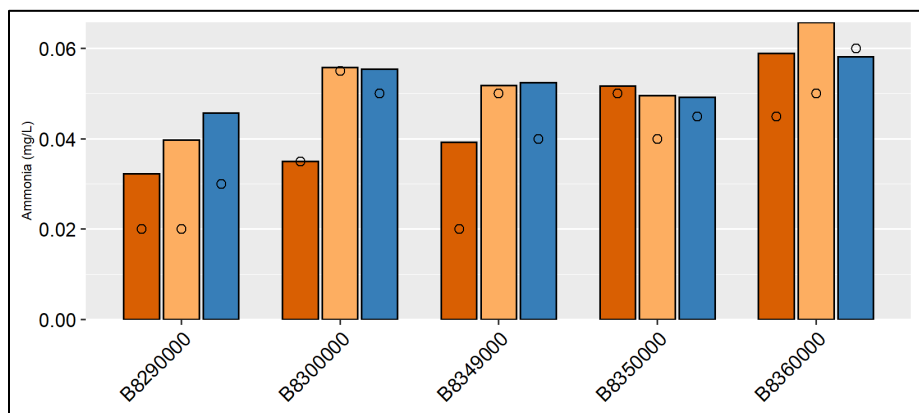
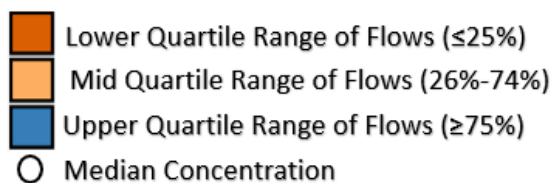
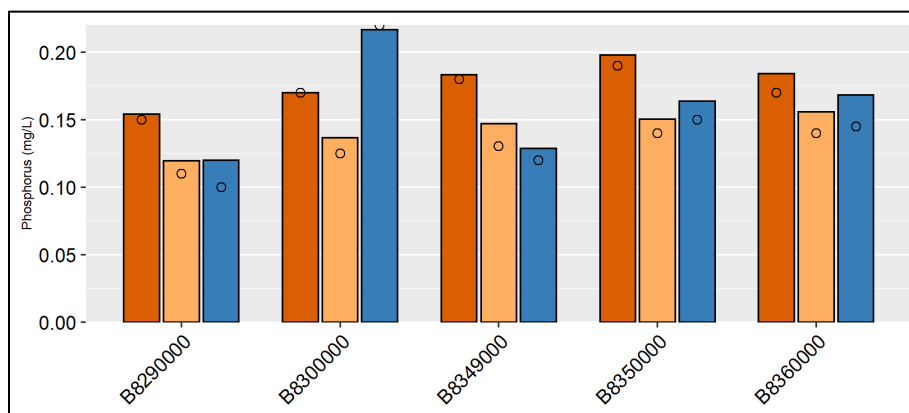


Figure 9-29: Mean Phosphorus (mg/L) for 2002-2020 and Flow Bins at Five Lower Cape Fear Mainstem Stations



Stations B8290000 and B8300000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS gage Cape Fear River at Wilm O Huske Lock Nr Tarheel (Lock and Dam #3), NC (02105500) discharge from 1985-2020. Stations B3490000, B8350000, and B360000 show mean and median concentrations for 2002-2020 with flow bins calculated from USGS Cape Fear River at Lock and Dam #1 Nr Kelly, NC (02105769) discharge from 1985-2020.

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.

## 1.8 Lower Cape Fear River Watershed Restoration Plans

The first step to watershed restoration is to develop a watershed plan. A watershed plan is a strategy and a work plan for achieving water resource goals that provide assessment and management information in a watershed. The Lower Cape River subbasin has one EPA-defined 9-element watershed plan that has been developed to address impaired waterbodies (*Table 9-15*). The City of Wilmington completed a 9-Element watershed restoration plan for Greenfield Lake, which is impaired for Chlorophyll *a*. See Section 9.9.6.1 Brunswick River-Cape Fear River Physical and Chemical Monitoring, for more information on Greenfield Lake and Chapter 4 for more information on watershed planning and 9-element plans.

*Table 9-15: Lower Cape Fear River Subbasin Watershed Plan*

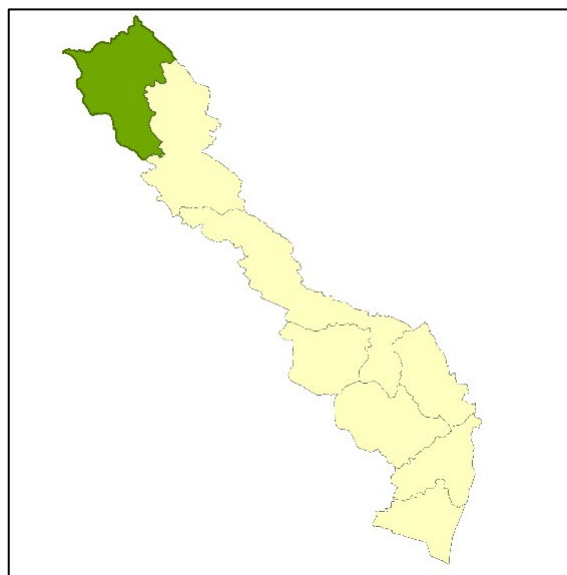
HUC8	HUC12	Watershed Plan	Plan Year	Plan Developer(s)
03030005	0503	<a href="#">Greenfield Lake 9-Element Plan</a>	2019	City of Wilmington

## 1.9 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 are 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 along with recommendations to protect and improve water resources in the watershed.

### 1.9.1 Harrison Creek-Cape Fear River (0303000501)

The Harrison Creek-Cape Fear River watershed is in the uppermost section of the Lower Cape Fear subbasin spanning 163 square miles in Cumberland and Bladen counties in the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions. This watershed receives drainage from the three upper subbasins, the Deep, Haw, and Upper Cape Fear. The Cape Fear River flows south through the watershed with the largest tributary, Harrison Creek, merging with the river at the lowest point of the watershed. Other smaller tributaries along the river from north to south include Cedar Creek, Big Alligator Swamp, Grays Creek, Hair Canal, Willis Creek, Georgia Branch, Huckleberry Swamp, and Phillips Creek. Part of the mainstem of the Cape Fear River and several tributaries, Hairs Mill Creek, Willis Creek, and Georgia Branch, are classified as WS-IV. The upper section of Grays Creek is Class B, or primary recreation.



In 2019, land cover in the Harrison Creek-Cape Fear River watershed was 23% agriculture, 25% forest, 35% wetland, and 8% development (*Table 9-6*). Agricultural lands, primarily found in the northwest corner, cover a higher percentage of the land in this watershed as compared to other watersheds in the Lower Cape Fear River subbasin (*Figure 9-6*). Pockets of development are also found in that northwestern corner along Grays Creek to the south of the Town of Hope Mills, which is in the Upper Cape Fear River subbasin. Wetlands are found in the southeastern section of the watershed along the Cape Fear River and to the east of it where several large intact Carolina bay wetlands are located, including Bushy Lake, a Carolina bay wetland that is classified as a unique wetland.

As of May 2022, there were one minor and three major NPDES wastewater discharge facilities permitted for 6.58 MGD, 13 AFOs permitted for 39,169 headcounts and 10,546,617 pounds of live weight, 1,120 acres of solid land application (primarily) and non-discharge wastewater fields, and three NPDES and 12 state stormwater facilities. The major NPDES facilities are industrial facilities that discharge directly to the Cape Fear River. The facilities include the Tar Heel Plant owned by Smithfield (NC0078344) with a permitted discharge of 3.0 MGD (described further below) and the Chemours Company-Fayetteville Works (described in the next section 9.9.1.1). Chemours Company-Fayetteville Works has two permits, NC0089915 with a permitted as-built discharge of 1.58 MGD for treated groundwater and stormwater and NC0003573 with a permitted flow of 2.0 MGD for processed wastewater discharged from Chemours tenants Dupont and Kuraray. In September 2022, Chemours received a third NPDES permit to discharge 2.38 MGD of treated stormwater and groundwater from seeps and extraction wells (NC0090042). AFO facilities include 10 swine COCs and three Animal Individual States. There are two permits associated with most of the residual land application fields in this watershed, the Fayetteville Public Works Commission (WQ0000527) facility for 473 acres and the Smithfield Fresh Meats Corps (WQ0014868) for 625 acres of residual solids. There is a concentration of residual solids land application fields along Grays Creek and the lower end of Harrison Creek near the Cape Fear River confluence (*Figure 9-19*).

Smithfield Farmland Corporation (NC0078344) – Tar Heel Plant is a 3.0 MGD treatment plant with a 2022 daily average flow of 2.27 MGD. This facility is regulated under the 2004 Federal Effluent Guidelines for Meat and Poultry Products, 40 CFR 432 new source performance standards (NSPS) [432.25(b)(1)]. This translates to a permitted TN limit of a monthly average (MA) of 134 mg/L and a daily mean (DM) of 194 mg/L. In 2022, the TN mean effluent concentration was 103.98 mg/L with a maximum concentration of 155 mg/L and a minimum concentration of 61.4 mg/L. The TN was made up of mostly NOx as the 2022 yearly mean concentration was 102.98 mg/L with a maximum and minimum of 154 and 60.4 mg/L, respectively. This type of industrial permit does not require a TP limit under the federal effluent guidelines. Their 2022 yearly mean TP concentration was 28.37 mg/L.

Smithfield NC0078344	2022 Yearly (1/1-12/30/22)		
	Mean	Max	Min
TN (mg/L)	103.98	155	61.4
NOx (mg/L)	102.98	154	60.4
NH3 (mg/L)	0.21	3.18	0.1
TKN (mg/L)	< 1.0	< 1.0	< 1.0
TP (mg/L)	28.37	42	16.5
Flow (MGD)	2.27	3.56	0.16

At its discharge point in the mainstem Cape Fear River, the Instream Waste Concentration (IWC) is only 0.58%, so the waste signature is highly diluted, but its overall load to the system is very large in comparison to other major dischargers in the region. The wastewater is approximately 98% industrial and 2% domestic with wastewater generated from the production areas, trailer wash, truck maintenance garage, and sanitary facilities. Sanitary wastewater is treated through a separate sanitary wastewater package plant and then mixed with treated processed wastewater before going through UV disinfection and discharged through its Outfall 001 to the Cape Fear River.

The facility was required to upgrade the system to meet the new federal effluent guidelines. They began WWTP improvements in 2007 to comply with the new permit limits. They are permitted to have a maximum annual production of 9,500,000 hogs per year (not to exceed a bi-weekly maximum of 390,000 hogs/two-week slaughter rate). According to the 2017 NPDES permit fact sheet, their maximum annual production was reported as 8,242,389 hogs/year.

For this assessment (2002-2020), there are six ambient stream monitoring stations (one AMS, four Coalition, and one co-located), one benthic macroinvertebrate special study site, and one fish community station used to assess the water quality conditions (*Table 9-12*, also see the Chapter 2 Appendix).

#### 1.9.1.1 Emerging Contaminants (PFAS/GenX): Chemours

Since 2017, DEQ has taken decisive action to require Chemours to significantly reduce the release of PFAS, including GenX, into North Carolina’s air, water, and soil. GenX is the industry name for hexafluoropropylene oxide-dimer acid (HFPO-DA). It is a type of PFAS (per and poly-fluoroalkyl substances), a man-made chemical used in non-stick coatings and other manufacturing purposes. PFAS are known as “forever chemicals” because they are extremely persistent in the environment and do not break down naturally. Studies using animals exposed to PFAS at high levels have caused changes to the liver, thyroid, pancreas, and hormone levels. Chapter 2 has more information on Contaminants of Emerging Concern (CECs) and chapter 12 covers Cape Fear River Basin and statewide specific PFAS studies and actions taken by DEQ and EPA.

The Chemours facility is located on a 100-foot-high bluff on the west side of the Cape Fear River. The 2,000-acre property is bounded by Willis Creek to the north and Georgia Branch to the south in Bladen County. Historically, the DuPont Fayetteville Works facility (NC0003573) was permitted to discharge 2.0 MGD to a channel just below Lock & Dam #3 (W.O. Huske Dam). In June 2012, the outfall was moved upriver approximately 0.7 miles to an internal outfall, above the dam and closer to the facility. In 2015, ownership changed to Chemours, and the permit was re-issued (NC0003573) in July for the same as-built discharge from the internal outfall.

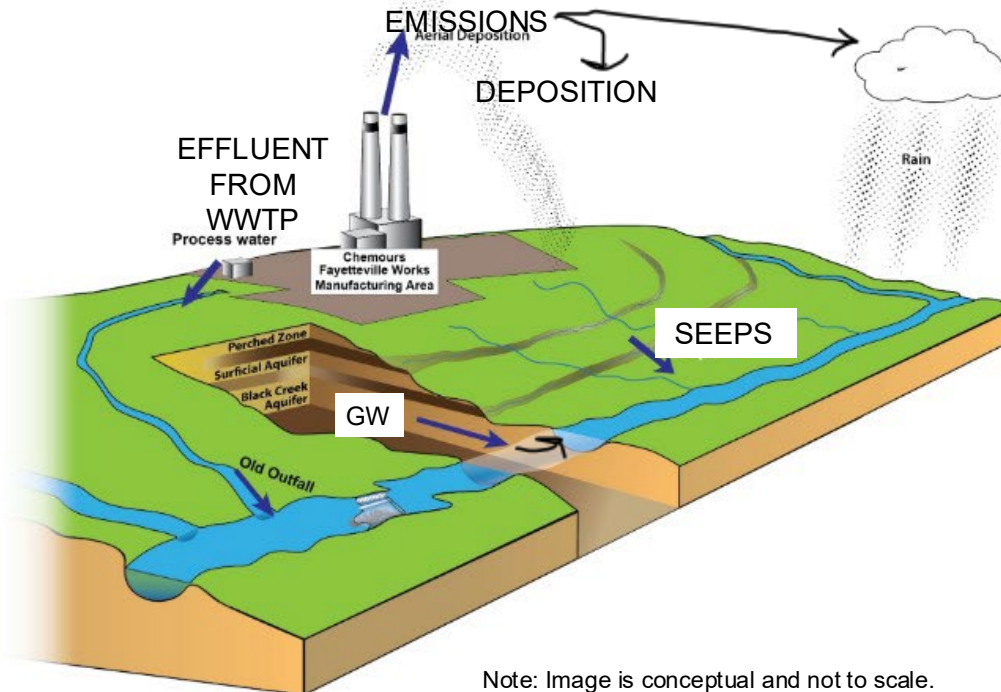
In 2016, PFAS, specifically GenX was discovered in the Cape Fear River, prompting a coordinated [investigation](#) by DEQ and NC DHHS to identify the source. High levels of PFAS compounds were found in monitoring wells on the property owned by Chemours. Since the Chemours facility is upstream of four drinking water supply intakes and surrounded by private drinking water, mitigative steps were essential to protect the drinking water of residents. NC DHHS established a provisional drinking water health goal for GenX of 140 ppt (parts per trillion). In June 2022, EPA established a final GenX health advisory of 10 ppt and in April 2024, finalized 10ppt as the EPA National Primary Drinking Water Regulation enforceable drinking water standard that applies to public drinking water systems. Since 2017, DEQ has prohibited the discharge of all process wastewater from Chemours to the Cape Fear River. Continued investigation at the Chemours site found PFAS entered the environment through four sources: the old outfall channel (discharging below the dam), four seeps, groundwater, and through air emissions from facility stacks in wet and dry deposition form (*Figure 9-30*).

In February 2019, a [Consent Order](#) between DEQ, the Cape Fear River Watch (represented by the Southern Environmental Law Center [SELC]), and Chemours was entered in the Bladen County Superior Court. The court-enforceable order requires Chemours to address PFAS sources and contamination at the facility to prevent further impacts to air, soil, groundwater, and surface waters, including:

- Sampling of private wells for PFAS and providing replacement drinking water supplies to impacted residents.
- Implementing multiple remedial strategies to significantly reduce Chemours' PFAS discharges to the Cape Fear River.
- Installation of a thermal oxidizer and reduction of GenX air emissions facility-wide by 99.9%.
- Conducting a comprehensive assessment of on- and off-site groundwater contamination that complies with the requirements of Title 15A of the North Carolina Administrative Code (NCAC), [Subchapter 2L Groundwater Classification and Standards](#).
- Other compliance measures to characterize and reduce PFAS pollution leaving the Fayetteville Works site.

In August 2020, NCDEQ ordered significant additional actions by Chemours to prevent PFAS pollution from entering the Cape Fear River in the [Addendum to the Consent Order](#). These actions address more than 90% of the PFAS entering the Cape Fear River through groundwater from the residual contamination on the site. The addendum required the design of a barrier wall, with extraction wells and a treatment system to address the contaminated groundwater beneath the site that flows to the Cape Fear River.

Figure 9-30: Main sources of PFAS from Chemours to environment before 2017 ([NCDEQ](#), October 2022)



To reduce the PFAS loading to the Cape Fear River, pursuant to the 2019 Consent Order, Chemours requested a new NPDES permit (NC0089915) for the discharge of treated groundwater, stormwater, and surface water from a stream located on the southern portion of its property. Referred to as Old Outfall 002, the channel was used to discharge processed wastewater from the facility until June 2012 when the processed wastewater discharge was moved to its current location above Lock & Dam #3. The new permit allowed Chemours to begin remediation steps to meet the requirements in the Consent Order and reduce PFAS loading to the Cape Fear River by implementing a treatment system to capture and treat flow at Outfall 003 (Old Outfall 002) before discharging to the river by September 30, 2020. The treatment system had to meet discharge standards set by DEQ. In addition, a minimum 99% effective removal of indicator PFAS parameters, including GenX and two other compounds (perfluoro-2-methoxy acetic acid [PFMOAA] and perfluoro-2-methoxypropanoic acetic acid [PMPA]), had to be achieved. The Outfall 003 treatment system, installed in 2020, has multiple components to treat water, including influent oxidation, coagulation and pH adjustment, ultrafiltration, and granulated active carbon (GAC) to remove PFAS compounds. Chemours also installed seep flow-through cells at the four seeps that contain activated carbon to treat groundwater that surfaces before it enters the river, and a capture dam on the channel for Outfall 003. Treated process water is discharged below the capture dam. Water captured behind the dam is treated before it is discharged through Outfall 003 ([Fact Sheet NPDES Permit Number NC0089915](#), February 12, 2020).

Chemours has had one enforcement case (NOV-2021-PC-0047) under permit NC0089915 for a daily maximum exceedance limit violation that occurred on October 29, 2020. The 1.2 µg/L calculated value

was 14.18% over the 0.85 µg/L limit value for PFMOAA. A history of [Enforcement Actions](#) and available related documents are available [here](#).

Contaminated groundwater, the residual effect of decades of manufacturing, still flows into the Cape Fear River along the facility's riverbanks. Groundwater is the largest reoccurring source of PFAS from the Chemours site to the Cape Fear River. The installation of a barrier wall and extraction system was completed on June 11, 2023, to intercept and treat groundwater before it enters the river. The wall will also intercept and treat flow from the four main seeps (*Figure 9-31 and Figure 9-32*). The underground wall is over one mile long (6,050 ft), three feet wide, and have a depth of 75-100 feet with a design for low permeability and strength of 100 psi (pounds per square inch). Sixty-eight extraction wells have been installed behind the wall footprint to collect contaminated groundwater stopped by the wall. Contaminated groundwater is pumped into a treatment system for the removal of PFAS compounds. Process water from the treatment system will be discharged through Outfall 004 (Chemours remediation NPDES permit number NC0090042), and the solids generated in the treatment process will be tested and shipped off-site to either an incinerator or a licensed landfill. The permit for Outfall 004 requires:

- Treatment to remove 99% of the PFAS compounds collected from the groundwater extraction wells and four main seeps near the riverbanks (per Consent Order)
- Technology limits requiring maximum treatment removal beyond 99%
- Comprehensive stream sampling to assess loadings of PFAS in the river as the wall is being installed and after completion.

*Figure 9-31: Barrier Wall and Groundwater Treatment System*

### Proposed Groundwater Treatment System

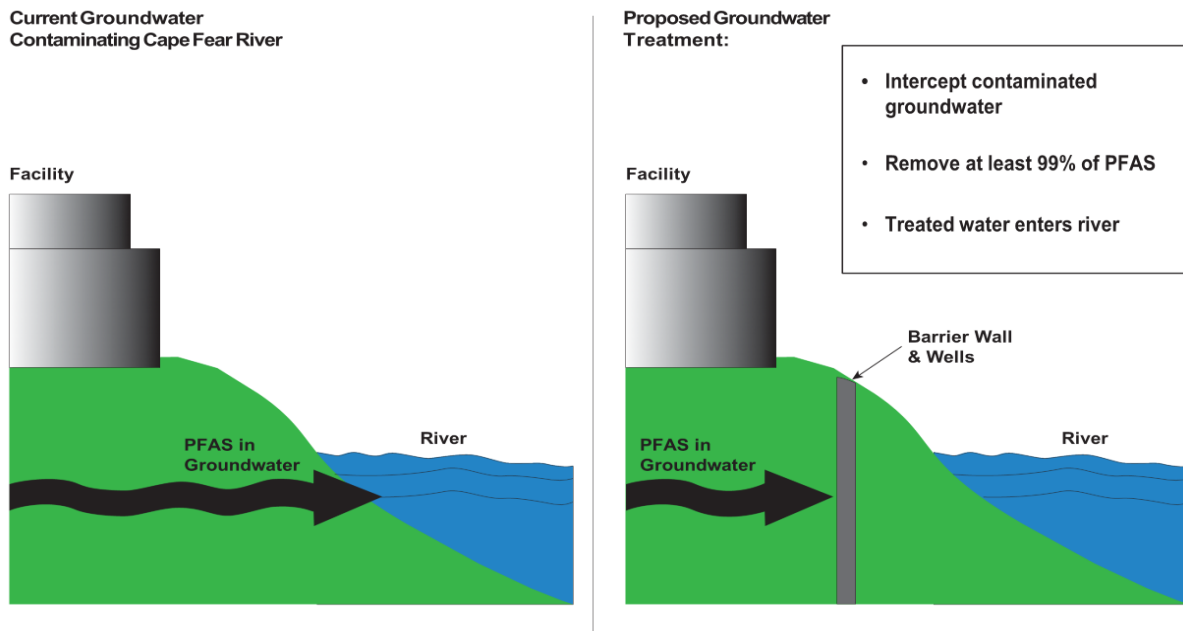
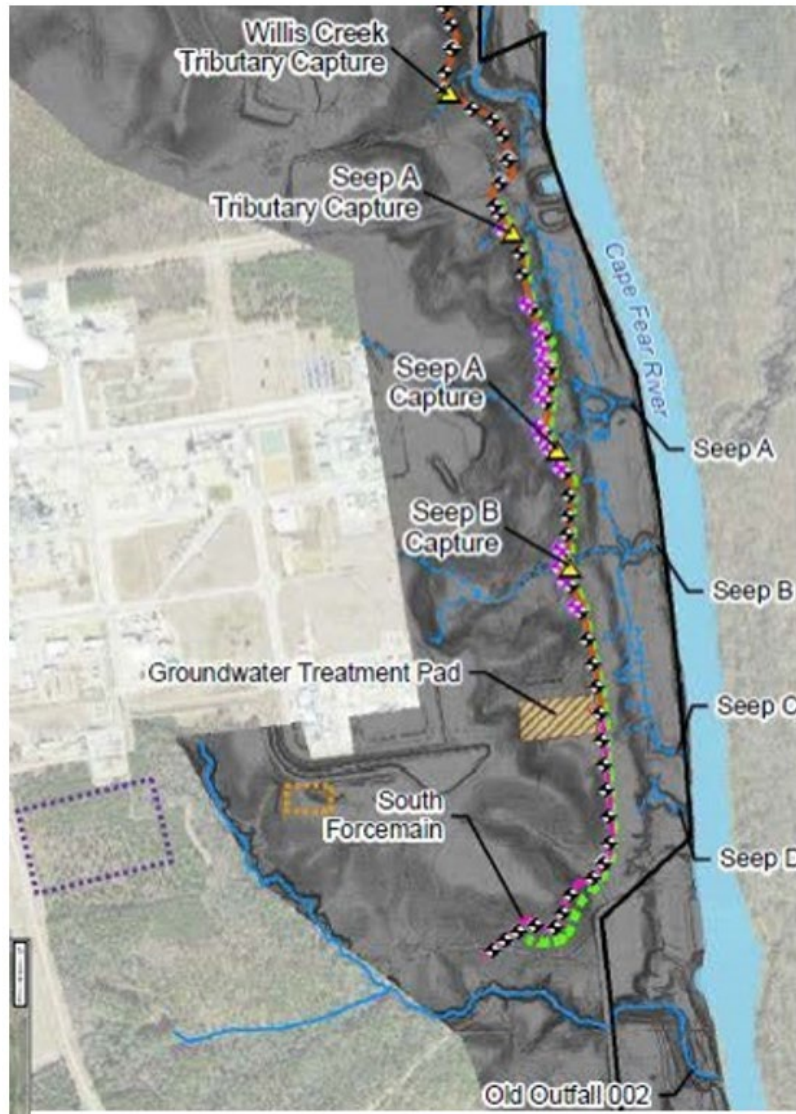


Figure 9-32: Barrier Wall and Groundwater Treatment System (NCDEQ, October 2022)



The remediation permit (NC0090042) allowed Chemours a six-month optimization period to achieve 99% removal of the indicator PFAS parameters, HFPO-DA, PFMOAA, and PMPA. After six months the permit sets Technology Based PFAS Limits greater than 99% removal for:

- HFPO-DA (GenX) at  $<0.010 \mu\text{g/L}$
- PFMOAA at  $<0.020 \mu\text{g/L}$
- PMPA not to exceed  $0.010 \mu\text{g/L}$ .

The design flow for Outfall 004 is 2.38 MGD. It is for treated contaminated groundwater, stormwater, and two seeps (A and B) and will be rerouted to Outfall 002, which will allow for the potential consolidation with Chemours' other NPDES wastewater permit (NC0003573) in the future. The permit does not authorize the discharge of any process wastewater from Chemours. The only process wastewater

discharge comes from Chemours tenants, Dupont, and Kuraray. The permit requires extensive instream monitoring ([Fact Sheet NPDES Permit Number NC0090042](#), September 14, 2022).

### Statewide approach to PFAS

As a result of the experience related to contamination from Chemours, North Carolina has been aggressively moving forward to manage the risks of PFAS statewide. On June 7, 2022, the [North Carolina DEQ Action Strategy for PFAS](#) was released. The strategy prioritizes three key action areas:

- **Protecting Communities** – NCDEQ will continue to identify and notify those who may be at risk of exposure, investigate the human health risks and expand the base of scientific knowledge for North Carolina-specific PFAS compounds.
- **Protecting Drinking Water** – NCDEQ will work to minimize future releases of PFAS to drinking water sources by setting regulatory standards and driving actions to prevent future PFAS pollution.
- **Cleaning Up Existing Contamination** – NCDEQ will continue to hold responsible parties accountable for remediating known PFAS contamination sites affecting drinking water.

Under the Action Strategy for PFAS, DEQ is taking a whole-of-department approach to protect communities by identifying, reducing, and remediating PFAS pollution.

An in-depth PFAS chapter (Chapter 12) is included in this basin plan, which focuses on how DEQ is addressing PFAS contamination in the Cape Fear River Basin as well as statewide. The PFAS chapter identifies studies that have been completed (through 2024 and part of 2025) and how those studies are helping identify actions and strategies for reducing PFAS in air, groundwater and surface water.

#### 1.9.1.2 Harrison Creek-Cape Fear River Physical and Chemical Monitoring Ambient Stream Monitoring

At the HUC10 level, the Harrison Creek-Cape Fear River watershed had the highest mean concentrations for TKN, NO<sub>x</sub>, TN, and turbidity in the Lower Cape Fear subbasin from 2016 to 2020 (see [Table 9-13](#)). However, only three stations along the mainstem, B82900000, B8302000, and B8305000, fit the minimum five years and 40 record requirements for the evaluation. One tributary station, B8315000, and four mainstem stations, B82900000, B8300000, B8302000, B8305000, were monitored for the 2022 IR. The tributary stations are described in this section and the mainstem stations are described in Section 9.9.3, Harrison Creek and Turnbull Creek Cape Fear River Mainstem Physical and Chemical Evaluation.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistic as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

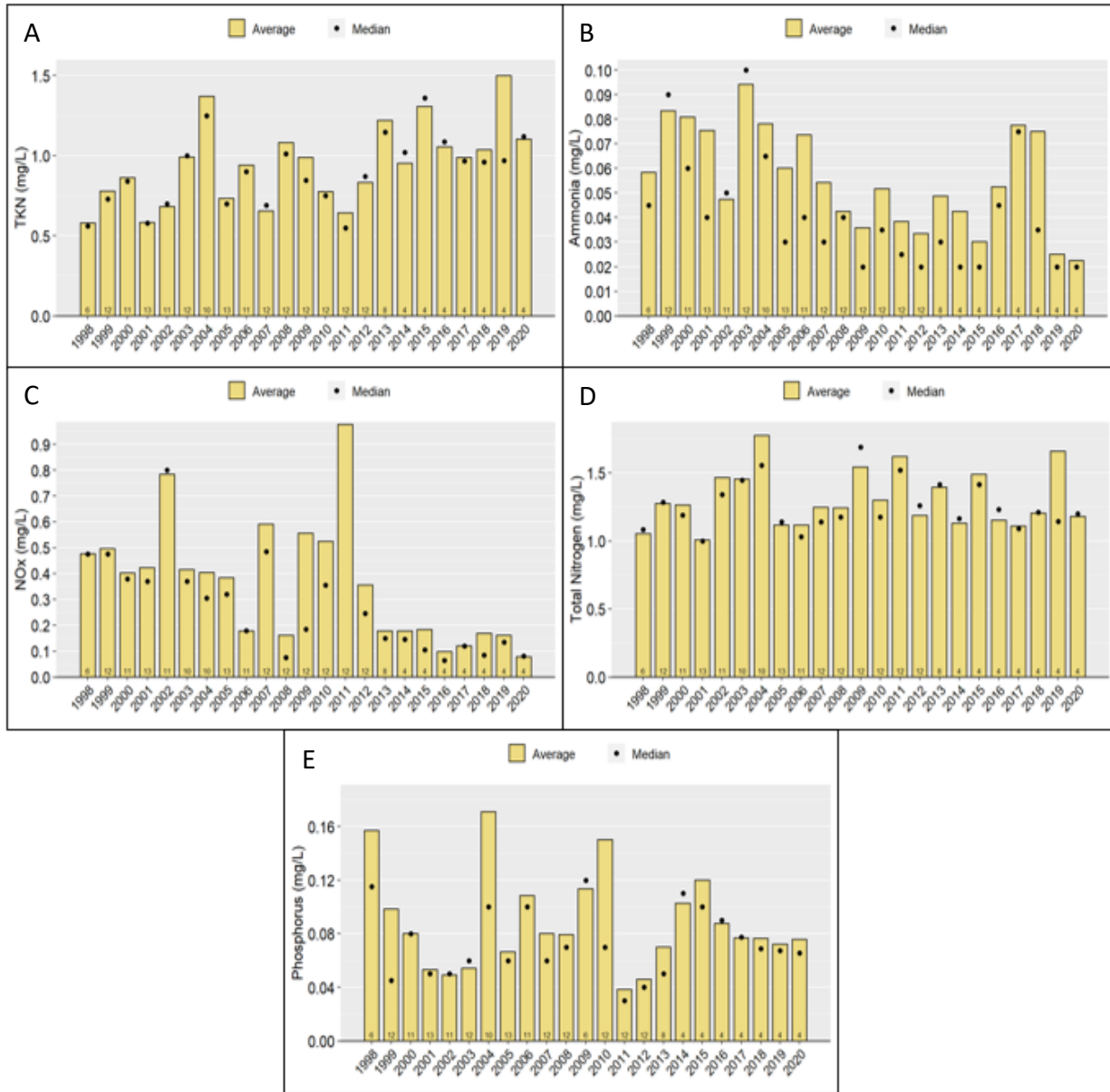
Station B8315000 was monitored by the MCFBA along the lowest Cape Fear tributary, Harrison Creek. The Harrison Creek assessment unit (AU# 18-42b), also called Little Alligator Swamp, is defined as class C from source to 0.3 miles downstream of SR1318 for 4.8 FW miles. In 2019, the 33 mi<sup>2</sup> rural watershed for B8315000 was 56% wetland, 14% agriculture, 18% forest, and 8.5% grassland/shrub. There has been a 1%

loss of forest since 2001 in this watershed (see Chapter 2 Appendix, Land Use and Land Cover for AMs and Coalition Station Watersheds table). In May 2022, the B8315000 watershed had three swine AFOs with 3,212,700 lbs allowable weight and 83 acres of residual solid land application fields for Smithfield Fresh Meats Corps. The residual solids fields are located close to the stream and more field acres are below the station. On the 2022 IR, this AU was meeting criteria for all parameters except fish community, which was data inconclusive (see the next section).

Station B8315000 was sampled monthly from 2002 until 2013 when the sampling schedule was changed to quarterly. Mean concentrations over the last five years (2016-2020) at B8315000 were 3.82 NTU for turbidity, 4.24 for pH, 7.32 mg/L for DO, 127.0 colonies/100 mL for fecal coliform, and 56.55  $\mu$ S/cm for specific conductivity. The exceedance rate below the 6.0 standard for pH has been 100% over the last five years and most years prior. This is likely due to the high percentage of wetland cover in the watershed. The AU was assessed in category 3a, potentially due to natural conditions for the 2022 IR. A natural condition assessment should still be done on this AU. There have been few exceedances for DO and none for turbidity since 2002. Fecal coliform has had no yearly exceedances over 400 colonies/100 mL since 2013, before that, yearly exceedance ranged from 8% to 18%, with no notable monthly pattern when the exceedances occurred.

Mean concentrations for nutrients over the last five years were 1.13 mg/L TKN, 0.05 mg/L ammonia, 0.12 mg/L NO<sub>x</sub>, 1.26 mg/L TN, and 0.08 mg/L TP. TKN is notably high, ranging from 0.59 to 3.43 mg/L with a 75<sup>th</sup> percentile of 1.23 mg/L. TKN and NO<sub>x</sub> concentrations indicate station B8315000 has a high organic-to-inorganic nitrogen ratio. Yearly means also suggest TKN has been increasing, ammonia and NO<sub>x</sub> have been decreasing, and TN concentrations have remained consistent (*Figure 9-33A, B, C, D*). TP has been variable, with higher concentrations before 2013, and lower concentrations, in more recent years (*Figure 9-33E*).

Figure 9-33: Station B83150000 Yearly Mean Nutrient Concentrations Harrison Creek



A comparison of these five-year nutrient means to DWR’s WSS Intensive Survey Branch (ISB) special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) shows TKN concentrations are extremely high, more than twice the recommended <0.5 mg/L. TN is also over 0.8 mg/L, the Coastal Plain recommendation due to the TKN fraction. Ammonia is comparable to the 0.05 mg/L recommendation and NOx, at 0.12 mg/L, is well within the <0.3 mg/L recommendation. TP concentrations are also very high, 60% over the recommended 0.5 mg/L. The change in organic nitrogen (TKN minus ammonia) could be related to several factors, including the presence of residual solids fields near the stream, permitted AFOs,

and change in land use. Aerial photography also indicates there may be a few poultry farms in this watershed.

When environmental conditions are optimal, the elevated nutrients in the Cape Fear River system can result in algal bloom development. HABs have been identified in the Cape Fear River since 2009. NC DHHS routinely warns the public to avoid contact with large accumulations of algae and to prevent children and pets from swimming or ingesting water in areas of algal blooms. Chlorophyll *a* and algal bloom results are discussed below in section 9.10.4 for the mainstem Cape Fear River as a whole.

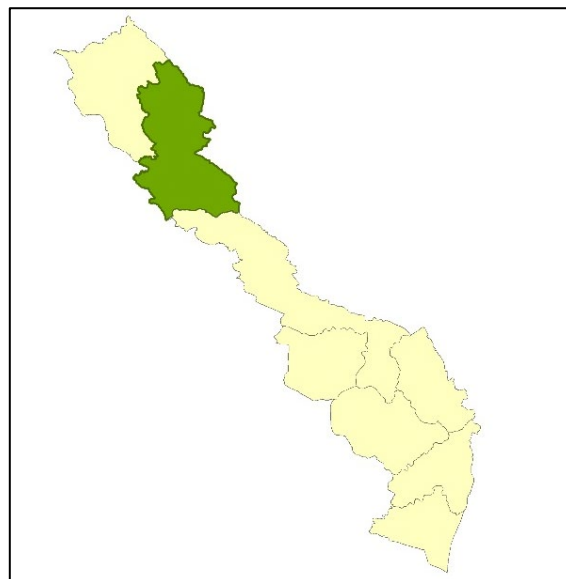
### 1.9.1.3 Harrison Creek-Cape Fear River Biology Monitoring

There are two biological monitoring sites, one benthos, and one fish, co-located on Harrison Creek. Benthic community site BB271 at SR 1318 was last sampled as a Special Study site in 2003 and received a bioclassification rating of Good-Fair. Fourteen EPT taxa were collected in 2003, down from 17 when it was sampled in 1998. Biologists noted instream substrate dominated by sand and described water clarity as “tannic”. pH at the time of sampling was 4.4 and DO was 4.6 mg/L. DO is close to the 4.0 mg/L standard and pH is below the 6.0 standard. As was noted in the previous section, this is likely due to the high percentage of wetland cover in the watershed. A natural condition assessment should be done on this AU. Water quality conditions are likely natural to this system and not indicative of water quality impacts, although there appears to be some agricultural and timbering activity in the catchment, which could be influencing instream habitat composition. Fish community site BF91 was sampled once in 2008 when it was Not Rated, potentially due to drought conditions.

Year	Bioclassification
<b>BB271</b>	
2003	Good-Fair
<b>BF91</b>	
2008	Not Rated

### 1.9.2 Turnbull Creek-Cape Fear River Watershed (0303000502)

The Turnbull Creek-Cape Fear River watershed receives drainage from the upper three subbasins and the Harrison Creek-Cape Fear River watershed. This watershed spans 193 square miles of the Southeastern Plains and Middle Atlantic Coastal Plain ecoregions in primarily Bladen County. The Town of Elizabethtown is the largest municipality in the Turnbull Creek-Cape Fear River watershed. The Cape Fear River passes through the western side of the watershed flowing in a southeastern direction. Turnbull Creek merges with the Cape Fear River near Elizabethtown in the lower part of the watershed. Other smaller Cape Fear River tributaries include Bakers and Ellis creeks, located north of Elizabethtown, and Browns Creek, located on the southern side of Elizabethtown.



In 2019, the Turnbull Creek-Cape Fear River watershed had nearly 30% forest and over 40% wetland cover, there was also 9% grassland/shrub cover, 11% agriculture, and 6% development (see [Table 9-6](#) and [Figure 9-6](#)). Most of the wetlands and much of the forested areas occur in the lower elevation Middle Atlantic

Coastal Plain portion of the watershed to the east of the Cape Fear River. This section of the watershed, in the vicinity of Ellis and Turnbull creeks, has a dense array of Carolina bays, including several that have formed lakes: Jones, Salters, Little Singletary, and White. There are several properties in this watershed managed for biodiversity (see Chapter 4, Land Conservation and Preservation). The wetlands surrounding Jones and Salters lakes, in Jones Lake State Park, are classified as unique wetlands. Jones, Salters, and White lakes are also Class B, primary recreation waters open for swimming.

As of 2022, there were one major and two minor NPDES wastewater discharge facilities permitted for 1.225 MGD as-built, 21 swine AFOs, 55 acres of land application of residual solids fields, and six NPDES stormwater and three state stormwater facilities in the Turnbull Creek-Cape Fear watershed. The swine AFOs are permitted for a total headcount of 119,252 and a total live weight of 15,273,300 lbs with 72 lagoons. The one major NPDES facility in this watershed, Elizabethtown WWTP (NC0026671), is permitted to discharge 1.225 MGD to the Cape Fear River mainstem.

For the years assessed in this plan (2002-2020), there are nine ambient stream monitoring stations (two AMS, seven Coalition), three benthic macroinvertebrate basin sites, and one fish community station used to assess the water quality conditions over this time period (*Table 9-12*, also see the Chapter 2 Appendix). Three of the four bay lakes were monitored during the timespan of this plan in the Turnbull-Cape Fear watershed, Jones, Salters, and White lakes. White Lake has had concerning water quality issues that include eutrophication, algal communities changing from green to blue-green, and fish kills. Jones Lake, 214.1 acres in size (AU# 18-46-7-1) was impaired for pH in 2022 due to acidic conditions likely from swamp stream drainage. A supplemental Sw classification may be warranted for this AU.

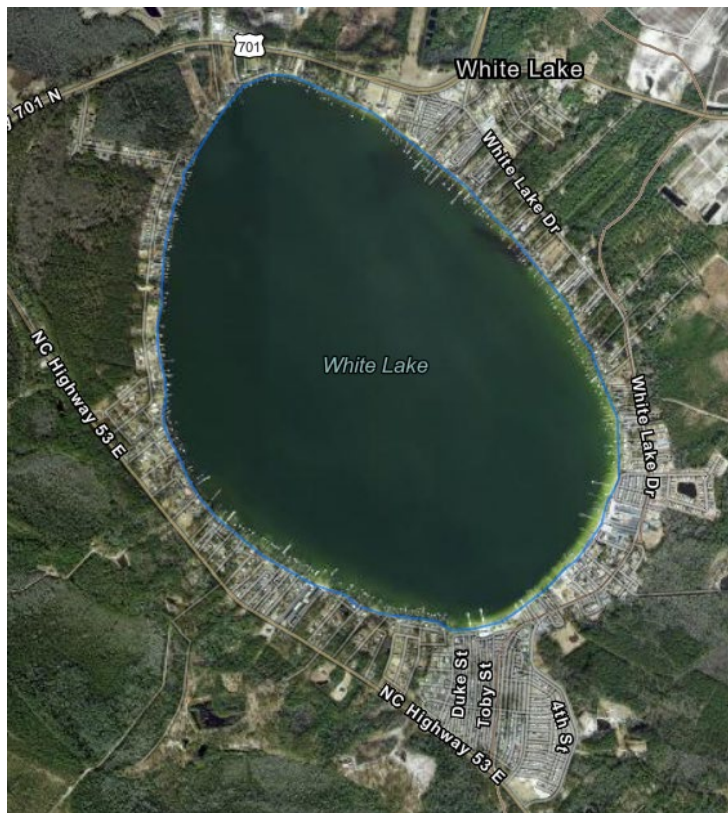
### 1.9.2.1 Turnbull Creek-Cape Fear River Physical and Chemical Monitoring Lakes Monitoring

Jones (AU# 18-68-17-5-1) and Salters (AU# 18-46-8-1) lakes are both natural, shallow, undeveloped bay lakes located within Jones Lake State Park in Bladen County. Both bay lakes are considered “dystrophic,” meaning they contain high amounts of humic substances and organic acids. Dystrophic lakes have characteristic tea coloration naturally colored by tannins. North Carolina Trophic State Index (NCTSI) scores are not generated for dystrophic lakes. These bay lakes receive almost no overland inputs of water, relying instead on precipitation and groundwater for recharge. The lakes are located within the swampy terrain of the surrounding Carolina bays, which likely contributed to the acidic conditions of both lakes (NC DWR 2018). In 2018, the pH levels ranged from 3.8 to 4.9 in Salters Lake and 3.9 to 4.8 in Jones Lake, which was also impaired for pH in 2022. DO levels were also low, ranging from 3.8 to 4.9 mg/L



at Salters and 3.9 to 4.8 mg/L at Jones. At Salters Lake, total phosphorus concentrations in 2018 were consistently 0.02 mg/L from May through September. TKN ranged from 0.52 to 0.71 mg/L and total organic nitrogen ranged from 0.05 to 0.12 mg/L. Chlorophyll *a* values ranged from 2 to 18 µg/L (micrograms per liter), which was well below the state water quality standard of 40 µg/L. At Jones Lake in 2018, total phosphorus ranged from <0.2 to 0.04 mg/L and TKN ranged from 0.63 to 0.77 mg/L. Chlorophyll *a* values monitored in September were at their highest record, 42 µg/L, exceeding the 42 µg/L state standard (NC DWR 2018). A natural conditions assessment should be done for both lakes to determine if pH impairment is warranted.

White Lake (AU# 18-46-8-1) is a shallow, 1,068-acre Carolina bay lake located near Elizabethtown, in Bladen County close to the Black River subbasin watershed boundary (NC DWR 2018). Except for a small, 0.12-mile-long strip of land along the northern shoreline, the entire 4.8-mile shoreline is developed for residential and some commercial uses. Approximately two-thirds of the lake shoreline is bulk-headed with the remaining one-third of the lake shoreline being gently sloped. The clear water has made it a popular recreation and tourist destination for years and an important resource for the local economy (NC DEQ September 2019). White Lake is an unusual Carolina bay lake in that the water of this lake has historically been clear rather than tea-colored by tannins like the other Carolina bay lakes in the basin.



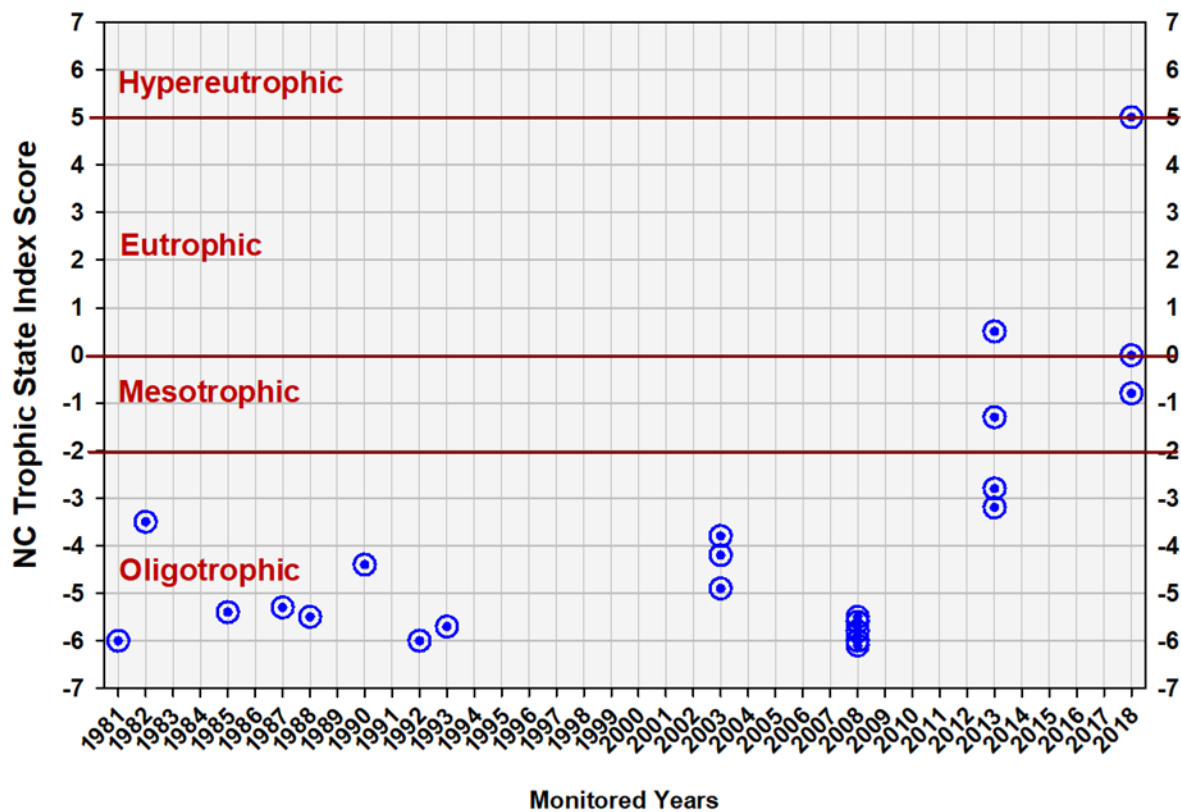
The clarity has been attributed to the numerous springs at the bottom of the lake that historically dominated water inputs as opposed to shallow (near-surface and organic) groundwater inflow typically observed in other Carolina bay lakes. The water level of White Lake is determined by the regional water table and, in drought years, will drop in response to the decrease in rainfall and groundwater spring input. The outlet channel is in the northwestern section of the lake as opposed to the southeastern section as in other bay lakes (Frey, D.G., June 1949; Wells, B.W. et al., 1953).

DWR has monitored White Lake since 1981 as part of the routine basinwide assessment. The historically clear, oligotrophic water started changing around 2010 as documented by the 2013 Basinwide Assessment Program. White Lake was predominately oligotrophic from 1981 to 2008 and is the only lake in the basin that has changed from oligotrophic in 2008 (NC DWR 2009), to mesotrophic in 2013 (NC DWR 2014), then to eutrophic in 2018 (NC DWR 2018) (Figure 9-34). The formula for determining NCTSI trophic level is comprised of total organic nitrogen (TON) and TP, Secchi depth, and chlorophyll *a*. Of those

components, TON, and chlorophyll *a* were the most significant contributors to the upward trend in NCTSI over the 34-year time frame (NC DWR 2017).

The increase in trophic status in such a short period is of particular concern as water quality in the once crystal-clear lake declined. Monitoring data showed a substantial increase from the 1981-2008 pH range of 3.3 to 5.3 up to 5.6 to 8.5 from 2013-2018 (NC DWR, 2017[Trend paper]) & NC DWR 2019 [2019 report of 2018 conditions]) (Figure 9-35). A significant increase was also seen in nutrients, mostly organic nitrogen and phosphorus, which caused higher biological productivity documented in high chlorophyll *a* concentrations (Figure 9-35 and Figure 9-36). The shift in pH and nutrient availability produced a shift in the lake flora and fauna. DWR first identified the presence of blue-green algae in White Lake in 2015. Since that time, the relative abundance of chrysophytes, cryptomonads, and diatoms has decreased, while the abundance of blue-green algae has increased. The shift in the algal community is an indication of nutrient enrichment and reflects a change in the trophic state of White Lake from oligotrophic to eutrophic (Figure 9-34).

Figure 9-34: White Lake Trophic Status Index (NCTSI)



As a result of the drastic water quality changes identified as part of the 2013 basinwide assessment, DWR conducted a [special study](#) from 2015 to 2017 on in-lake water quality and potential causes which focused on historic and current lake condition, groundwater, and the surrounding watershed. The findings

suggested that shallow groundwater and nonpoint source nutrients are elevated and the volume of artesian spring input to the lake may be decreasing. Nearby groundwater and surface runoff have shown elevated nutrient concentrations (especially ammonium); potentially from failing/leaky local collection system infrastructure in the densely-developed area immediately surrounding the lake.

In 2018, after a series of requests by the Town of White Lake to conduct in-situ treatments (i.e., ozonation & algaecides) of the lake to reduce algal growths and improve clarity, DWR issued a one-time use permit for the application of alum. DWR continued to monitor the water quality from May through August 2018. Surface dissolved oxygen ranged from 6.5 to 10.2 mg/L and surface pH ranged from 5.8 to 8.5. The pH values on May 3<sup>rd</sup> were the highest values recorded by DWR in 2018. A few days after this sampling trip, the Town of White Lake applied alum to the lake to reduce total phosphorus and, consequently, decreased algal growth (*Figure 9-35*). The alum application during an algal bloom and the subsequent stress of the bloom along with the alum caused an unprecedented fish kill. The Wildlife Resources Commission (WRC) estimated the mortality at 114,770 fish with a total of 42,779 pounds at a value of \$634,132 (WRC 2018). The WRC estimated this fish kill removed 40-50% of the total fish biomass in the lake. DWR conducted an assessment and based on the evidence available, it was determined that the cause of the fish kill was linked to levels of dissolved aluminum and copper at acute and chronically toxic levels and that the “alum application played a major role in the unprecedented fish kill that occurred in White Lake in 2018” ([NC DEQ, September 2019](#)). The report also noted that a fisheries biologist with the NC Wildlife Resource Commission indicated “that concurrent to the fish kill, DO and pH levels remained well within the bounds for aquatic life support, absent the alum application”.

The Town of White Lake contracted with Bald Head Island Conservancy in 2018 to conduct a groundwater survey on hydrological factors surrounding the lake (Shank & Zamora 2019). The key findings of that survey were:

- 1) Rainfall is the dominant water source of White Lake.
- 2) Particularly high nutrient loads were consistent at two locations.
- 3) These locations also had critically high fecal coliform bacteria levels in July and August.
- 4) The combination of high nutrients and fecal coliform bacteria is indicative of substantial wastewater contamination.
- 5) Groundwater along the northern and eastern lake edges that exhibited little to no apparent wastewater influence is characterized by a low pH (4-5) that is consistent with the historic pH values of the lake.

More current work funded by the town found rainfall data in surrounding stations to be increasing in pH. This data has been used to suggest the increase in the lake’s pH can be contributed to a change in the rainfall pH (Lauritsen 2020). The Town is also funding a [White Lake Watch website](#) to address the many complex issues surrounding White Lake and has established a Lake Stewardship position in local government.

Figure 9-35: White Lake Changing Surface pH Levels and Depth Integrated Chlorophyll a Concentrations 1981-2018

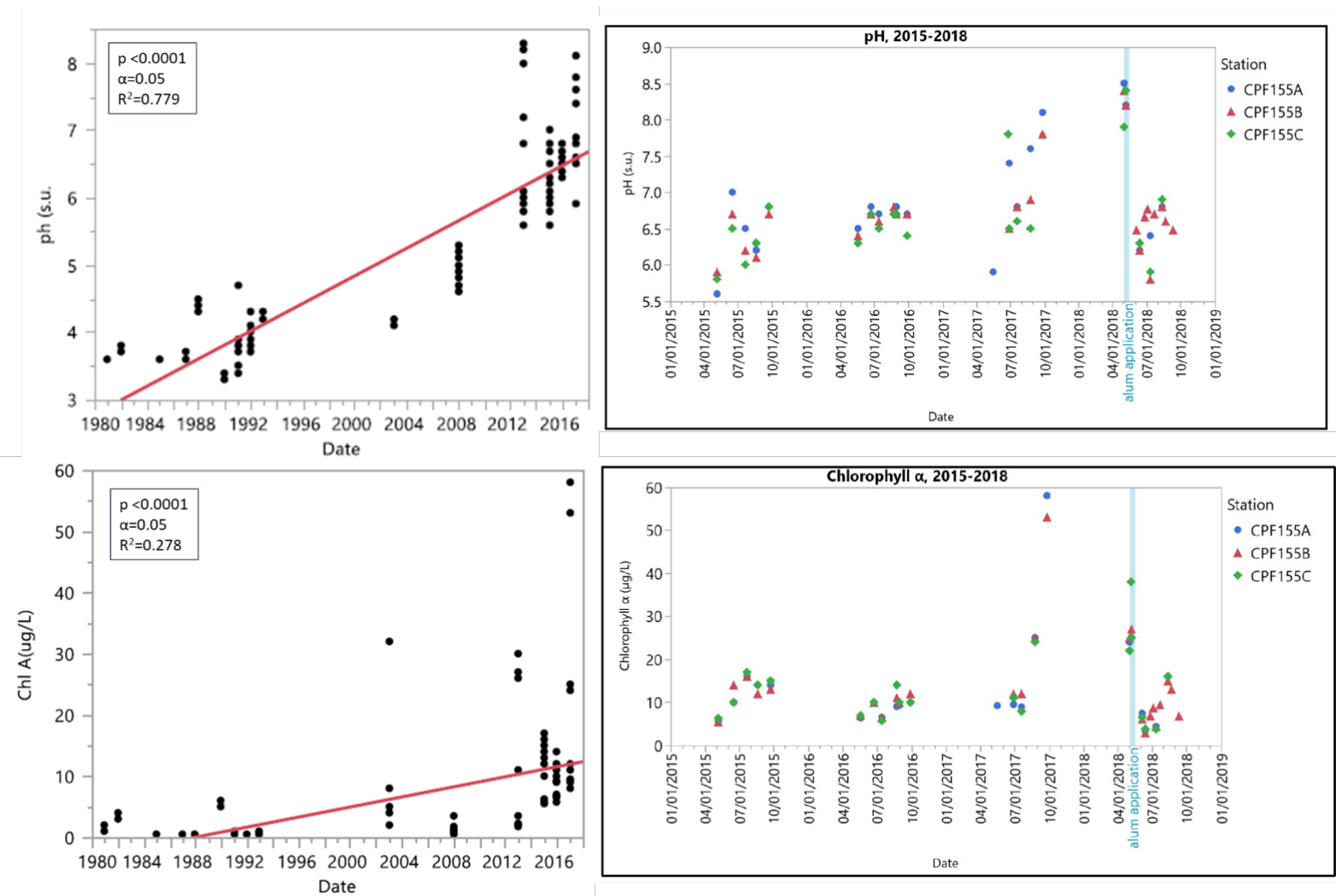
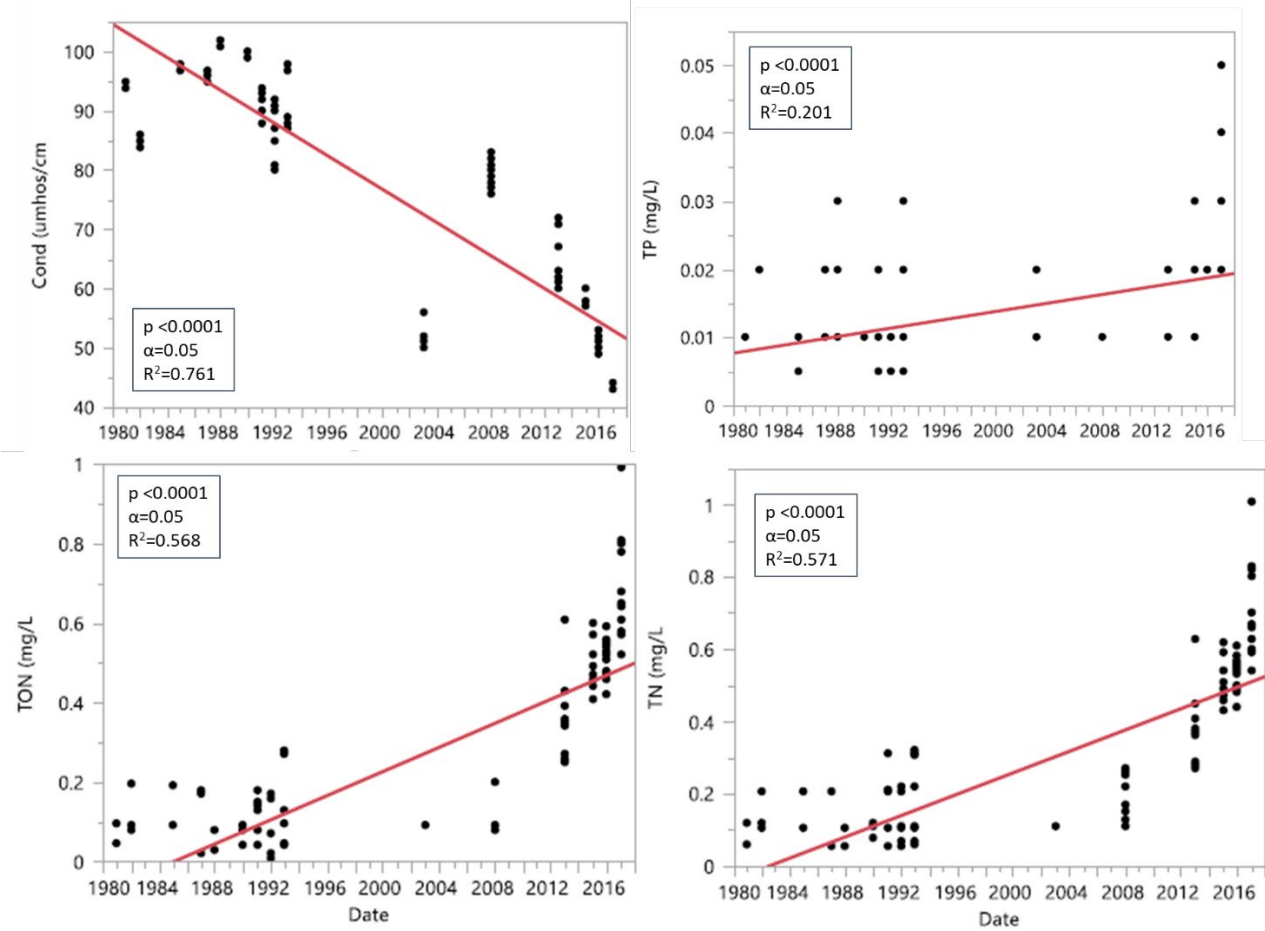


Figure 9-36: White Lake Changing Surface Conductivity and Depth Integrated TP, TON, and TN Concentrations 1981-2017 (From [2017 DWR White Lake Trends Report](#)).



To improve water quality in the lake, the town needs to repair its collection system leakage issue. This can also be a problem during rain events when excess water flows into the same system and can increase the volume of wastewater to be treated and discharged into Colly Creek. See the Colly Creek section 10.6.5 write-up for more information on the WWTP. There is a concern with high ammonia concentrations discharged from the White Lake WWTP to Colly Creek.

The town should work with residents to develop a watershed action plan to reduce nutrients from all sources including stormwater and lawn fertilizers.



### **Ambient Stream Monitoring**

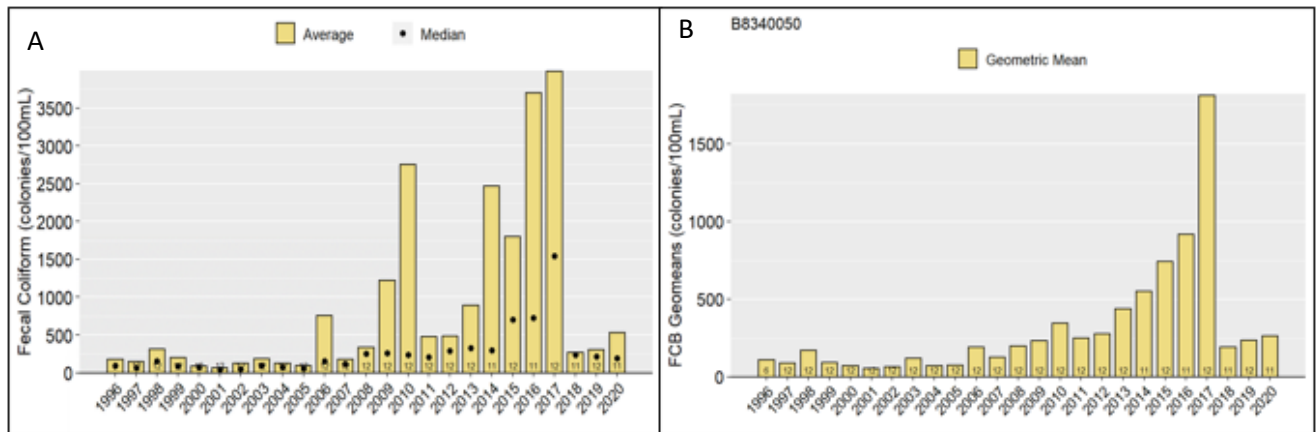
Three tributary stations--B8340050, B8321000, B8340100--and four mainstem stations--8306000, B8320000, B83339000, B83041300--were monitored for the 2022 IR. The tributary stations are described in this section and the mainstem stations are described in Section 9.9.3. Harrison Creek and Turnbull Creek Cape Fear River Mainstem Physical and Chemical Evaluation.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistic as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Station B8340050, monitored by the LCFRP, was used to assess Brown Creek (AU# 18-45) for the 2022 IR. The Brown Creek AU is a 10.5 FW mile class C stream located to the south and west of Elizabethtown from the source to the confluence with the Cape Fear River. In 2019, the 16.7 mi<sup>2</sup> watershed for station B8340050 was 20% agriculture, 21% developed, 31% forest, 10% grassland/shrub, and 18% wetland. Between 2001 to 2019, agriculture declined by 1.1%, grassland/shrub increased by 1.2%, forest declined by 0.5% and development increased by 0.5% (see Chapter 2 Appendix, Land Use and Land Cover for AMS and Coalition Station Watersheds table). In May 2022, the B8340050 watershed had two AFOs, with four lagoons, permitted for 1,468,800 lbs live weight and 18 acres of residual land application fields for Elizabethtown (WQ0004038), mostly located very near this station. Brown Creek was meeting criteria for all parameters on the 2022 IR except fecal coliform and fish community, which rated data inconclusive. See the next section for more information on biology monitoring in Browns Creek.

Mean concentrations at station B8340050 over the last five years (2016-2020) were 9.56 NTU for turbidity, 6.64 for pH, 8.65 mg/L for DO, 1,770 colonies/100 mL for fecal coliform bacteria, and 118.9 µS/cm for specific conductivity. The exceedance rate for fecal coliform over the last five years was 44% over the 400 colonies/100 mL standard. During the previous five-year timeframe, from 2011 to 2015, exceedance was 36%, and during the five years prior, exceedance was 23% for fecal coliform. Yearly fecal coliform bacteria means and geomeans suggest levels increased from 2008 to 2017, peaking close to 4,000 colonies/100 mL annual mean and 1,800 colonies/100 mL geomean (*Figure 9-37A, B*). After 2017, fecal coliform levels dropped sharply. DWR conducted a screening level Mann-Kendall trend seasonal test with station B8340050 data years 2000 to 2019 that showed significant increasing trends calculated at 95% confidence for fecal coliform bacteria. Elizabethtown's nearby residual land application fields and AFOs in the watershed may have been the source of some of the fecal coliform bacteria issues in this watershed. There have been few exceedances for pH and turbidity, and none for DO at station B8340050 during the timeframe of this plan.

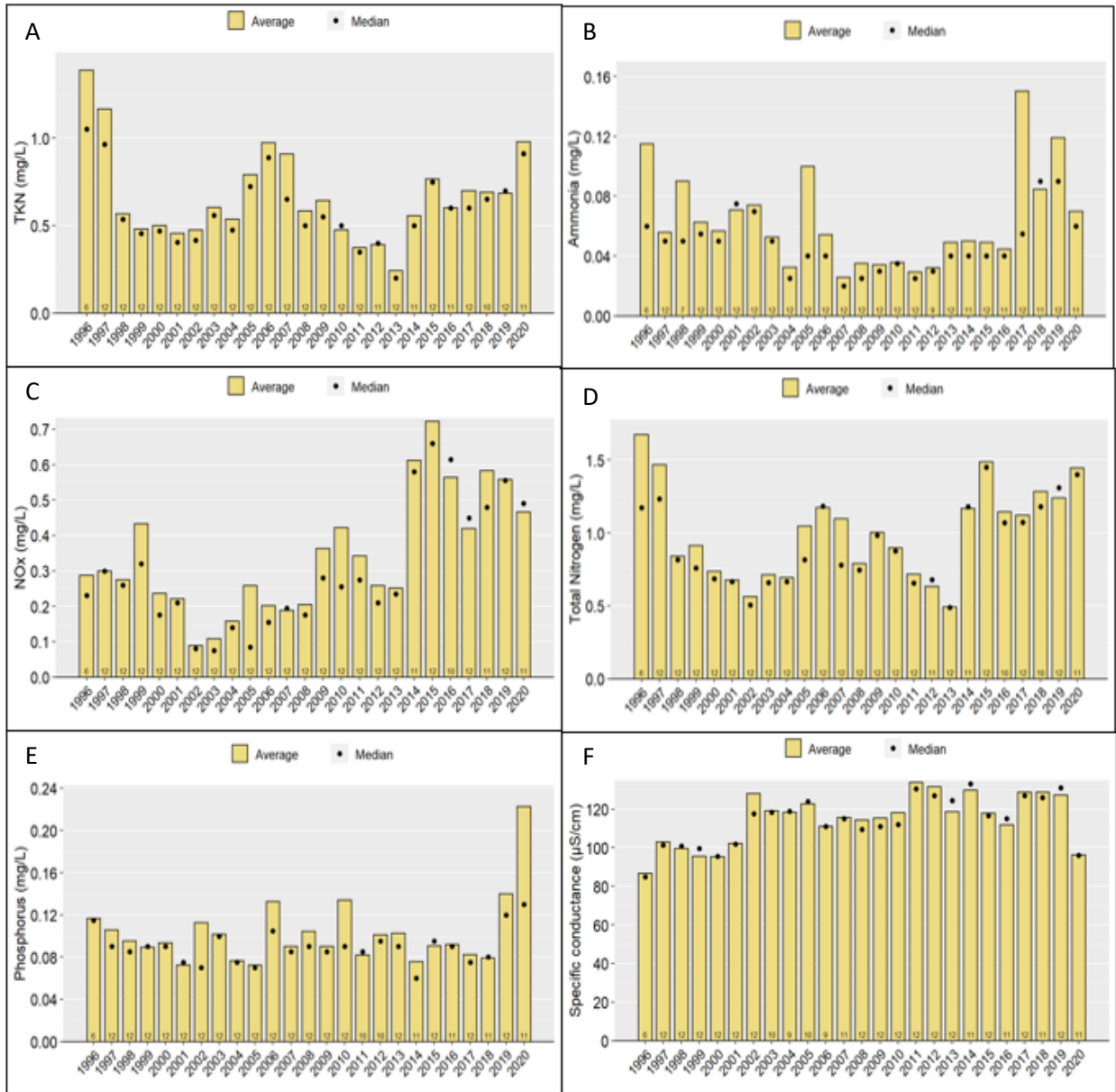
Figure 9-37: Station B8340050 Fecal Coliform Annual Means and Geomeans for Brown Creek



Station B8340050’s nutrient yearly means are displayed in *Figure 9-38*. Mean concentrations for nutrients over the last five years at station B8340050 were 0.73 mg/L TKN, 0.10 mg/L ammonia, 0.52 mg/L NOx, 1.25 mg/L TN, and 0.12 mg/L TP. A comparison of these five-year nutrient means to DWR’s WSS-ISB special study findings for minimally impacted Coastal Plain streams, in *Table 9-13*, shows all nutrient concentrations are over the recommendation values. TP concentrations are extremely high, three times the recommended <0.03 mg/L. From 2016 to 2020, TP ranged from 0.02 to 0.71 mg/L, the maximum value was an extreme outlier that occurred in October 2020. Yearly data show TP mean concentrations elevated in 2019 and 2020 (*Figure 9-38E*). Ammonia was also very high, twice the recommended 0.5 mg/L with yearly means showing ammonia concentrations increased in 2017 (*Figure 9-38B*). NOx and TN were about 40% over the Coastal Plain recommendation (0.3 mg/L for NOx and 0.8 mg/L for TN) (*Figure 9-38 C, D*). Mann-Kendall screening level tests found NOx was significantly increasing from 2000 to 2019 and 2010 to 2019 and that TKN was significantly increasing from 2010 to 2019. Yearly means show the upward trend of NOx since 2000 and TKN since 2010 (*Figure 9-38A*). Specific conductivity, often associated with NOx and point sources, was also significantly increased in both the 2000 to 2019 and 2010 to 2019 timeframes. Mean yearly values for specific conductivity are also shown in *Figure 9-38F*.

The Turnbull Creek assessment unit (AU# 18-46) is a 31.6-mile C class stream that includes monitoring from two ambient stations: AMS station B8321000, located just below the Panther Branch confluence and MCFBA B8340100, located further downstream below Smith Swamp, which drains Jones Lake (see Lake Monitoring below). Turnbull Creek converges with the Cape Fear River on the northeast side, just 0.2 miles downstream from the Brown Creek confluence. The rural watershed for the lower station is 81.2 mi<sup>2</sup> (B8340100) with 43% wetland, 32% forest, 10% grassland/shrub, and 11% agriculture in 2019. Forest declined by 2.3% while grassland/shrub cover increased by 2.5% since 2001 (see the Chapter 2 Appendix, Land Use Land Cover for AMS, and Coalition Station Watersheds table). The 61.7-mi<sup>2</sup> watershed for the upper station (B8321000) was comparable overall. Swine farming is prevalent in both station watersheds with 13 AFOs permitted for 7,827,920 lbs live weight and 42 lagoons at the lower station. Ten of the 13 AFOs are located above the upper station. On the 2022 IR, Turnbull Creek was meeting all criteria except pH, which was data-inconclusive.

Figure 9-38: Station B8340050 Yearly Mean Nutrient Concentrations and Specific Conductivity for Brown Creek

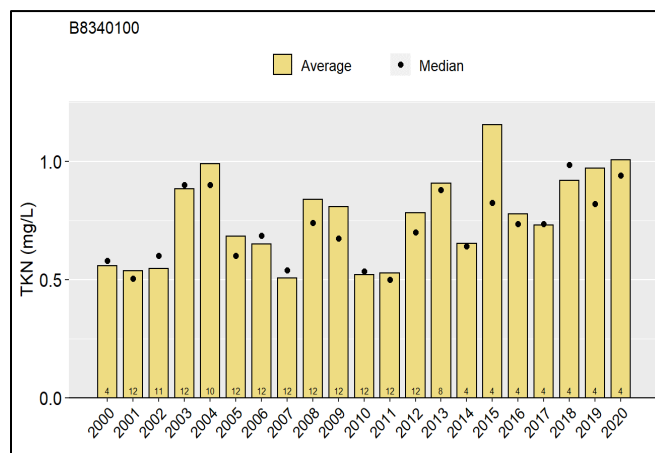


Annual means and exceedance rates were evaluated and compared at the upper, B8321000, and lower, B8340100, stations for the most recent five monitoring years, 2016 to 2020. The upper station was sampled monthly and the lower station quarterly. Mean turbidity levels were very low at both stations, 4.16 NTU at the upper and 3.41 NTU at the lower with few exceedances over the 50 NTU standard at either station. Both the upper and lower stations had acidic conditions, with similar mean levels, 4.12 at the upper and 4.2 at the lower with 100% exceedance below the 6.0. standard at both. These acidic conditions are likely associated with the many wetlands in this watershed. The AU was assessed in category 3a, potentially due to natural conditions for the 2022 IR. A natural condition assessment should still be done on this AU. The upper station had 6.51 mg/L DO with 11% exceedance below the 4 mg/L

standard and the lower station had 7.18 mg/L DO with zero exceedance below the standard. Fecal coliform levels were 179 colonies/100 mL at the upper with a 12% exceedance over the 400 colonies/100 mL standard. The lower station had 88 colonies/100 mL with a 5% exceedance over the standard. Specific conductivity levels were 61.62 µS/cm at the upper station and 54 µS/cm at the lower station.

Nutrients were only collected at the lower station, B8340100, during the last five years (2016-2020), with mean levels at 0.88 mg/L for TKN, 0.07 mg/L for ammonia, 0.06 mg/L for NOx, 0.94 mg/L for TN, and 0.07 mg/L for TP. A comparison of these five-year nutrient means to DWR’s WSS-ISB special study findings for minimally impacted Coastal Plain streams, in *Table 9-13*, shows TKN concentrations are 70% over the recommended 0.5 mg/L, ammonia is 40% over the recommended 0.05 mg/L, NOx is 80% below the recommended 0.3 mg/L, TN is 18% over the recommended 0.8 mg/L, and TP is 40% over the recommended 0.05 mg/L. The high levels of TKN (minus ammonia) indicate a high organic-to-inorganic ratio for TN. Several outliers have occurred, including high levels of TKN at 2.75 mg/L and NOx at 42.6 mg/L on October 19, 2015, and 0.67 mg/L ammonia on July 5, 2016. Graphical data showing yearly means for TKN suggests levels have been increasing (*Figure 9-39*).

Figure 9-39: TKN Yearly Means at B8340100



#### 1.9.2.2 Turnbull Creek-Cape Fear River Biology Monitoring

Four sites in the Turnbull Creek catchment have been monitored for biology since 2003. Benthic community site BB143, Ellis Creek at NC53, was last sampled in 2003 when it received a bioclassification of Good-Fair. Biologists noted a low pH at the sample site (4.4), sand and silt-dominated substrate, and tannic water clarity. This catchment is primarily wetland and forested, but there is some timbering activity and a small amount of agriculture, which could be influencing instream habitat. EPT taxa richness and bioclassification have remained steady since sampling began at this site in 1993. Similarly, site BB155, Browns Creek, also exhibited swamp conditions the four times it has been sampled during the plan period and was sampled using Swamp methodology. It was last sampled in 2018 when it received a Natural bioclassification. Fish community site BF77 on Browns Creek is co-located with BB155 and was not

Year	Bioclassification
<b>BB143 – Ellis Creek</b>	
2003	Good-Fair
<b>BB155 - Browns Creek</b>	
2003	Moderate
2008	Moderate
2013	Natural
2018	Natural
<b>BF77 - Browns Creek</b>	
2008	Not Rated
<b>BB305 – Turnbull Creek</b>	
2003	Good-Fair

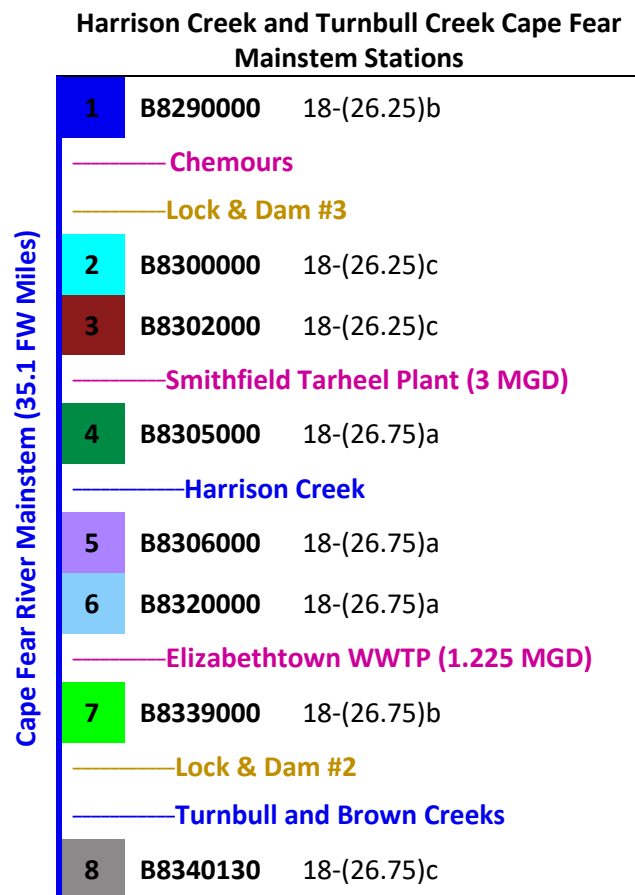
rated the only time it was sampled in 2008. Biologists noted a sand and silt-dominated substrate and tannic water clarity, but pH was higher (6.4) than the site on Ellis Creek. There is more agriculture in the Browns Creek watershed, and it also appears to be developing, which may be contributing to a slightly elevated specific conductance at this sampling site (135.5  $\mu\text{S}/\text{cm}$  in 2018). Like Ellis and Browns creeks, Turnbull Creek appeared to be exhibiting swamp-influenced conditions at benthic community site BB305 when it was sampled in 2003 and received a bioclassification of Good-Fair. Sand and silt-dominated substrate, along with low pH (4.0) and tannic water clarity were noted by biologists. All three sites are likely exhibiting natural swamp conditions as land use in the catchment is primarily wetland and forest.

### 1.9.3 Harrison Creek and Turnbull Creek Cape Fear River Mainstem Physical and Chemical Evaluation

The Harrison Creek and Turnbull Creek Cape Fear River mainstem evaluation included eight stations located along 35.1 FW miles composed of five assessment units (see diagram to right and *Table 9-14* for AU descriptions). All stations are located in the Southeastern Plains ecoregion with class C or class C & WS-IV waters. The diagram to the right shows the Harrison Creek and Turnbull Creek-Cape Fear River mainstem station locations relative to Lock and Dam #2 and #3, three major NPDES discharge facilities, and the Harrison Creek (see Section 9.9.1.2) and Turnbull and Brown creeks (see Section 9.9.2.1) tributaries.

The 2022 IR found one AU, 18-(26.25)c, where the second (B8300000) and third (B8302000) stations are located, to be data inconclusive for 1,4-Dioxane. This AU is defined as “from Lock and Dam #3 to a point approximately 0.5 miles upstream of the Smithfield Packing Company intake” (*Table 9-14*). All other parameters assessed for this AU and other AUs for the 2022 IR along this segment of the Cape Fear River were meeting the criteria.

As of May 2022, along the Harrison Creek and Turnbull Creek Cape Fear River mainstem segment of the Cape Fear River, there were a total of three major (Chemours, Smithfield Tarheel Plant, and Elizabethtown WWTP) and three minor NPDES dischargers with a collective permitted as-built flow of 5.805 MGD, five NPDES stormwater facilities, 30 AFOs (primarily swine) with 93 lagoons and over 24.5 million pounds of permitted live weight, and 377 acres of residual solids land application (mostly) and non-discharge wastewater fields. Also, see the discussion on the Chemours facility and Smithfield Tarheel Plant in Section 9.9.1. The fields are clustered near Harrison Creek and Elizabethtown where four of the five NPDES



stormwater facilities are also located, while the AFOs are scattered throughout the tributary watersheds that drain this mainstem segment (*Figure 9-19*). It should also be noted that between the last station along the Upper Cape Fear River mainstem (B7500000), and the first station in the Lower Cape Fear River (B8290000), there are four major NPDES dischargers with a collective as-built flow of 26.75 MGD, 34 NPDES stormwater facilities, 982 non-discharge and residual solids land application fields, and four AFOs. Two of the major dischargers are on the Cape Fear River mainstem and two are on Rockfish Creek, a tributary (see Chapter 8). Also see Chapter 3, Section 3.9.1 Ambient Water Quality Station Drainage Area Permit Analysis for the Cape Fear River for a full permit analysis of mainstem ambient stations.

Ambient water quality monitoring station B8300000 (WS-IV) on the Cape Fear River downstream of Lock and Dam #3, is part of a special study on 1,4-dioxane in the Cape Fear River Basin. Thirty-five (61.4%) of the 57 samples collected between April 2019 and December 2024 exceeded the EPA health-based drinking water concentration representing a 1-in-a-million ( $1 \times 10^{-6}$ ) cancer risk level for 1,4-dioxane of 0.35  $\mu\text{g/L}$  (EPA IRIS, 2013). These samples ranged between 1.1 and 5.7  $\mu\text{g/L}$  with an average 1,4-dioxane concentration of 2.3  $\mu\text{g/L}$ . Twenty-Two or 38.6% of the samples collected were below the PQL of 1  $\mu\text{g/L}$ . DWR will continue to work with upstream dischargers to identify and reduce the source of 1,4-dioxane at the source of the contaminant. For more information on 1,4-dioxane see Chapter 2 (section 2.13.2) and Chapter 13 for summary tables and figures for 1,4-dioxane in the Cape Fear River Basin.

Yearly means and exceedance rates from 2002 to 2020 for the Harrison Creek and Turnbull Creek Cape Fear River mainstem evaluation were graphed for the eight stations located along this segment (*Table 9-14*). Five-year means were also graphed for NO<sub>x</sub> and TP, a full set of five-year graphics is available in the Subbasin Chapter Appendix. Only the second station, B8300000, a DWR AMS station, does not have a complete set of data. This station has field parameter monitoring data for most years; however, there was no data in 2012 and 2015, turbidity and nutrients data only in 2019 and 2020, and no fecal coliform bacteria data. The station was included in the 2019-2020 central Cape Fear River modeling special study. (See Chapter 2 Section 2.14 for more details). All other stations are monitored by the MCFBA, with the fourth station co-monitored by DWR from 2002-2006 (*Table 9-14*). As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter. (See Chapter 2 for more information on the IR). DWR also conducted screening level seasonal and non-seasonal Mann-Kendall trend tests at 95% confidence for monitoring data collected from 2000 to 2019 and 2010 to 2020 on the Harrison Creek and Turnbull Creek Cape Fear River stations. Only field parameter trend tests for 2000 to 2019 were conducted on DO, pH, and specific conductivity at the second station, B8300000, due to a lack of data.

Turbidity yearly means along this segment of the lower Cape Fear River typically ranged from >10 to <30 NTUs with all yearly means below the 50 NTU standard (*Figure 9-40*). Turbidity correlated with discharge in most years, except 2013, which indicates nonpoint stormwater sources generally contributed more than point sources. This is clearly seen in the flow separated analysis for the upper two stations where the assessment was completed (*Figure 9-24*). The annual means in 2013 increased significantly while the yearly mean discharge of 4,639 cfs was just shy of the 2002-2020 mean flow of 4,987 cfs at the associated USGS gage. There were, however, two very high-flow events during the summer of 2013 that likely caused

the higher turbidity levels and excursions of the standard. In 2013, turbidity means and exceedances were both elevated at the third and fourth stations, B8302000 and B8305000, respectively, with the exceedances rate >30% (*Figure 9-41*). The third station, B8302000, is located below the Chemours Fayetteville Works facility, operated by Dupont until 2015. Dupont Fayetteville Works changed the location of its outfall from an old channel to an internal outfall in 2012. Therefore, 2013 was the first full year the new outfall was operational and may have contributed to the higher turbidity levels. The first and most upstream station, B8290000, also had several years with elevated turbidity levels (2003, 2006, 2016, and 2018), which suggests the source of turbidity is probably in the Upper Cape Fear River subbasin. The screening level seasonal and non-seasonal Mann-Kendall trend test found this first station, B8290000, to be significantly increasing from 2010 to 2019 at 95% confidence. The second AMS station was monitored just in 2019 and 2020 and also had relatively high turbidity in 2020 with a yearly mean of 40 NTU and >20% exceedance. This may be related to the constructed mitigation measures to address PFAS at the Chemours site (see Section 9.9.1.1). The AMS and coalition stations do not have synchronous sampling schedules, thus higher levels were not measured downstream.

pH generally decreased from upstream to downstream along the Harrison Creek and Turnbull Creek section of the mainstem Cape Fear River (*Figure 9-42*). The declining pH levels were primarily due to tributaries draining wetlands with naturally acidic conditions. Most years there was a dip in pH levels at the second station, monitored monthly only by DWR. The coalition collects field data twice a month during warmer months (May – September). Sampling frequency and instrumentation differences may have caused a slight difference in station results. Overall, there were more exceedances before 2011 (*Figure 9-43*), indicating a potential change in the watershed. Mann-Kendall screening trend tests for pH caused a significant decrease at six of the eight stations from 2000 to 2019 (B8290000, B83020000, B8306000, B8320000, B8339000, and B8340130) and no significant change at any station from 2010 to 2019.

Mean yearly DO along this segment of the mainstem generally ranged from 7.0 to 8.0 mg/L (*Figure 9-44*). There was often a rise in DO at the second station and sometimes the last station, B8340130, both located directly below the run-of-the-river lock and dams. The twice-a-month monitoring during the warm season at the coalition stations would also have lowered the mean yearly DO levels in comparison to the second station, monitored monthly by DWR. There were few DO exceedances under the 4 mg/L standard, with the highest exceedance also occurring at the second station (14%) in 2011, a low flow year (*Figure 9-45*). Dams increase residence time in low-flow years and therefore can decrease DO levels. The Mann-Kendall screening trend tests found DO levels were significantly decreasing at the last station, B8340130, during both the 2000 to 2019 and 2010 to 2019 time periods. The third station, B8302000, also significantly decreased from 2000 to 2019.

The fecal coliform bacteria levels between the Harrison and Turnbull creeks mainstem Cape Fear River segment were variable with most yearly means below the 400 colonies/100 mL standard (*Figure 9-46*). Overall, fecal coliform mean levels (*Figure 9-46*), exceedances (*Figure 9-47*), and yearly geomeans (*Figure 9-48*) correlated with discharge, suggesting fecal coliform is primarily nonpoint source stormwater driven. This is clearly seen in the flow-separated analysis for station B8290000 (*Figure 9-25*). Fecal coliform levels were often highest at the most upstream station, B8290000, indicating the Upper Cape Fear is likely a contributing source during these years (*Figure 9-48*). (See five-year mean graphics in the Subbasin Chapters Appendix). The highest exceedances, or >50%, occurred in 2018 at that first station; however,

levels were also high at the lowest Upper Cape Fear River mainstem station (B7500000) in 2018 (see Chapter 8). In 2003, 2004, and 2005 there was a rise in fecal coliform at the fourth station, B8305000, which is located below the Smithfield Tarheel Plant and may have been a contributing source (see Section 9.9.1). There are no classified tributaries or other permitted facilities between the third and fourth stations currently. The eighth station, B8340130, located below Turnbull and Brown creeks, also was elevated above other stations on occasion. Mann-Kendall screening level trends found the fourth (B8305000) and seventh (B8339000) stations to be significantly decreasing from 2000 to 2019 and the eighth station to be significantly decreasing from 2010 to 2019.

Specific conductivity was negatively correlated with flow along the Harrison and Turnbull creeks mainstem Cape Fear River segment with yearly means generally ranging from 100 to 150  $\mu\text{S}/\text{cm}$  (Figure 9-49). During the lowest flow year in 2002, mean levels were over 175  $\mu\text{S}/\text{cm}$  while during the highest flow year in 2003 and 2020, mean levels were  $<100$   $\mu\text{S}/\text{cm}$ . This is clearly seen in the flow-separated analysis for the upper two stations where the assessment was completed (Figure 9-21). Screening level Mann-Kendall trend tests found the fifth (B8306000), sixth (B8320000), seventh (B8339000), and eighth (B8340130) stations were also significantly decreasing from 2000 to 2019 and all stations except the second station, which was not tested, were significantly decreasing from 2010 to 2019.

The Harrison Creek and Turnbull Creek Cape Fear River mean nutrient concentrations are shown in Figure 9-50 to Figure 9-56. The graphical pattern for TKN between the Harrison and Turnbull creeks mainstem reach of the Cape Fear River suggests yearly mean concentrations were positively correlated with discharge, indicating stormwater sources as the main driver (Figure 9-50). The graphical pattern for NO<sub>x</sub> (Figure 9-52) and TP (Figure 9-54), along this segment suggest concentrations were negatively correlated with discharge indicating point sources as the main driver. This is clearly seen in the flow-separated analysis for the upper two stations where the assessment was completed (Figure 9-28 and Figure 9-29). TN appeared to be variable with some years being negatively correlated and other years more positively correlated with discharge (Figure 9-56). Ammonia concentrations along this segment did not appear to correlate with discharge (Figure 9-51).

Eighty percent of nutrient concentrations for the Harrison to Turnbull creeks reach of the Cape Fear River mainstem ranged from 0.6 to 1.0 mg/L for TKN, 0.03 to 0.09 mg/L for ammonia, 0.6 to 1.1 mg/L for NO<sub>x</sub>, 1.3 to 1.9 mg/L for TN, and 0.12 to 0.25 mg/L for TP. DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams (Table 9-13) recommended  $<0.5$  mg/L for TKN,  $<0.05$  mg/L for ammonia,  $<0.3$  mg/L for NO<sub>x</sub>,  $<0.8$  mg/L for TN, and  $<0.05$  mg/L for TP. The EPA nutrient criteria study for Coastal Plain streams recommended  $<0.72$  mg/L for TN and 0.032 mg/L for TP (Table 9-13). Almost all of the TKN annual mean concentrations were over the recommended  $<0.5$  mg/L and some were twice as high, including annual means in 2018 and 2019. About half of the annual means were over the recommended  $<0.05$  mg/L for ammonia, with the majority occurring before 2014. All of the NO<sub>x</sub> annual means were over the recommended  $<0.3$  mg/L, with most being twice and sometimes three times as high. All of the TN annual means were also over the  $<0.8$  mg/L recommendation, with about half being twice as high. Almost all of the TP annual mean concentrations were at least twice as high as the recommended 0.05 mg/L, and more than half were three times as high or greater.

The graphical pattern for NO<sub>x</sub> (*Figure 9-52 and Figure 9-53*) and TP (*Figure 9-54 and Figure 9-55*) annual and five-year means show both parameters elevate at the third, 8302000, and fourth, B8305000, stations. Both stations are located below major industrial NPDES facilities, the third below Chemours, and the fourth below the Smithfield Tarheel Plant (see Section 9.9.1). Prior to 2010, the fourth station, B8305000, generally had the highest NO<sub>x</sub> mean concentration, except for 2003. The NO<sub>x</sub> concentration remains elevated downstream of the fourth station, B8305000. TN also shows a pattern of elevation at the third and fourth stations during the same years (*Figure 9-56*), although the relative increase is less notable for TN than for NO<sub>x</sub> and TP. There is also a rise in ammonia between the first, B8290000, and third stations most years before 2017 (*Figure 9-50*). Screening level Mann-Kendall tests suggest that the ratio of organic to inorganic nitrogen in the Harrison to Turnbull creeks reach of the Cape Fear River mainstem has been increasing. Before 2017, the NO<sub>x</sub> (inorganic) fraction was higher, while for the last three years, the TKN (organic) portion has been higher (*Figure 9-57*). There are several swine AFOs on the east side of the river, between the second and third station, that could potentially contribute nutrients during storm events. It is recommended that the Fayetteville Regional Office take surface water quality samples around these farms during their next inspection to verify that these AFO facilities are not contributing to the higher instream nutrient concentrations. See Subbasin Chapters Appendix for five-year mean graphics for the remaining parameters.

The two NPDES wastewater permits are contributing factors for the elevated nitrogen and phosphorus concentrations in this section of the mainstem Cape Fear River. A review of Chemours' and Smithfield Tarheel Plant's 2022 discharge loads found that Chemours and their associated dischargers (Dupont and Kuraray; NC0003573) released on average about 156 lbs/day of TN, where Smithfield discharged about 1,970 lbs/day TN and 537 lbs/day TP (NC0078344; based on 2022 average flow and concentration). (See permit information in section 9.9.1.)

DWR also conducted screening level seasonal and non-season Mann-Kendall trend tests for nutrient monitoring data (TKN, ammonia, NO<sub>x</sub>, and TP) collected from 2000 to 2019 and 2010 to 2020 on seven of the eight stations on the Harrison Creek to Turnbull Creek reach of the Cape Fear River (*Table 9-16*). The second station was not analyzed due to a lack of monitoring data. TKN was of particular concern as six of the seven analyzed stations significantly increased during one or both periods; only the third station, B8302000, was not significant during either period. All other nutrients significantly decreased or had no significant change during either period (*Table 9-16*). Ammonia significantly decreased at all seven analyzed stations from 2000 to 2019 and five of the seven also significantly decreased from 2010 to 2019. NO<sub>x</sub> significantly decreased at one of the seven from 2000 to 2019 and all seven from 2010 to 2019. TP significantly decreased at all seven stations during both periods. The Smithfield Foods WWTP improved its treatment process starting in late 2007. This is likely reflected in the decline of nitrogen and phosphorus.

When environmental conditions are optimal, the elevated nutrients in the Cape Fear River system can result in algal bloom development. HABs have been identified in the Cape Fear River since 2009. NC DHHS routinely warns the public to avoid contact with large accumulations of algae and to prevent children and pets from swimming or ingesting water in areas of algal blooms. Chlorophyll *a* and algal bloom results are discussed below in section 9.10.4 for the mainstem Cape Fear River as a whole.

Figure 9-40: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean Turbidity

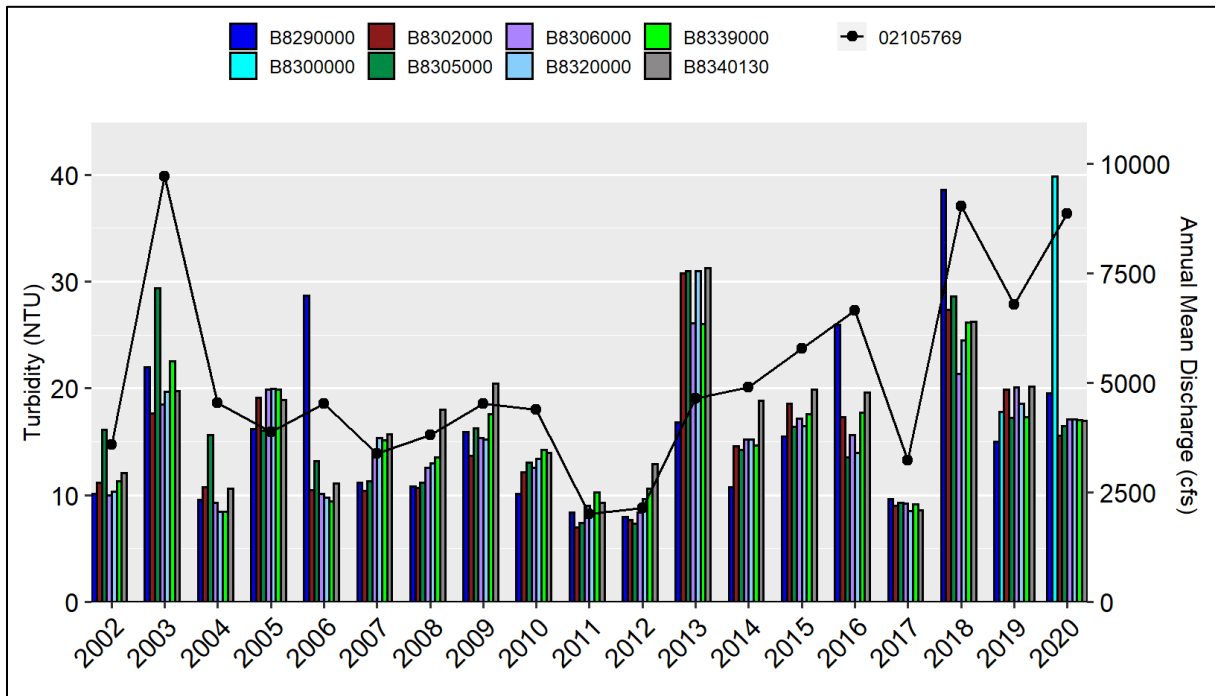


Figure 9-41: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Sample Percentages that Exceed the 50 NTU Water Quality Standard for Turbidity

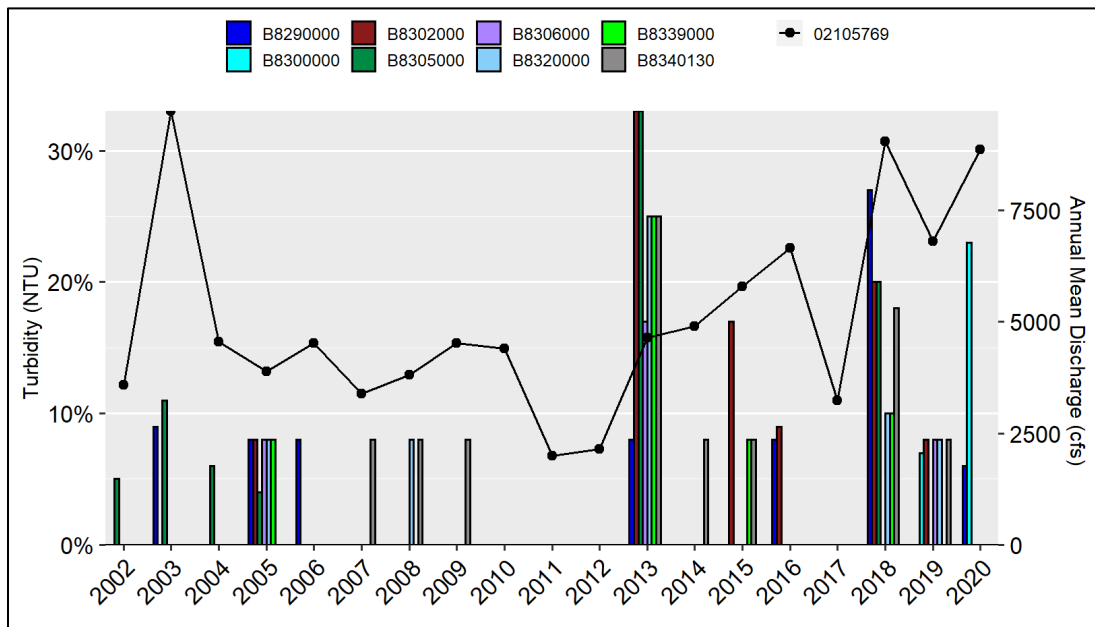


Figure 9-42: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean pH

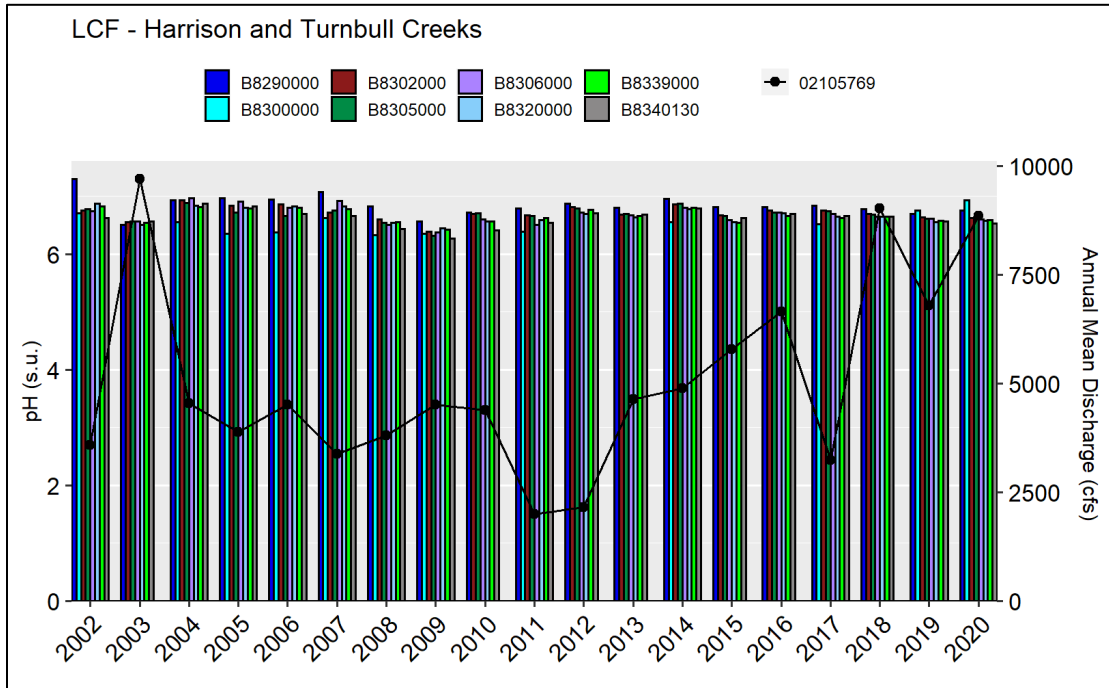


Figure 9-43: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Sample Percentages that exceed the 6 to 9 s.u. Water Quality Standard for pH

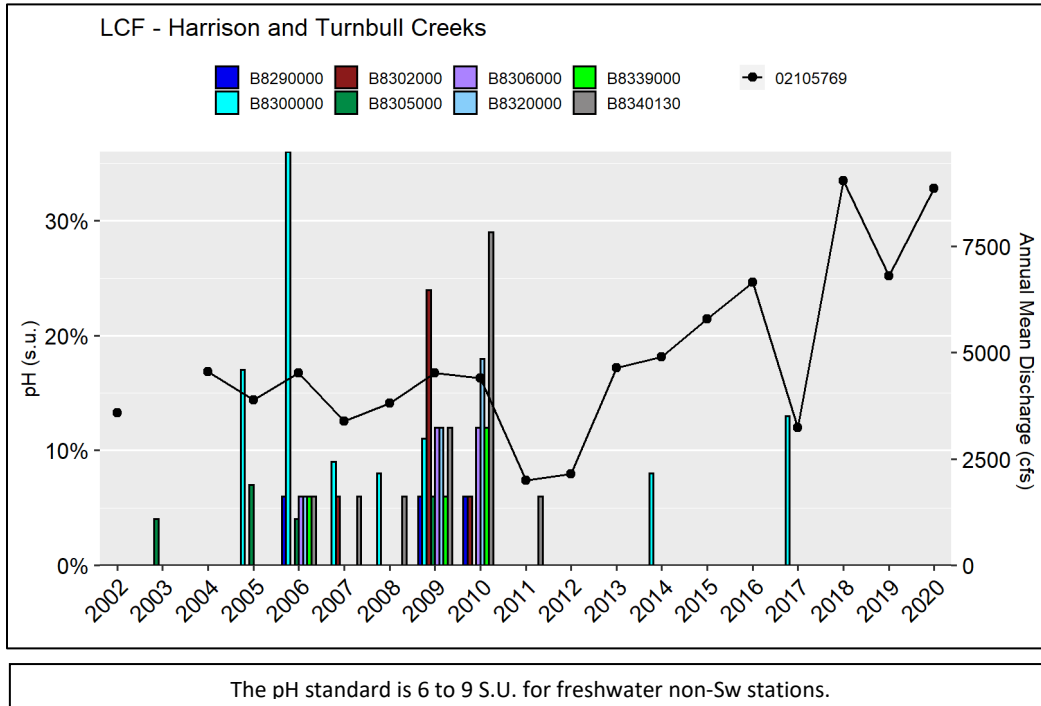


Figure 9-44: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean Dissolved Oxygen

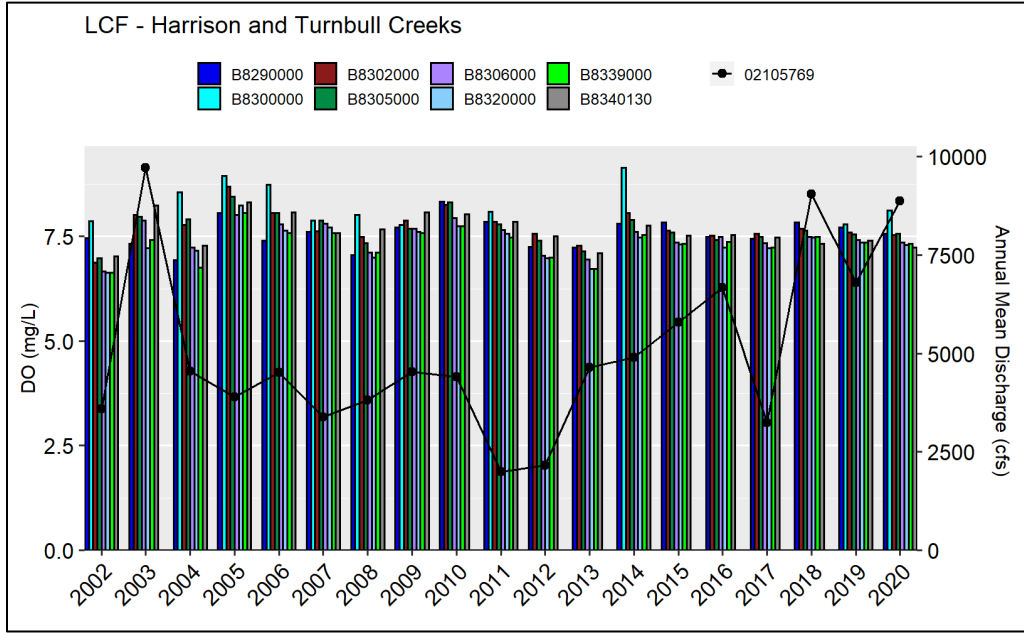


Figure 9-45: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations that exceeded the 4 mg/L Dissolved Oxygen Water Quality Standard

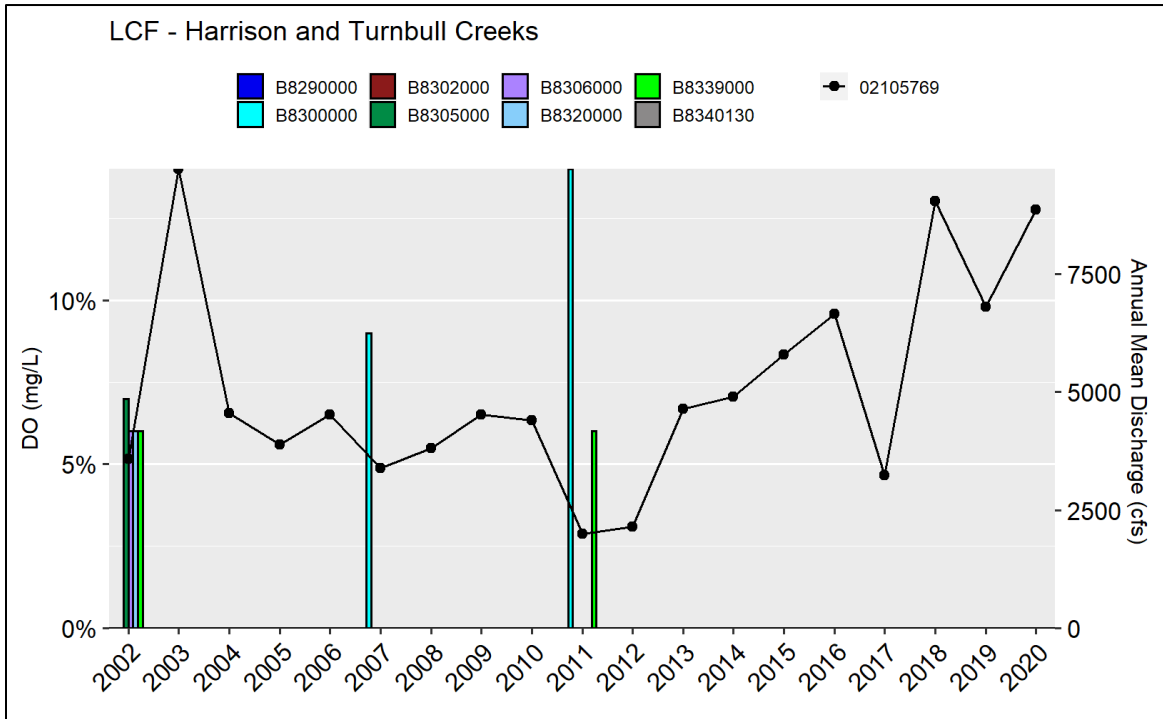


Figure 9-46: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean FCB (400 colonies/100 ml Standard for FCB is shown in graph figure)

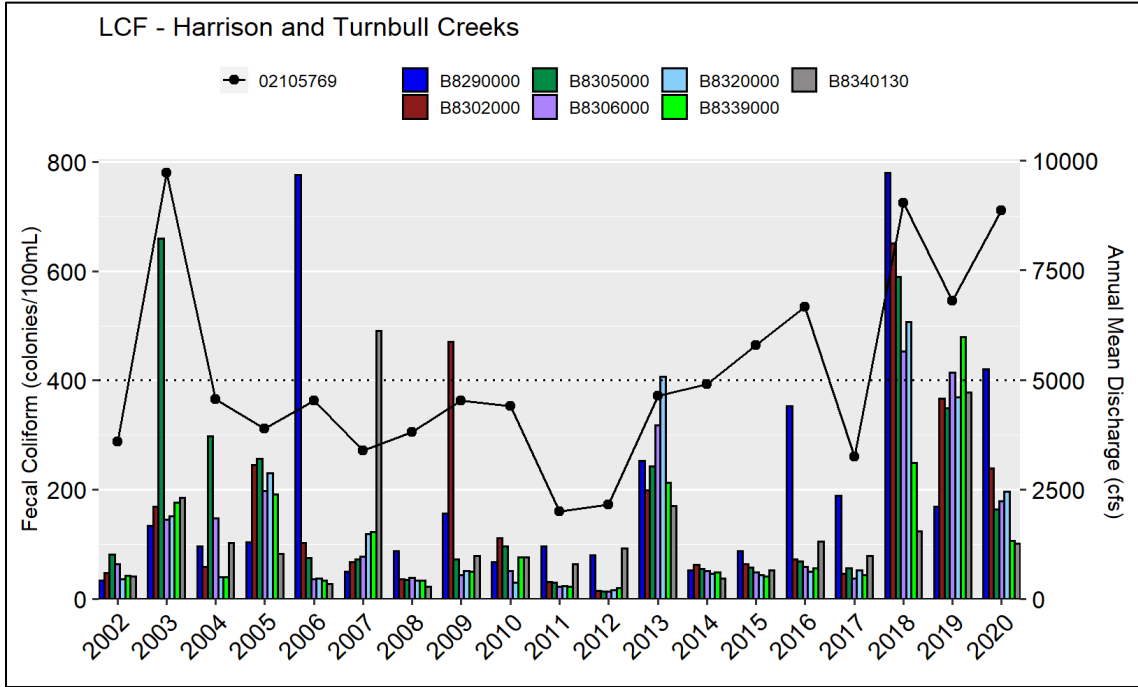


Figure 9-47: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Sample Percentages that exceeded the 400 colonies/100 ml Standard for FCB

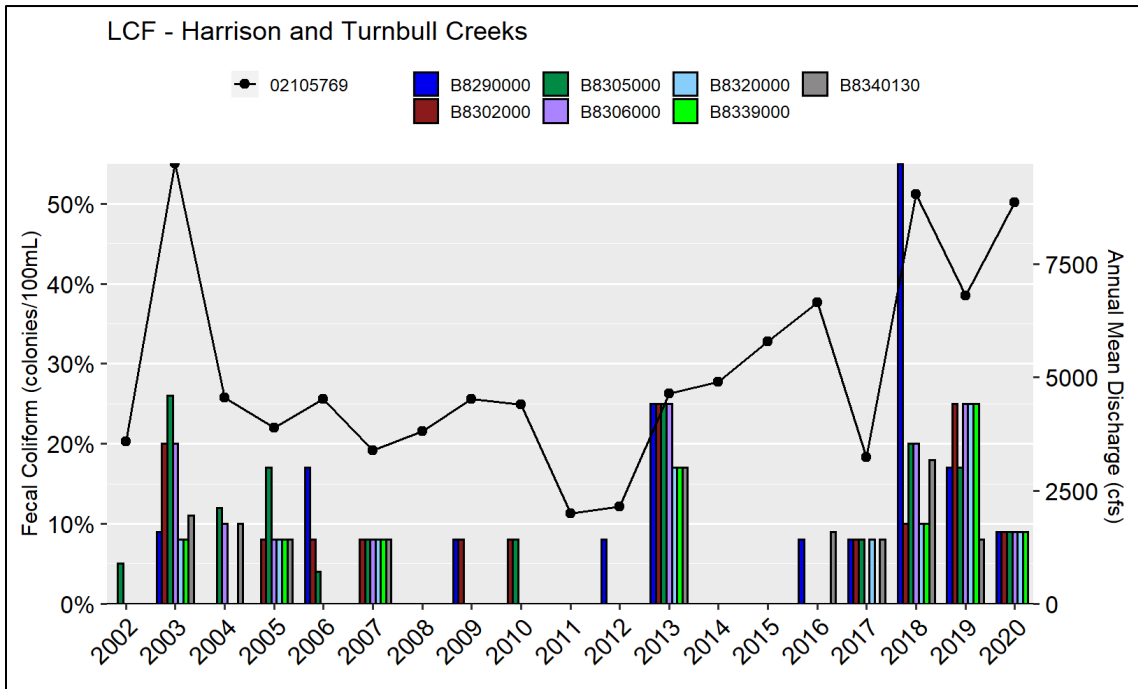


Figure 9-48: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations FCB Annual Geomeans (Geomean standard is 200 colonies/100 mL)

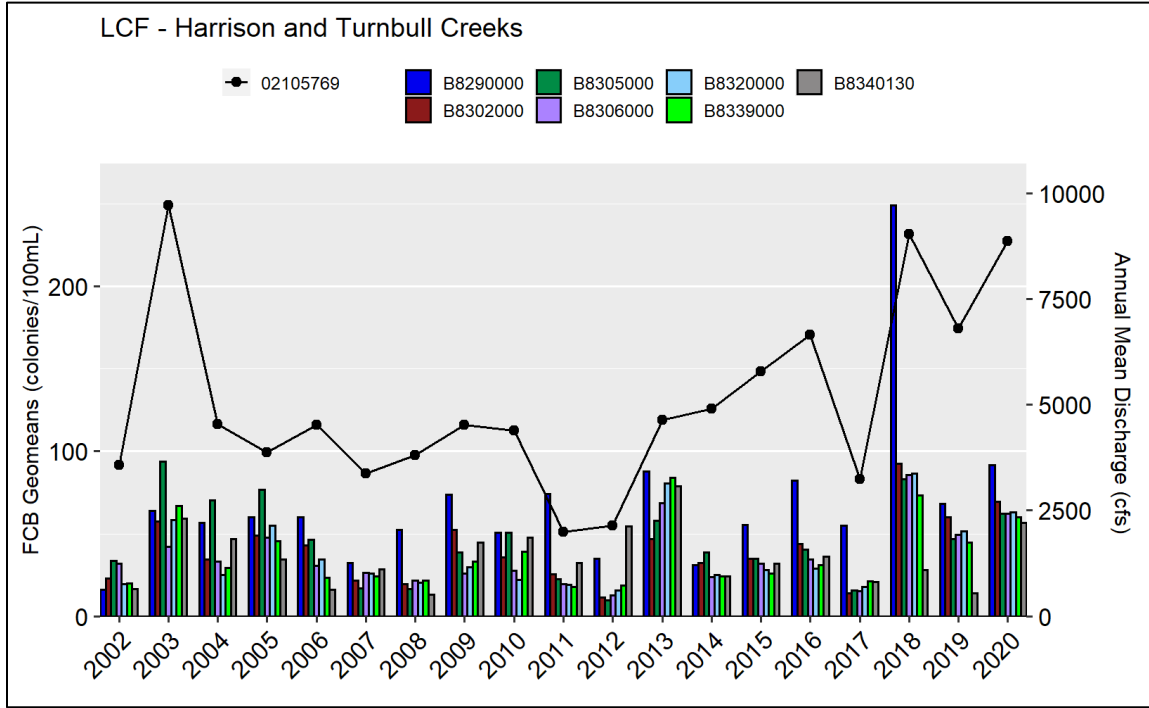


Figure 9-49: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean Specific Conductance

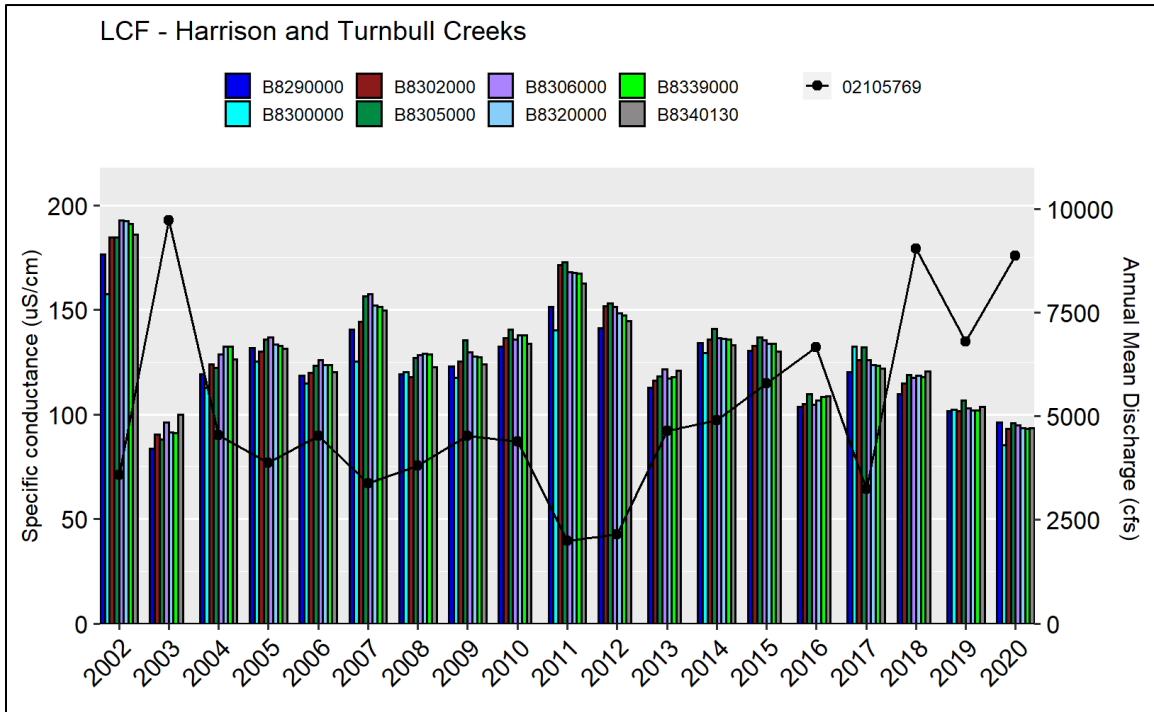


Figure 9-50: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean TKN

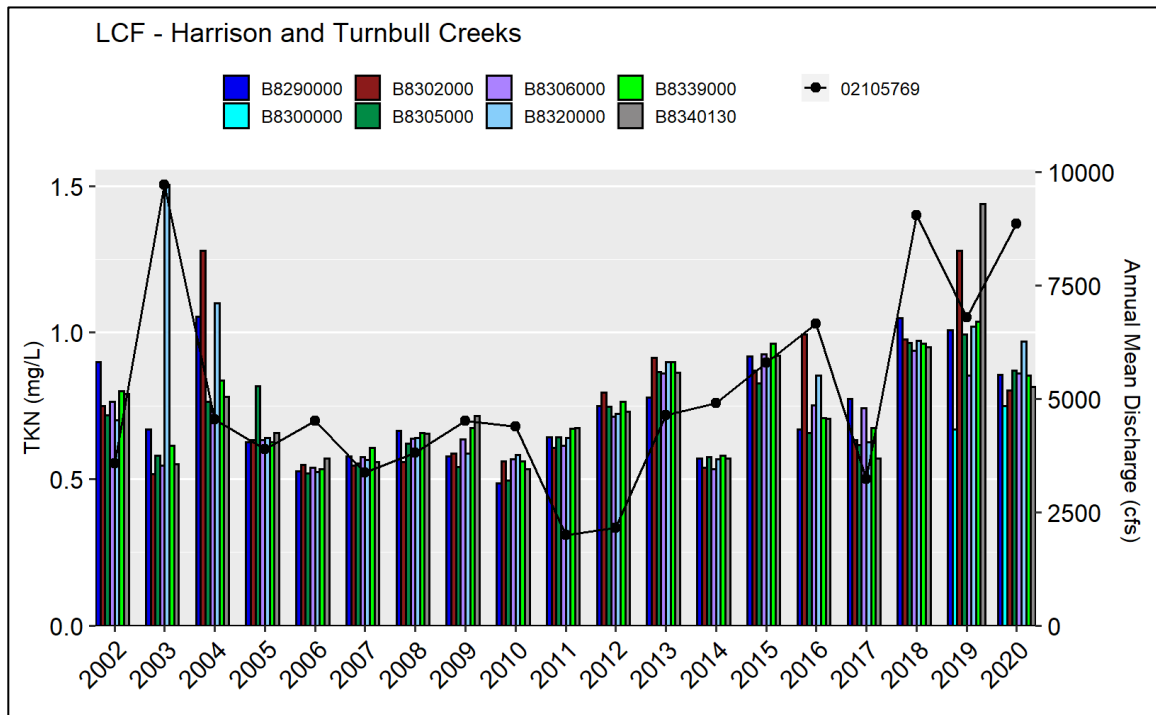


Figure 9-51: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean Ammonia

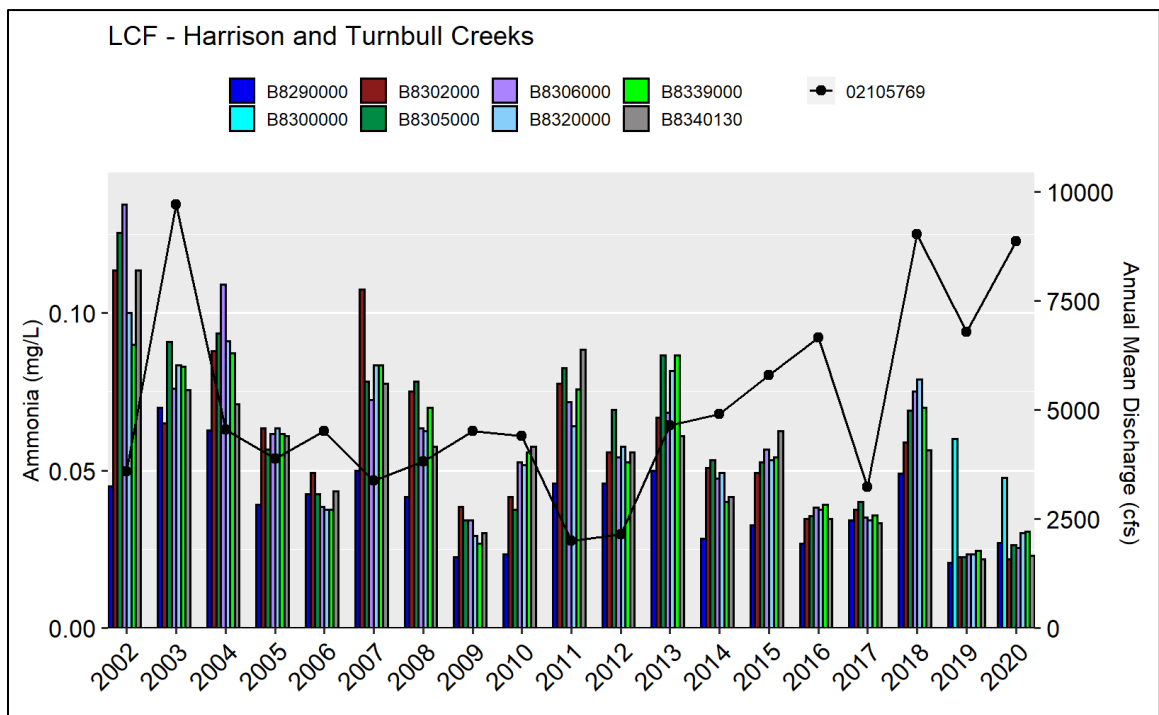


Figure 9-52: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Means for NOx

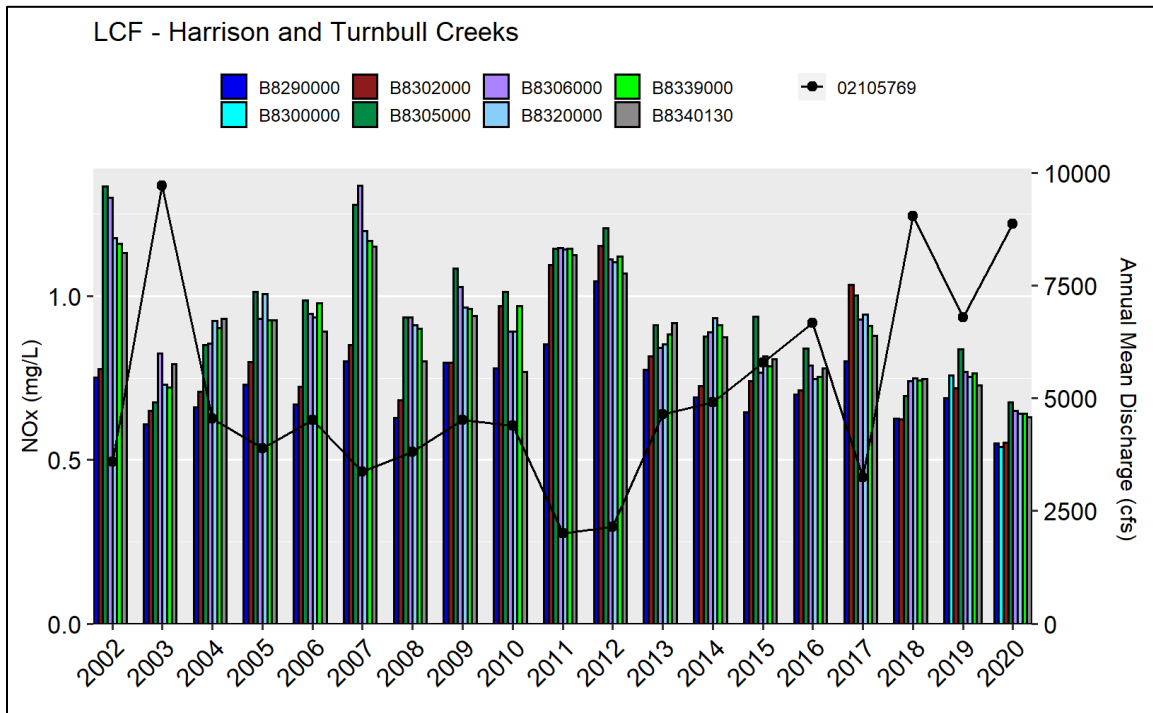


Figure 9-53: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Five-Year Means for NOx

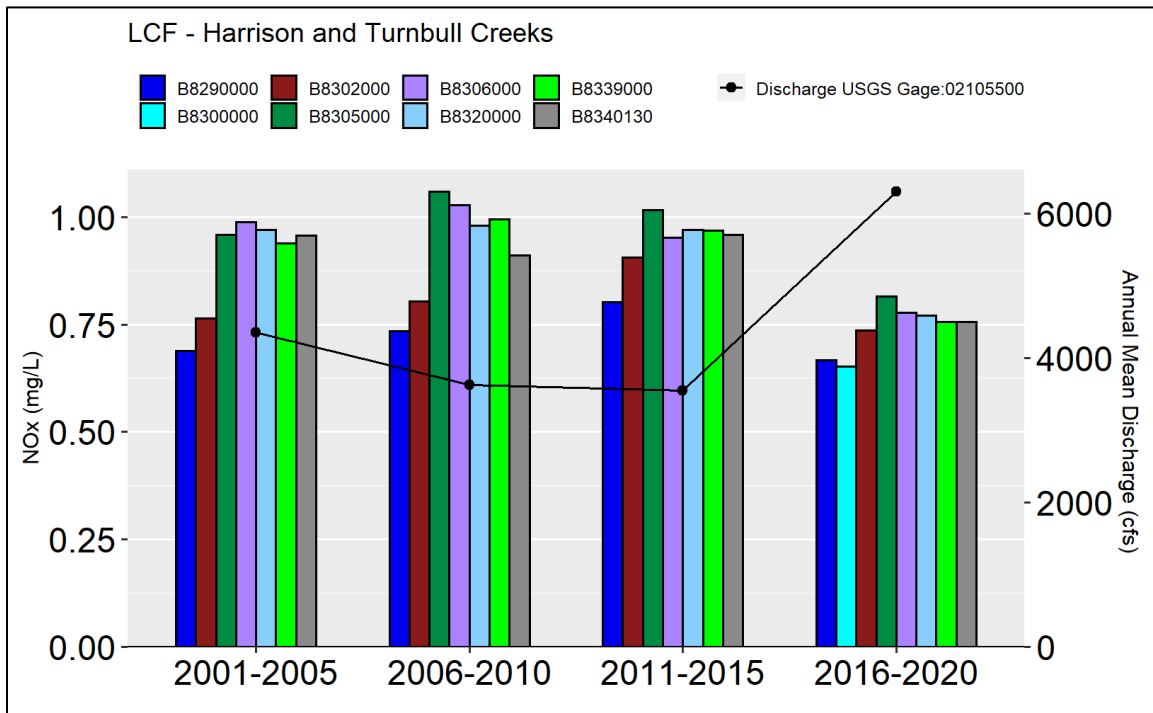


Figure 9-54: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Means for TP

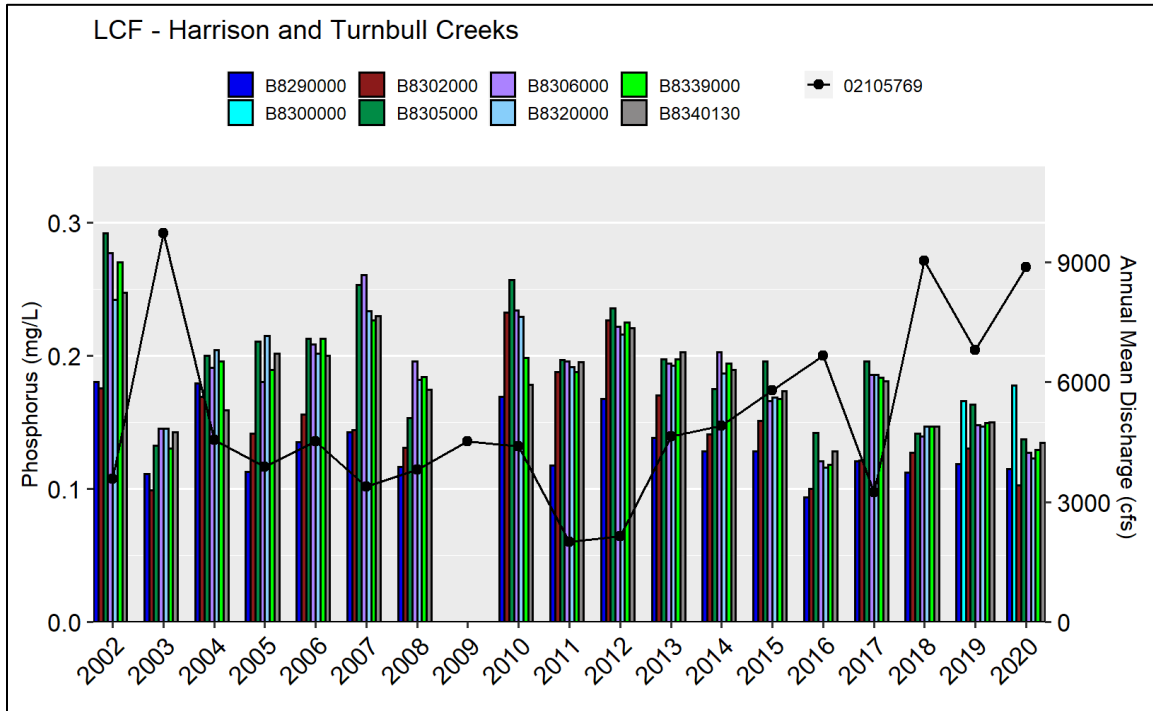


Figure 9-55: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Five-Year Means for TP

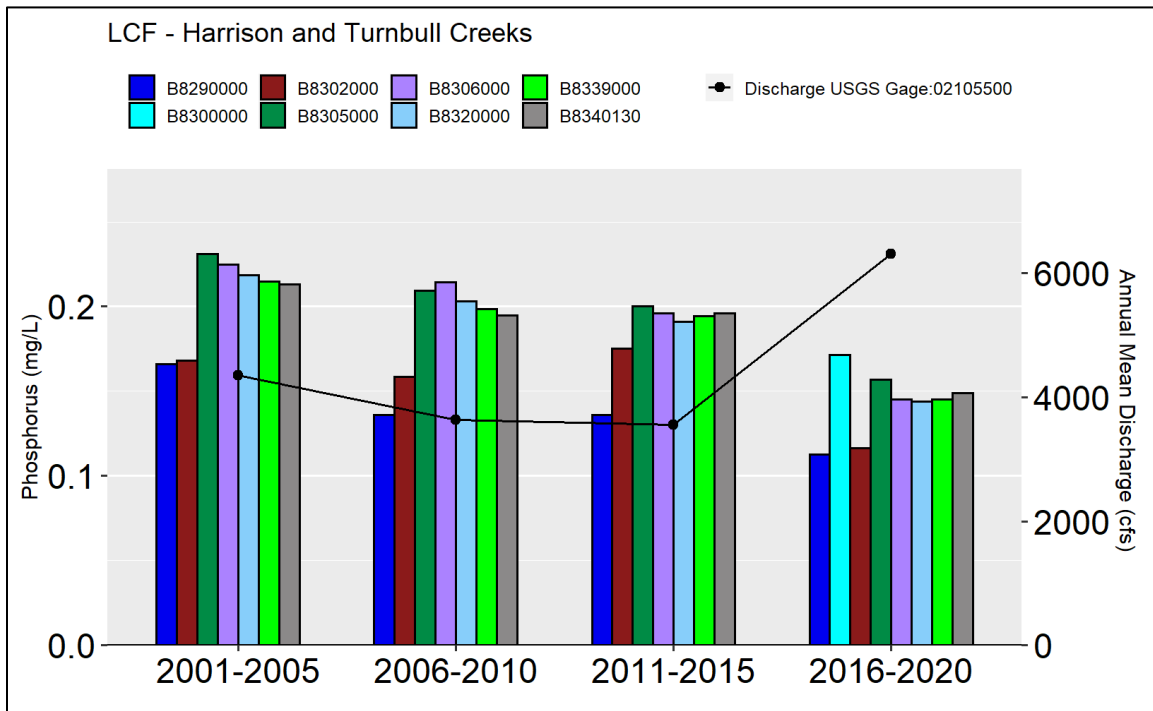


Figure 9-56: Harrison and Turnbull Creeks Lower Cape Fear Mainstem Stations Annual Mean for TN

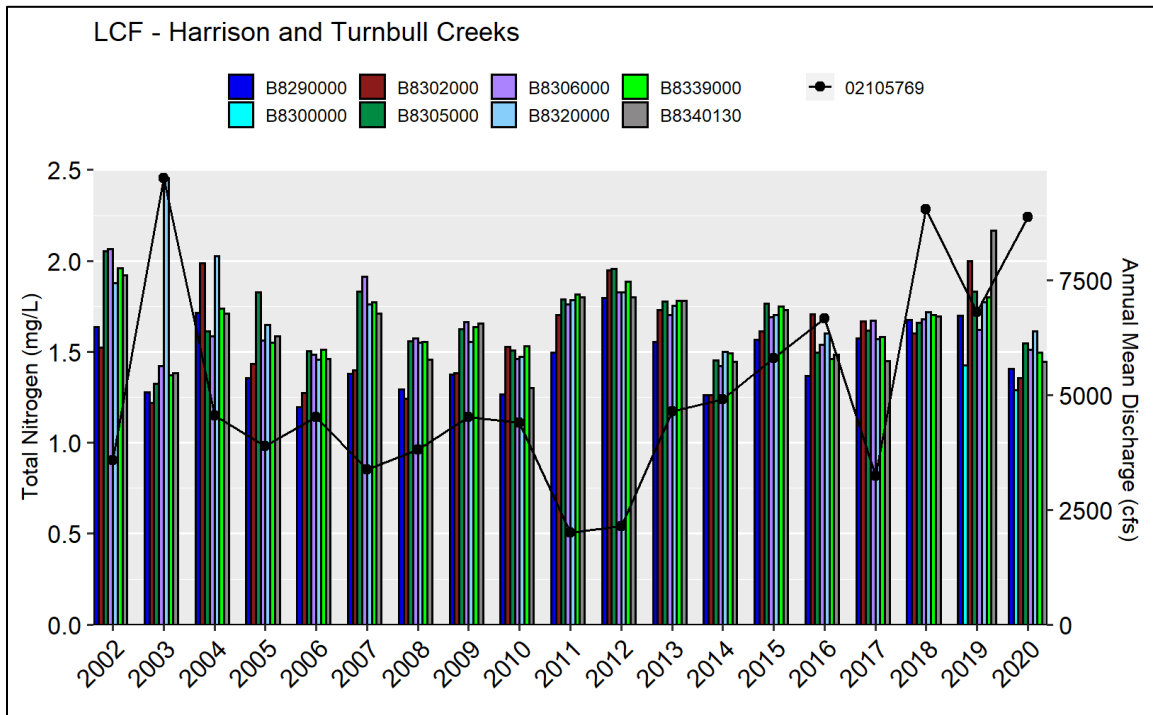


Figure 9-57: Harrison Creek and Turnbull Creek Cape Fear Mainstem TKN and NOx Annual Means

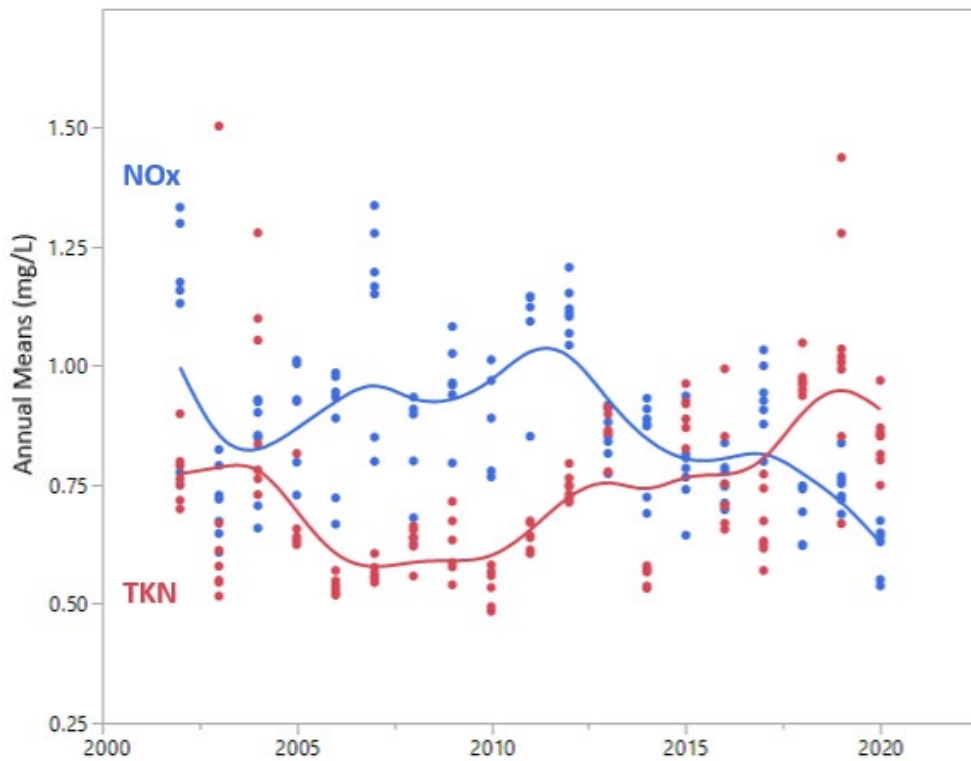


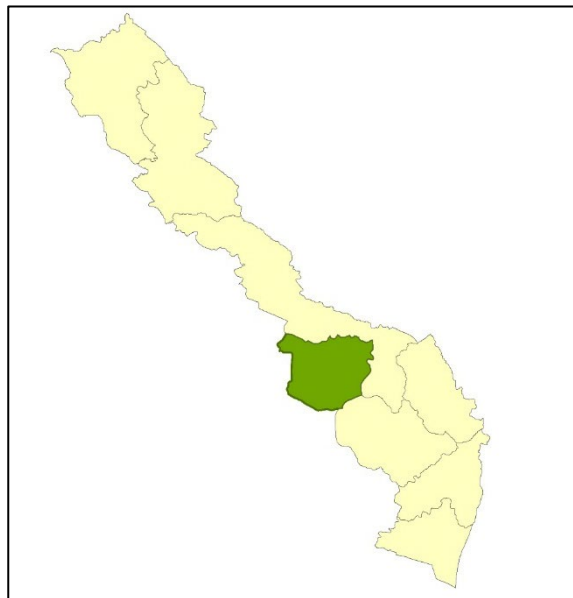
Table 9-16: Harrison Creek and Turnbull Creek Cape Fear mainstem station screening level Mann-Kendall tests for significance.

Parameter		TKN		Ammonia		NOx		Total Phosphorus	
Year		2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019
<b>1</b>	<b>B8290000</b>	not significant	significant increase	significant decrease	not significant	not significant	significant decrease	significant decrease	significant decrease
<p>———— Chemours</p> <p>———— Lock &amp; Dam #3</p>									
<b>2</b>	<b>B8300000</b>	not tested	not tested	not tested	not tested	not tested	not tested	not tested	not tested
<b>3</b>	<b>B8302000</b>	not significant	not significant	significant decrease	significant decrease	not significant	significant decrease	significant decrease	significant decrease
<p>———— Smithfield Tarheel Plant (3 MGD)</p>									
<b>4</b>	<b>B8305000</b>	significant increase	significant increase	significant decrease	significant decrease	not significant	significant decrease	significant decrease	significant decrease
<p>———— Harrison Creek</p>									
<b>5</b>	<b>B8306000</b>	significant increase	not significant	significant decrease	significant decrease	significant decrease	significant decrease	significant decrease	significant decrease
<b>6</b>	<b>B8320000</b>	significant increase	significant increase	significant decrease	not significant	not significant	significant decrease	significant decrease	significant decrease
<p>———— Elizabethtown WWTP (1.225 MGD)</p>									
<b>7</b>	<b>B8339000</b>	significant increase	significant increase	significant decrease	significant decrease	not significant	significant decrease	significant decrease	significant decrease
<p>———— Lock &amp; Dam #2</p> <p>———— Turnbull and Brown Creeks</p>									
<b>8</b>	<b>B8340130</b>	significant increase	not significant	significant decrease	significant decrease	not significant	significant decrease	significant decrease	significant decrease

Screening level Mann-Kendall tests were conducted by DWR Modeling and Assessment Branch. Stations had a minimum of six months of data ("good year") in the beginning and ending trend year and at least 70% of the years with the trend period have to be "good years." Trends were determined using the nonparametric seasonal and non-seasonal versions of the Mann-Kendall test at 95% confidence. B8300000 was only monitored in 2019 and 2020 and therefore was not evaluated.

#### 1.9.4 Livingston Creek Watershed (0303000503)

The Livingston Creek watershed spans 101 square miles of the Middle Atlantic Coastal Plain ecoregion in Columbus and Brunswick counties. This watershed only receives drainage from the network of creeks and streams that drain to Livingston Creek. The Cape Fear River confluence with Livingston Creek is located on the east side of the watershed close to the small communities of Riegelwood and Delco. All of Livingston Creek and its tributaries are classified as swamp waters.



The Livingston Creek watershed is 42% forest, 31% wetland, 11% agriculture, 9% grassland/shrub, and 5% developed (see [Table 9-6](#) and [Figure 9-6](#)). Much of the forest/timber, wetland, and grassland/shrub cover is in the upper headwaters portion of this watershed ([Figure 9-6](#)). Aerial photography indicates most of this area is on properties managed for timber harvesting. Agriculture is interspersed with patches of forest/timber and shrub cover in the center and upper portion of the watershed. International Paper has an industrial NPDES WWTP discharge facility, Riegelwood Mill (NC0003298), with property partly in this watershed and the adjacent Hood Creek-Cape Fear River watershed near the community of Riegelwood. This facility discharges to the Cape Fear River in the Hood Creek-Cape Fear River watershed described in the next section. Most development is within the vicinity of the Riegelwood and Delco communities near the Cape Fear River.

As of 2022, in the Livingston Creek watershed, there were three minor NPDES wastewater discharge facilities permitted for 0.135 MGD as-built discharge, 427 acres of residual solids land application fields permitted by the Cape Fear Public Utility Authority (WQ0001271), and four NPDES stormwater and 15 state stormwater facilities. There are no AFOs in this watershed. There is a concentration of residual solids land application fields near Livingston Creek and its Mill Creek and Johns Branch tributaries ([Figure 9-19](#)).

For this assessment (2002-2020), there were three ambient stations (two co-located stations and one RAMS station) and one benthic macroinvertebrate basin site used to assess the water quality conditions over this time-period ([Table 9-12](#), also see Chapter 2 Appendix). Station B8445000, located near the mouth of Livingston Creek, was monitored until 2005, and station B8441000, located further upstream, was monitored from 2004 to 2015. There is just one impairment in this watershed, Mill Creek (AU# 18-64-7-2) from source to Dans Creek (5.6 FW) that exceeded the pH 4.3 standard for Sw waters. This AU was impaired due to a RAMS station (B8374000) monitored in 2015 and 2016. There is currently no ambient monitoring in the Livingston Creek watershed.

A 758-acre Wright Chemical Corporation site was added to the EPA's superfund programs National Priorities List in 2011 because of contaminated groundwater, surface water, soil, sediment and aquatic biota. Livingston Creek runs along the northwest section of the property. From the 1880s until the 1960s, Acme Manufacturing Company operated a sulfuric acid manufacturing facility on the northern

portion of the property and a fertilizer manufacturing facility on the southern portion of the property. The property has changed hands many times and according to the EPA superfund website the site is still used to manufacture specialty chemicals; however, the site has not been updated in some time. Site studies occurred in 2015 and 2016 and the EPA was expected to propose a remedial plan and a record of decision in 2019. For more information see the EPA's [Wright Chemical Corporation superfund website](#).

#### 1.9.4.1 Livingston Creek Watershed Physical and Chemical Monitoring

One station, B8441000, was used for the 2022 IR in the Livingston Creek watershed. As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Station B8441000 is located along the lowest section (AU# 18[64b]) of Livingston Creek below all of its tributaries about 2.5 miles upstream of the Cape Fear River confluence. This 9.6-mile FW segment of Livingston Creek is classified C and Sw from Big Branch to the Cape Fear River. In 2019, the 101.6-mi<sup>2</sup> watershed for B8441000 was 9% agriculture, 5% developed, 42% forested (mostly timber), 12% grassland/shrub, and 32% wetland. There has been a 2.9% increase in forest and a 3.3% loss of grassland/shrub cover since 2001 in this watershed (see Chapter 2 Appendix, Land Use and Land Cover for AMs and Coalition Station Watersheds table). Station B8441000 is low enough in the Livingston Creek watershed to have all the same permits described at the HUC10 scale in the previous section. On the 2022 IR, the Livingston Creek AU was meeting criteria for all parameters except DO, which was data inconclusive. The DO rating was carried over from the 2020 IR assessment since there was no new data available.

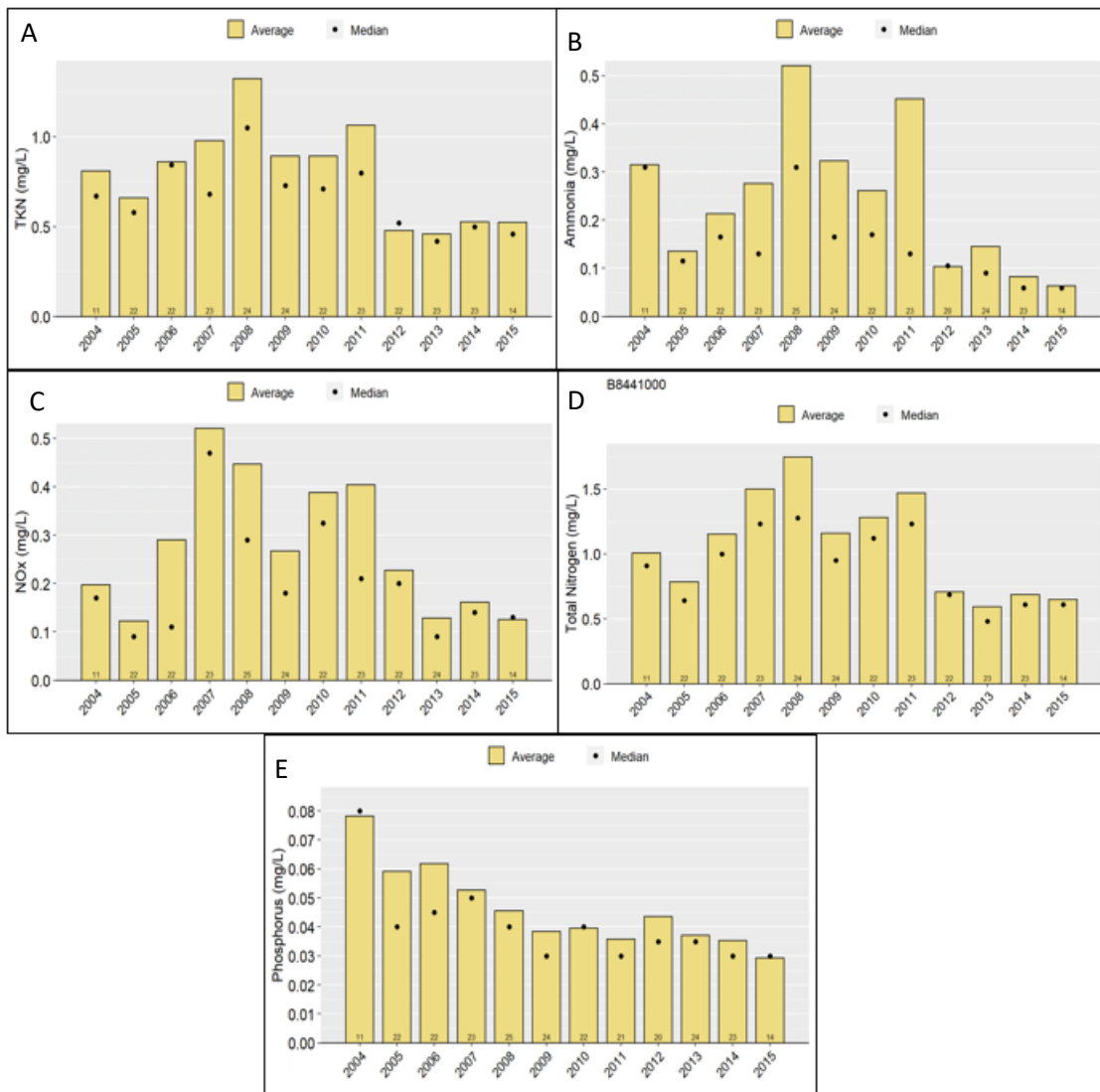
Co-located station B84410000 was monitored by DWR from 2004 to 2015 and by LCFRP from 2005-2015. Mean concentrations for the most recent five-year monitoring data available, 2011 to 2015, were 4.7 NTU for turbidity, 6.4 for pH, 5.49 mg/L for DO, 191.93 colonies/100 mL for fecal coliform bacteria, and 137.22  $\mu$ S/cm for specific conductivity. Fecal coliform bacteria had a few exceedances (6.5%) over the 400 colonies/100 mL during this time period with a maximum concentration of 5,100 cfu/100 mL. The DO concentrations ranged between 1.3 and 12 mg/L, pH between 5.7 and 7.5, and turbidity between 2.0 and 9.6 NTUs.

Mean concentrations for nutrients for the 2011 to 2015 five-year period were 0.62 mg/L TKN, 0.18 mg/L ammonia, 0.22 mg/L NO<sub>x</sub>, 0.84 mg/L TN, and 0.04 mg/L TP (*Figure 9-58 A, B, C, D, E*). Station B8441000 ammonia levels were higher than any other station in the subbasin during the 2011 to 2015 period with a maximum reading of 2.95 mg/L. Levels have been more concentrated during drier years, suggesting a potential point source. The Columbus County WWTP (NC0087947) has a minor 125,000 GPD discharge to Livingston Creek about 0.75 miles upstream of the former B8441000 station. It is likely that this WWTP is contributing to the elevated ammonia levels recorded. In 2015 and 2016, ammonia at the RAMS station (B8374000), located in the headwaters on UT to Mill Creek, ranged from 0.02 to 0.58 mg/L with a 0.18 mean. Ammonia levels were also high at station B8445000, located close to the Cape Fear River confluence, ranging from 0.02 to 1.2 mg/L from 2002 to 2005. TKN is also notably high, ranging from 0.2

to 4.4 mg/L with a 75<sup>th</sup> percentile of 0.7 mg/L. A comparison of these five-year nutrient mean concentrations to DWR’s WSS-ISB special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) shows the TKN mean was approximately 25% over the recommended <0.5 mg/L concentration. Basin planning will work with the regional office and NPDES permitting to investigate potential point source contributions to this watershed.

NOx and TP means were below the recommended concentrations of <0.3 mg/L for NOx and <0.5 mg/L for TP, and the TN mean was comparable to the recommended concentration of <0.8 mg/L. Yearly means showed both inorganic and organic nitrogen fractions had a similar pattern with higher concentrations occurring between 2006 to 2011, peaking in 2007 or 2008, and lower concentrations occurring more recently from 2012 to 2015. Drought occurred in 2007 and 2008, which suggests nitrogen is more point source influenced in this watershed as well. Yearly means for TP suggest a decreasing trend with mean levels being 0.08 mg/L in 2004, over two times the recommended Coastal Plain level, and close to 0.03 mg/L since 2009.

Figure 9-58: Station B8441000 Yearly Mean Nutrient Concentrations



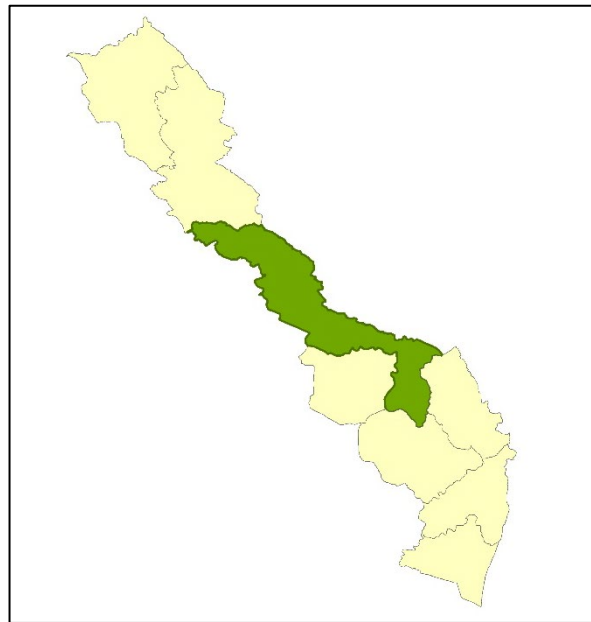
#### 1.9.4.2 Livingston Creek Watershed Biology Monitoring

There is one benthic community site located in the Livingston Creek catchment, site BB446 at US74. It has been sampled a total of three times, with the most recent sample taken in 2003 when it was rated Good-Fair. Sixteen EPT taxa were collected during the sampling event, down from 20 in the prior sample collected in 1998. Biologists noted a sand-dominated system with low DO (3.9 mg/L); the total habitat assessment score was 77/100. Specific conductance was also somewhat elevated, which could be a result of runoff from activities such as spreading residual solids and agriculture in the catchment area.

Year	Bioclassification
<b>BB446</b>	
2003	Good-Fair
1998	Good
1993	Fair

#### 1.9.5 Hood Creek-Cape Fear River Watershed (0303000504)

The Hood Creek-Cape Fear River watershed is the largest in the subbasin, spanning 215 square miles of Bladen, Columbus, Pender, and Brunswick counties. The linear-shaped watershed has a northwest-southeast orientation that follows the direction of the Cape Fear River. The northwestern portion of the watershed is in the Southeastern Plains ecoregion while the rest is in the Middle Atlantic Coastal Plain ecoregion. The Cape Fear River flows into the Hood Creek-Cape Fear River watershed, to the southeast of Elizabethtown, where it receives drainage from the upper three subbasins and the Harrison Creek-Cape Fear River and Turnbull Creek-Cape Fear River watersheds. The many tributaries that drain directly to the mainstem from upstream to down include Hammond Creek, Bandeau Creek, Drunken Run, Donoho Creek, Frenches Creek, Carvers Creek, Steep Run, Natmore Creek, Wayman Creek, Double Branch, Livingston Creek, Bryant Mill Creek, Lyon Thorofare, Grist Mill Branch, and Hood Creek. Livingston Creek drains the Livingston Creek HUC10 watershed discussed in the previous section (Section 9.9.4). The Lyon Thorofare is a slow-moving swamp stream that crosses subbasin boundaries, connecting the Cape Fear River mainstem with the Black River, five miles above the main confluence. The Cape Fear River and most of the tributaries, in the middle section of the watershed from Drunken Run to Double Branch, are classified as WS-IV. Waterbodies in the lower half of this watershed, including the Cape Fear River and its tributaries from Natmore Creek downstream are classified as swamp waters. Natmore Creek also originates in the Black River subbasin.



Land cover in the Hood Creek-Cape Fear River watershed is 35% forest, 33% wetland, 13% grass/shrub, 13% agriculture, and 5% developed (see [Table 9-6](#) and [Figure 9-6](#)). The Cape Fear River mainstem, and the many riverine forests in its floodplain, are closer to the eastern side of the watershed. Near the community of Riegelwood, where there is a large bend in the Cape Fear River, the floodplain widens. Aerial photography indicates many areas of forested wetland along this section have been cleared in recent years. It should be noted that changes from forested to non-forested wetlands are not documented in the land-use changes shown in see [Figure 9-6](#). The largest section of undisturbed riverine swamp forest in the

subbasin is located in the lowest part of the watershed below this cleared section. This riverine swamp section includes Roan Island, accessible only by boat and located between the Lyon Thorofare and the Black and Cape Fear Rivers. There are also several Carolina bays in the upper part of the watershed to the northeast of the Cape Fear River. Agriculture is interspersed with patches of forest and shrub cover on the west side of the Cape Fear River and its western tributaries. Aerial photography indicates that land cover classified as forest, grassland/shrub, and wetland, located in the western Cape Fear tributary headwaters (the interstream divide area), are managed timberland.

As of May 2022, there were three minor and one major NPDES wastewater discharge facilities permitted for 50.015 MGD, 20 AFOs, 54 acres of land application of residual solids fields owned by Elizabethtown (WQ004038), and five NPDES and 48 state stormwater facilities. The major NPDES facility is the industrial Riegelwood Mill facility (NC0003298), owned by International Paper, with a permitted as-built flow of 50.0 MGD for discharge to the Cape Fear River. This facility, which discharges just above the Livingston Creek confluence, has the highest permitted as-built flow in the subbasin, and second highest in the entire river basin behind Greensboro's T.Z. Osborne WWTP (NC0047384; 56 MGD). The AFOs include 19 swine COCs and one Individual Animal Facility, with 38 lagoons, permitted for a total headcount of 101,461 and total live weight of 15,602,539 lbs. AFOs are more prevalent in the upper half of the watershed (*Figure 9-7*).

For the 2002-2020 assessment, there are eleven ambient stream monitoring stations (two AMS, five Coalition, two co-located, and two RAMS), two benthic macroinvertebrate and two fish community stations used to assess the water quality conditions over this time-period (*Table 9-12*, also see the Chapter 2 Appendix). Along the Cape Fear River mainstem, there is one impairment for benthos (AU 18-(63)a; 3.8 FW mile), from the raw water supply intake at Federal Paper Board corporation (Riegelwood) to Bryant Mill Creek. This 2022 IR impairment is from monitoring done previous to the period of this plan.

A 24-acre Holtrachem/Honeywell Inc. Riegelwood site is on the EPA superfund site list. The site is currently owned by Honeywell Inc. and borders the Cape Fear River to the northeast, and the remaining three sides are bounded by International Paper's Riegelwood Mill. EPA, DEQ and Honeywell are working together to clean up the site. Hazardous chemicals above ground were removed from the site in 2002-2004. In 2008, PCB contamination was identified, and in 2017, EPA selected the cleanup plan for the site that involves excavating contaminated soils and constructing a chemical waste landfill to contain contaminated soils. For more information see the EPA [Holtrachem/Honeywell superfund website](#).

#### 1.9.5.1 Hood Creek-Cape Fear Physical and Chemical Monitoring

At the HUC10 level, the Hood Creek-Cape Fear River watershed had the highest mean levels of fecal coliform bacteria in the Lower Cape Fear River subbasin from 2016 to 2020 (*Table 9-13*). One tributary station (B8340200) on Hammond Creek, and seven Cape Fear River mainstem stations--B8340650, B8348000, B8349000, B8350000, B8360000, B8450000, and B8465000--were monitored for the 2022 IR.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Station B8340200 was monitored by LCFRP along Hammond Creek tributary, the uppermost tributary in the watershed, that flows in a southeasterly direction, merging with the Cape Fear River on the west side. Station B8340200 is located several miles upstream from the confluence. The Hammond Creek assessment unit (AU# 18-50) is defined as class C from the source to the Cape Fear River for 11.4 FW miles. In 2019, the 17.5-mi<sup>2</sup> watershed (B8340200) was 27% agriculture, 7% development, 41% forest (a lot of timber production), 11% grassland/shrub, and 13% wetland. There has been a 4% loss of forest and a 4.2% increase of grassland/shrub since 2001 in this watershed (see Chapter 2 Appendix, Land Use and Land Cover for AMs and Coalition Station Watersheds table). The development is primarily from the Curtis L. Brown Jr. Field Airport. The small community of Mount Olive is also located in this watershed. In May 2022, the B8340200 station watershed had eight swine AFOs with 15 lagoons permitted for 4,492,920 lbs allowable weight and 54 acres of residual solids land application fields for the Elizabethtown RLAP (WQ0004038), located near the airport. Other permitted AFO facilities are located along Hammond Creek below station B8340200. On the 2022 IR, this AU was meeting criteria for all parameters except fish community, which was data inconclusive (see the next section).

Mean concentrations over the last five years (2016-2020) at B8340200 have been 8.98 NTU for turbidity, 6.78 for pH, 8.06 mg/L for DO, 3,712 colonies/100 mL for fecal coliform, and 162.21  $\mu$ S/cm for specific conductivity. Fecal coliform has ranged from 270 to 60,000 colonies/100 mL with a 39% exceedance rate over the 400 colonies/100 mL standard during these five years. Fecal coliform levels peaked in 2016 and 2017, 14 of 23 daily records were >1,000 colonies/100 mL and 5 of 23 were > 5,000/100 mL during these two years (*Figure 9-59*). Recent fecal coliform annual mean levels from 2018 to 2020 have been much closer to the standard. Turbidity, DO, and pH had 0% exceedance of standards over the last five years. DO did have 10% over the 4.0 mg/L standard from 2006 to 2010, a time-period that included some drought years. DWR conducted screening level Mann-Kendall trend seasonal tests for station B8340200 at 95% confidence and found fecal coliform to be significantly increasing from 2000 to 2019, which was supported by the annual means graphical pattern (*Figure 9-59*).

Mean concentrations for nutrients over the last five years were 0.74 mg/L TKN, 0.08 mg/L ammonia, 0.37 mg/L NO<sub>x</sub>, 1.11 mg/L TN, and 0.17 mg/L TP (*Figure 9-60A,B,C,D,E*). TP is notably high, ranging from 0.02 to 0.45 mg/L with a 75<sup>th</sup> percentile of 0.23 mg/L. A comparison of these five-year nutrient means to DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams shows all nutrient concentrations are over the recommended concentrations (*Table 9-13*). TP was three times over the recommended <0.05 mg/L. TKN is about 50% over the recommended <0.5 mg/L and ammonia is about 60% over the recommended 0.05 mg/L. NO<sub>x</sub> is over the 0.3 mg/L recommendation by 23% and TN is over the 0.8 mg/L recommendation by 39%. DWR conducted screening level Mann-Kendall trend seasonal tests which show a significant increasing trends calculated at 95% confidence for TKN and ammonia for 2010-2019 and NO<sub>x</sub> for 2000-2019. Specific conductivity, which is often correlated with a pollution source, was also increasing significantly from 2000-2019 (*Figure 9-60F*).

Figure 9-59: Station B8340200 Fecal Coliform Annual Means and Geomeans

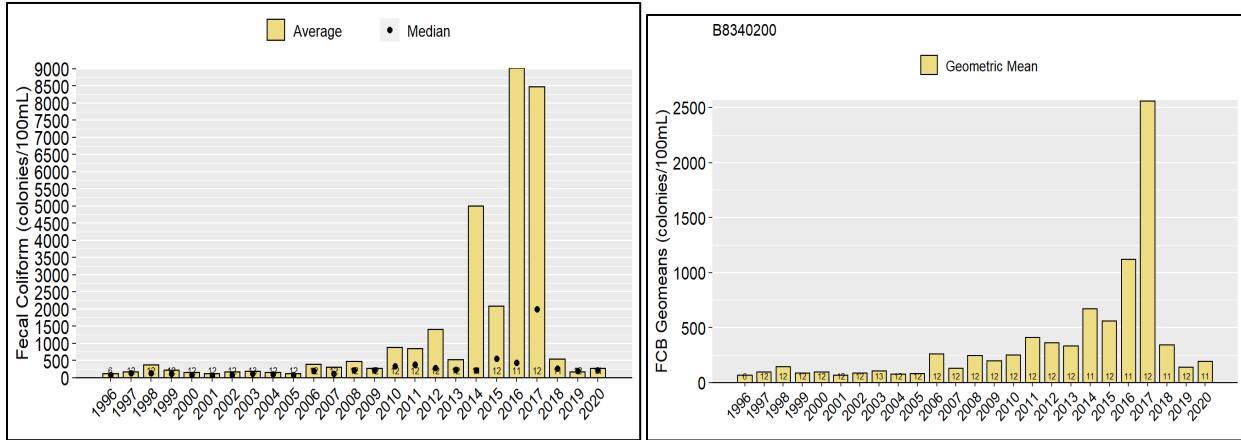
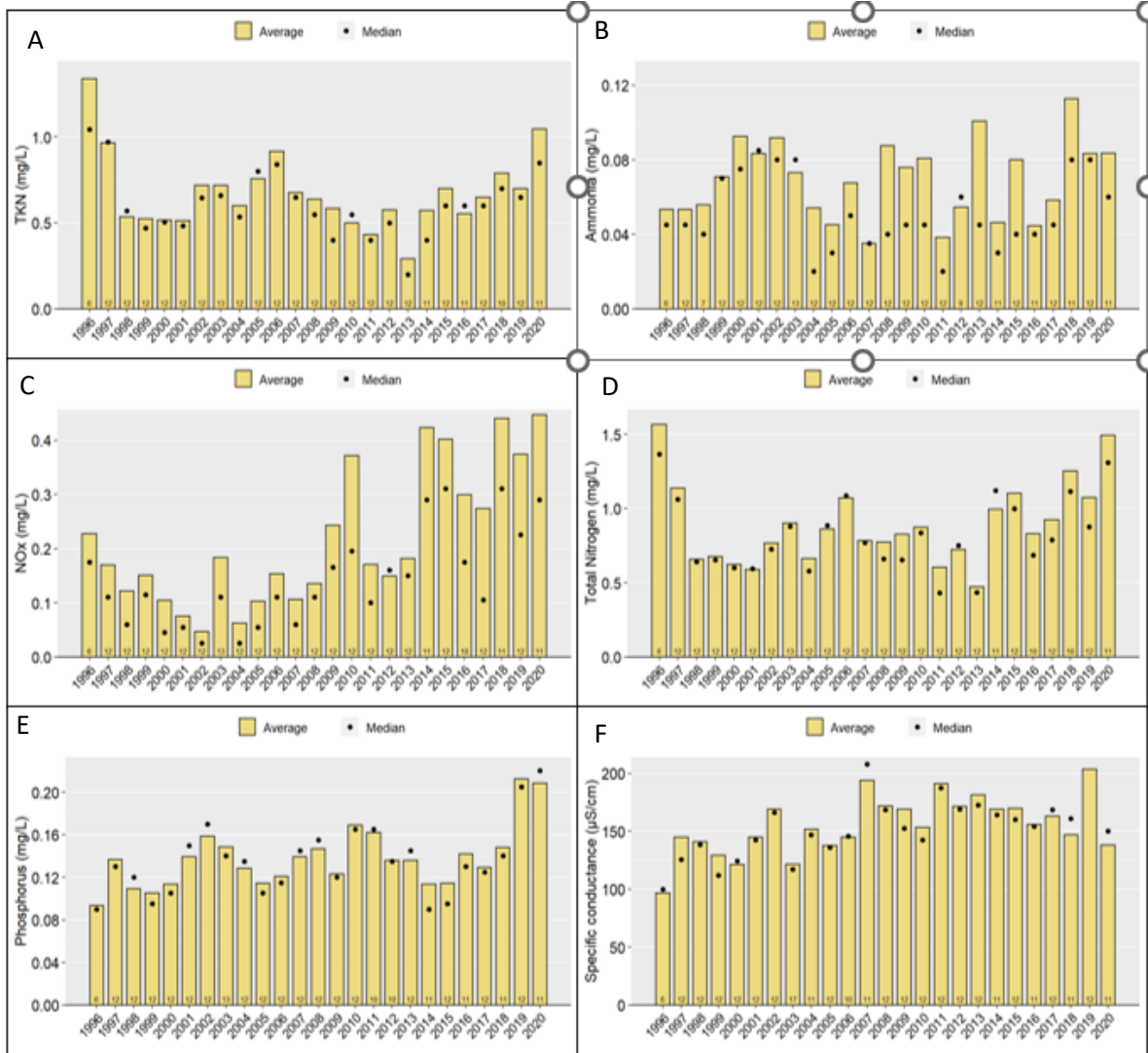
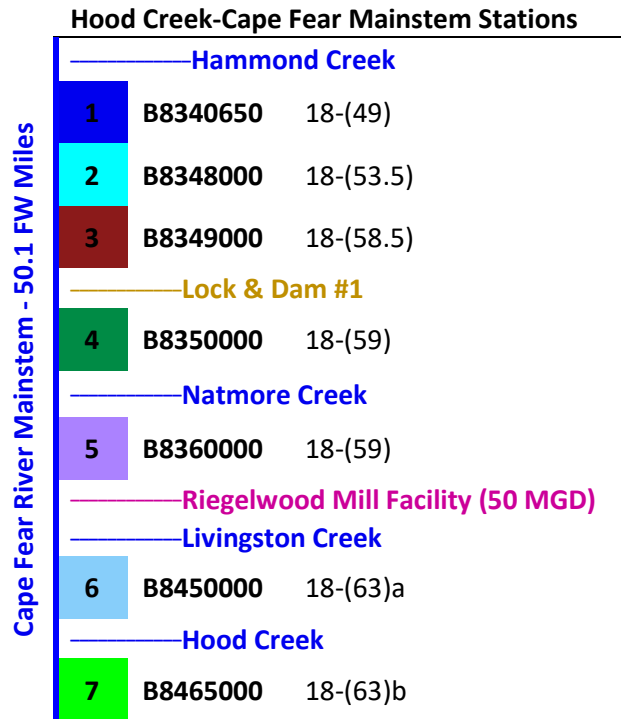


Figure 9-60: Station B8340200 Yearly Mean Nutrient Concentrations



The Hood Creek-Cape Fear River mainstem evaluation included seven stations located along 50.1 FW miles composed of five assessment units: 18-(49), 18-(53.5), 18-(59), 18-(63)a, and 18-(63)b (see diagram to right and *Table 9-14* for AU descriptions). All stations are in the Mid-Atlantic Coastal Plain ecoregion. The diagram to the right shows the Hood Creek-Cape Fear River mainstem station locations relative to LD1, Hammond Creek (see earlier discussion on station B8340200), Livingston Creek (Section 9.9.4.1), Natmore and Hood creeks, and the one major NPDES facility along this segment (Riegelwood Mill). The first three stations are classified as C waters and the last four stations are C and Sw class waters. The 2022 IR found AU 18-(59) (fourth and fifth stations, B8350000 and B8360000, respectively) to be data inconclusive for 1,4-dioxane (WS, WS); AU 18-(63)a (sixth station, B8450000) to be impaired for benthos from data collected pre-2002; and AU 18-(63)b (seventh station, B8465000) to be data inconclusive for chloride (230 mg/L, AI, FW), fluoride (1.8 mg/L, AL, FW), chlorophyll *a* (40 ug/L, AL, NC) and a suite of dissolved metals.



Along this segment of the Cape Fear River, the one major and six minor dischargers have a collective as-built flow of 50.15 MGD. Riegelwood Mill Facility, which accounts for 50 MGD, located between stations B8360000 and B8450000 above the Livingston Creek confluence (see above diagram), as noted in the previous section, is the second largest NPDES discharger in the basin. There are also nine NPDES stormwater facilities mostly located below station B8360000 and along Livingston Creek, 426.7 residual solids application fields, also located along Livingston Creek, and four AFOs permitted for 2.7 million pounds of live weight and four lagoons. It should also be noted that between the first station in this segment (B8340650) and the last station (B8340130) in the next upriver segment, there are 12 AFOs (mostly swine) with 34 lagoons permitted for 12.9 million pounds of live weight and another 54 acres of residual solids application fields. Also see Chapter 3, Section 3.9.1 Ambient Water Quality Station Drainage Area Permit Analysis for the Cape Fear River.

Ambient water quality monitoring station B8350000 (WS-IV; Sw) on the Cape Fear River downstream of LD1, is part of a special study on 1,4-dioxane in the Cape Fear River Basin. Thirty-seven (62.7%) of the 59 samples collected between February 2018 and December 2024 exceeded the EPA health-based drinking water concentration representing a 1-in-a-million ( $1 \times 10^{-6}$ ) cancer risk level for 1,4-dioxane of 0.35  $\mu\text{g/L}$  (EPA IRIS, 2013). These samples ranged between 1.0 and 11.0  $\mu\text{g/L}$  with an average 1,4-dioxane concentration of 2.8  $\mu\text{g/L}$ . Twenty-Two or 37.3% of the samples collected were below the PQL of 1  $\mu\text{g/L}$ . DWR will continue to work with upstream dischargers to identify and reduce the source of 1,4-dioxane at the source of the contaminant. For more information on 1,4-dioxane see Chapter 2 (section 2.13.2) and Chapter 13 for summary tables and figures for 1,4-dioxane in the Cape Fear River Basin.

Yearly means and exceedance rates from 2002 to 2020 for the Hood-Creek Cape Fear River mainstem evaluation were graphed for the seven stations located along this segment (*Table 9-14*). Five-year means were also graphed for ammonia and NO<sub>x</sub>. A full set of five-year graphics is available in the Subbasin Chapter Appendix. Turbidity was not collected at the last LCFRP station, B8465000, while all other stations had complete sets of data (*Table 9-14*). The first three stations were monitored by the MCFBA coalition, the fourth station was monitored by DWR, the fifth and sixth stations were co-located and monitored by the LCFRP and DWR, and the seventh station was monitored by LCFRP.

Turbidity annual means generally ranged from 7 to 25 NTUs with the highest annual means of about 35 NTUs in 2015 at B8350000 just downstream of LD1 (*Figure 9-61*). Turbidity generally correlated with discharge most years, indicating nonpoint stormwater sources typically contributed more than point sources. The flow-separated analysis of the Cape Fear River mainstem stations show that the concentrations are much higher at the high flows (*Figure 9-24*). The fourth and sixth stations, B8350000 and B8450000, respectively, had relatively higher mean turbidity levels than the other stations for several years. The fourth station is directly below LD1 where more rapid water movement likely spikes the turbidity and the sixth is below the Riegelwood Mill Facility and Livingston Creek and each may be contributing to turbidity. The higher levels at the first three stations--B8340650, B8348000, B8349000--in 2013, and the first station only in 2018, probably came from upriver (see Section 9.10.1 and *Figure 9-40*). The yearly turbidity exceedances were usually <10% with a few in the 15% to 20% range or greater (*Figure 9-62*). Several of the higher exceedances were at the first, fourth, and sixth stations. DWR conducted screening level seasonal and non-seasonal Mann-Kendall trend tests at 95% confidence for monitoring data collected from 2000 to 2019 and 2010 to 2020 on the Hood Creek-Cape Fear River stations. The turbidity trend test results were insignificant at all six stations that had monitoring data.

The pH annual means ranged from 6.4 to 7.0 (*Figure 9-63*) with yearly exceedances generally less than 10% (*Figure 9-64*). There were different sampling frequencies between the MCFBA, AMS, and LCFRP. MCFBA sampled at the first three stations--B8340650, B8348000, B8349000; AMS sampled at the fourth station--B8350000; the LCFRP and AMS co-sampled at the fifth and sixth stations--B8360000, B8450000; and LCFRP sampled the seventh station--B8465000. The different instrumentation and sampling frequency between the three programs may have had a minor effect on the yearly means, causing the lower stations to be higher some years. Exceedances, typically less than 10%, only occurred at the first three stations below the pH standard (6 to 8) which is more stringent than the Sw pH standard ( $\geq 4.3$ ) assigned to the lower four stations (*Figure 9-64*, *Table 9-14*). There were more exceedances before 2011 at the three upstream stations, similar to the Harrison and Turnbull creeks mainstem segment, indicating potential upriver influence. Mann-Kendall screening trend tests for pH showed a significant decrease at the first (B8340650) and fourth (B8350000) from 2000 to 2019; seventh (B8465000) from 2010 to 2019; and fifth (B8360000) and sixth (B8450000) during both periods.

Annual mean DO concentrations in this segment of Cape Fear River generally ranged from 6.0 to 9.0 mg/L (*Figure 9-65*). Most years, the fourth station, B8350000, was generally higher than the other stations. This DWR station is located right below LD1 where mixing over the rock arch ramp likely increases the DO level and it is only monitored monthly year-round. The increased monitoring frequency of the coalition stations during the warmer months lowers the annual mean DO concentrations. The seventh station (B8465000)

generally has the lowest mean DO concentrations. This station also may have slower-moving water as it is located where the river splits around a small island possibly slowing the current. A few exceedances of the 4.0 mg/L standard occurred at the first three stations that do not have the Sw supplemental classification (*Figure 9-66, Table 9-14*). The DO exceedance assessment is not done in Sw waters as the standard allows for naturally occurring lower DO concentrations. Mann-Kendall screening trend tests found DO significantly decreased at the sixth (B8450000) station from 2000 to 2019, the fourth (B8350000) station from 2010 to 2019, and the fifth (B8360000) station during both periods.

Most fecal coliform annual means were well under the 400 colonies/100 mL standard, ranging from 20 to 150 colonies/100 mL (*Figure 9-67*). Annual mean levels at the last two stations were extremely high in 2016, reaching 1,700 colonies/100 mL at the sixth (B8450000) station and 1,250 colonies/100 mL at the seventh (B8465000) station. In 2016, a couple of outliers at the sixth station were >10,000 colonies/100 mL, possibly due to pollutant sources in the Livingston Creek watershed where a concentration of residual solids application fields were located (*Figure 9-19*). However, there is no water quality data for Livingston Creek after 2015. Exceedances for fecal coliform were typically <20% and usually <10%, except in 2015, when the fifth, B8360000, and seventh, B8465000, stations were over 30% (*Figure 9-68*). All fecal coliform annual geomeans were below the 200 colonies/100mL standard (*Figure 9-69*). Fecal coliform results varied from year to year, but the annual geomeans suggest that overall fecal coliform correlates with discharge (*Figure 9-69*), indicating that nonpoint source stormwater runoff contributes more to fecal coliform. The flow-separated analysis of the Cape Fear River mainstem stations show that the concentrations are much higher at the high flows (*Figure 9-25*). Mann-Kendall screening trend tests for fecal coliform found levels significantly increased from 2000 to 2019 at the fifth (B8360000), sixth (B8450000), and seventh (B8465000) stations while results for 2010 to 2019 found fecal coliform levels significantly decreased at the first (B8340650), second (B8348000), and third (B8349000) stations and significantly increased at the fourth station (B8350000).

Specific conductivity annual means ranged typically from near 100  $\mu$ S to 200  $\mu$ S (*Figure 9-70*). The graphical pattern indicates specific conductivity negatively correlates with flow suggesting point sources have a stronger influence on this parameter. This is clearly seen in the flow-separated analysis for the three mainstem station in this section of the Cape Fear River: station B8349000 upstream of LD1; station B8350000 downstream of LD1; and station B8360000 approximately two miles downstream of LD1 (*Figure 9-21*). There was a rise in specific conductivity at the sixth (B8450000) and seventh (B8465000) stations, both located below the Riegelwood Mill Facility, which was likely the main cause of the increase (*Figure 9-70*). The lower two stations could also be influenced by saltwater tidal impacts during low-flow drought periods. Screening level Mann-Kendall tests for specific conductivity found the first (B8340650) and sixth (B8450000) stations significantly decreased from 2000 to 2019 while all seven stations significantly decreased from 2010 to 2019.

The Hood Creek-Cape Fear River nutrient yearly mean concentrations are shown in *Figure 9-71* to *Figure 9-77*. The graphical pattern for NO<sub>x</sub> (*Figure 9-74*), TN (*Figure 9-76*), and TP (*Figure 9-77*) along the Hood Creek-Cape Fear River mainstem suggest concentrations were negatively correlated with discharge, indicating point sources as the main driver. TKN (*Figure 9-71*) and ammonia (*Figure 9-72*) concentrations along this segment were more variable and did not correlate as well with discharge. The flow-separated

analysis at the three Cape Fear River mainstem stations show a similar pattern (*Figure 9-26, Figure 9-27, Figure 9-28 and Figure 9-29*).

Eighty percent of nutrient concentrations for the Hood Creek-Cape Fear River mainstem ranged from 0.5 to 0.9 mg/L for TKN, 0.03 to 0.11 mg/L for ammonia, 0.5 to 1.0 mg/L for NO<sub>x</sub>, 1.3 to 1.8 mg/L for TN, and 0.13 to 0.21 mg/L for TP. DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) recommended <0.5 mg/L for TKN, <0.05 mg/L for ammonia, <0.3 mg/L for NO<sub>x</sub>, <0.8 mg/L for TN, and <0.05 mg/L for TP. The EPA nutrient criteria study for Coastal Plain streams recommended <0.72 mg/L for TN and 0.032 mg/L for TP (*Table 9-13*). Ninety percent of the TKN annual mean concentrations were over the recommended <0.5 mg/L and a few yearly means were twice as high. Half of the annual means were over the recommended <0.05 mg/L for ammonia, with the fifth (B8360000), sixth (B8450000), and seventh (B8465000) stations most commonly being over the recommendation. The majority of the NO<sub>x</sub> annual means were well over the recommended <0.3 mg/L, with three-quarters being twice as high and some three times as high. All of the TN annual means were also over the <0.8 mg/L recommendation, with about half being twice as high. Almost all of the TP annual mean concentrations were at least twice as high as the recommended 0.05 mg/L and more than half were three times as high or greater.

The graphical pattern for TKN (*Figure 9-71*) at the first three stations above LD1--B8340650, B8348000, B8349000, generally followed the same pattern as the Harrison to Turnbull creeks reach of the Cape Fear River segment, indicating upstream sources (*Figure 9-50*). The TKN concentrations in the lower three stations below LD1 (B8360000, B8450000, B8465000) were higher than the first four stations between 2005 and 2009 and dropped substantially between 2010 and 2013. The yearly TKN means increased and are comparable or lower in later years. Natmore Creek, with its headwaters in the Black River subbasin, is located between the fourth (B8350000) and fifth (B8360000) stations. (See the Cape Fear River mainstem diagram above.) It has many agricultural fields and some wetlands that may have contributed to TKN levels. The notable rise in TKN at the lowest two stations in 2006 and 2007 was potentially due to the Riegelwood Mill Facility, located above the sixth station (B8450000). The five-year mean graphics, available in Subbasin Chapters Appendix, show a distinct rise in the TKN at the lower two stations during that same time period and dropping in the years afterwards. The same trend occurred in Livingston Creek. These lower stations have more swamp drainage that might have affected this area during that time period as well.

For ammonia, the upper four stations have a comparable pattern to the Harrison to Turnbull creeks mainstem Cape Fear River segment, indicating upstream influence. However, ammonia also has a notable jump most years at the fifth or sixth stations (*Figure 9-72*). Possibly, both the Natmore Creek watershed and Riegelwood Mill Facility and/or Livingston Creek have contributed to these increased concentrations. Livingston Creek, which flows into the Cape Fear River above the sixth station (B8450000), has also had extremely high instream ammonia levels that have likely affected concentrations in the Cape Fear River. The five-year mean graphics show a distinct rise in the ammonia concentration at the lower two stations below Livingston Creek. Basin planners will work with the Wilmington Regional Office and water quality monitoring staff to better understand the ammonia sources and impacts on the system. When resources allow, adding a monitoring station in Livingston Creek and assessing the need to add effluent and instream monitoring requirements to point source dischargers in this area is recommended.

The Hood Creek-Cape Fear River NO<sub>x</sub> graphical pattern was similar to the Harrison to Turnbull creeks mainstem Cape Fear River segment with relatively higher concentrations at the upper four stations, indicating upriver sources for NO<sub>x</sub> (*Figure 9-52 and Figure 9-74*). The instream concentration generally declines moving downstream, which is obvious in the five-year mean graphic (*Figure 9-75*). This could be the result of uptake from instream biological processes or dilution from drainage in the watershed. The yearly means generally range between about 0.4 and 1.0 mg/L (*Figure 9-74*). The flow-separated analysis at the Cape Fear River mainstem stations show that the concentrations are higher at low flows, suggesting point sources have a strong influence on this parameter (*Figure 9-28*).

TN concentrations at the upper three stations (*Figure 9-76*) were also comparable to the upriver segment (*Figure 9-56*). The TKN to NO<sub>x</sub> ratio of TN increased at the first three stations with the TKN (organic fraction) being higher over the last two monitoring years (*Figure 9-78*). The lower three stations were more variable with the TKN being higher before 2010 and after 2014. The fourth station (B8350000) had less variability between years with a higher ratio of NO<sub>x</sub> to TKN remaining stable through the 2002 to 2020 monitoring period.

TP concentrations were also usually comparable to upriver and had minimal variability between stations, except in 2019 and 2020 when the lower three stations (B8360000, B8450000, and B8465000) were elevated to over 0.2 mg/L, well over the recommended 0.05 mg/L value (*Figure 9-77*). TP sources causing this elevation likely originated in the Natmore Creek watershed where there are extensive agricultural fields. The Colly Creek station B9891000, located in the same general vicinity of the Black River subbasin, was also elevated in 2019 and 2020 (*Figure 9-79*). The 2021 and 2022 LCFRP data indicate both the Cape Fear mainstem stations below Natmore Creek (B8360000) and the Colly Creek station (B9891000) remained elevated in 2021 and 2022, although less so in 2022. Yearly TP means for B8360000 were 0.32 mg/L in 2021 and 0.23 mg/L in 2022. Basin planning will work with the Wilmington Regional Office to investigate the sudden increase in TP.

DWR conducted screening level seasonal and non-seasonal Mann-Kendall trend tests for nutrient monitoring data collected from 2000 to 2019 and 2010 to 2020 at the seven Hood Creek-Cape Fear stations (*Table 9-17*). TKN was of particular concern as there was a significant increase during one or both periods at all seven stations. TKN significantly increased from 2000 to 2019 at the third (B8349000) and fourth (B8350000) stations; from 2010 to 2019 at the fifth (B8360000), sixth (B8450000), and seventh (B8465000) stations; and during both periods at the first two stations (B8340650, B8348000). All other nutrients decreased significantly or had no significant change during the two periods. The first, second, and third stations decreased significantly during one of both periods for ammonia, NO<sub>x</sub>, and TP. The fourth and fifth stations had no significant change. The sixth and seventh stations decreased significantly for NO<sub>x</sub> from 2010 to 2019 and had no significant change from 2000 to 2019 for NO<sub>x</sub>, and no significant change for either period for ammonia or TP.

When environmental conditions are optimal, the elevated nutrients in the Cape Fear River system can result in algal bloom development. HABs have been identified in the Cape Fear River since 2009. NC DHHS routinely warns the public to avoid contact with large accumulations of algae and to prevent children and

pets from swimming or ingesting water in areas of algal blooms. Chlorophyll *a* and algal bloom results are discussed below in section 9.10.4 for the mainstem Cape Fear River as a whole.

Figure 9-61: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean Turbidity

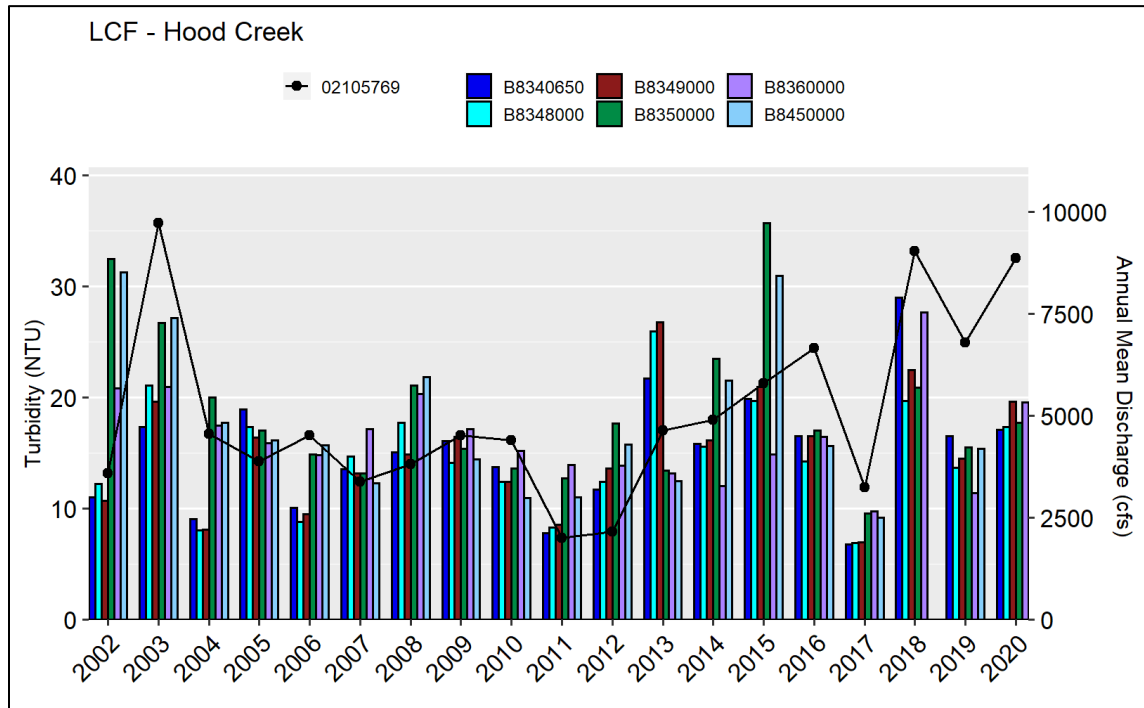


Figure 9-62: Hood Creek Lower Cape Fear Mainstem Stations Sample Percentages that Exceed the 50 NTU Water Quality Standard for Turbidity

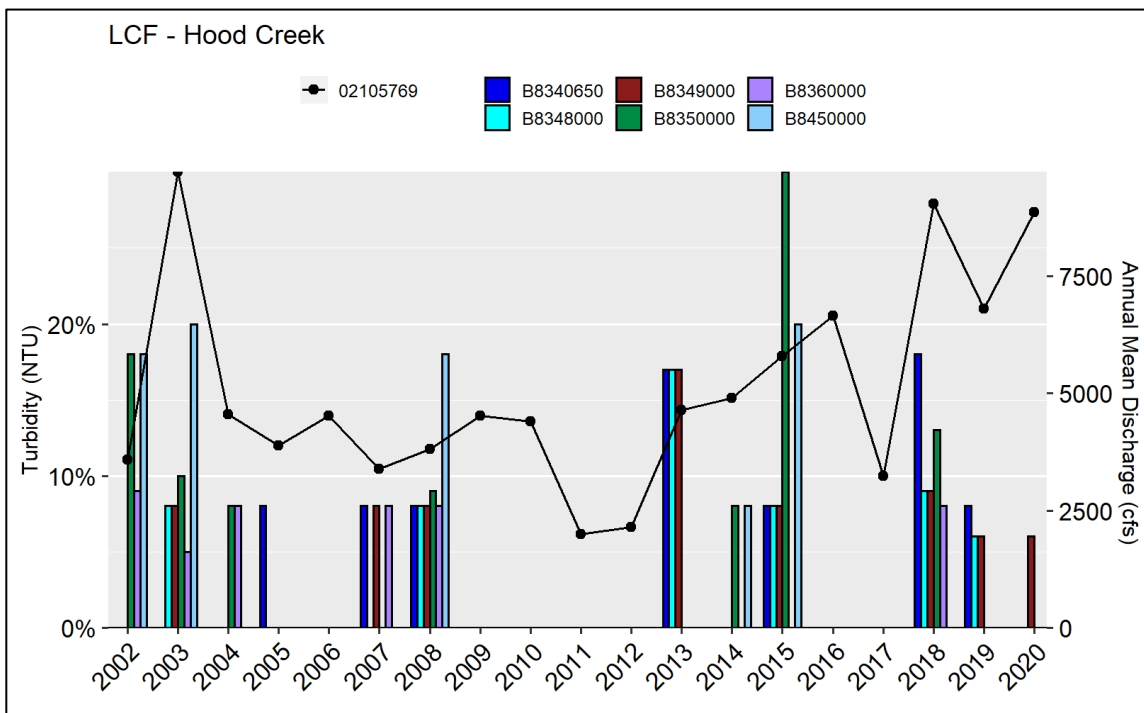


Figure 9-63: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean pH

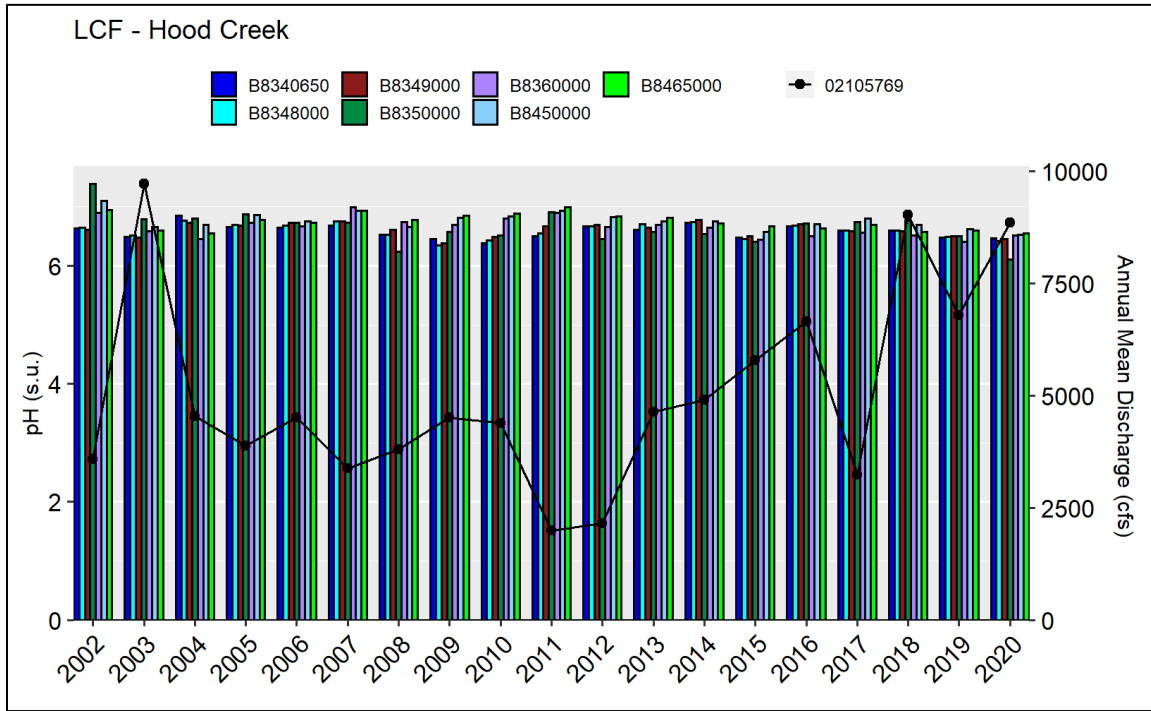
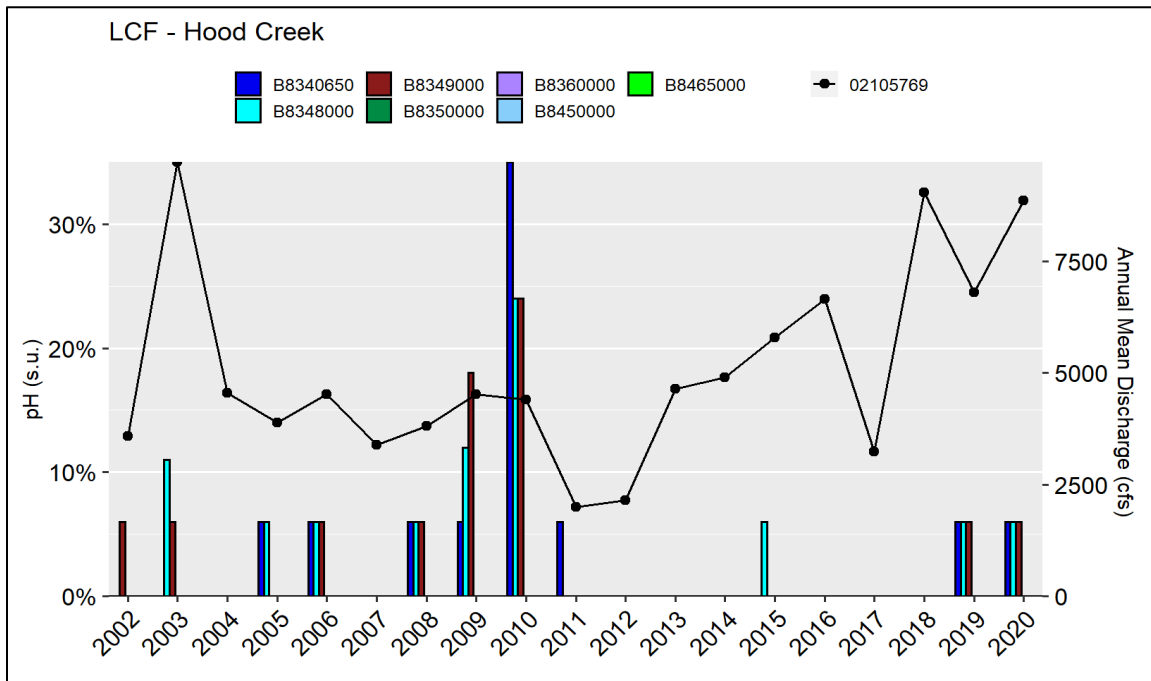


Figure 9-64: Hood Creek Lower Cape Fear Mainstem Stations Sample Percentages that exceed the Water Quality Standard for pH.



The pH standard is 6 to 9 S.U. for freshwater non Sw stations B8340650, B8348000, B8349000 and  $\geq 4.3$  S.U. for freshwater Sw stations, B8350000, B8360000, B8450000, B8465000.

Figure 9-65: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean Dissolved Oxygen

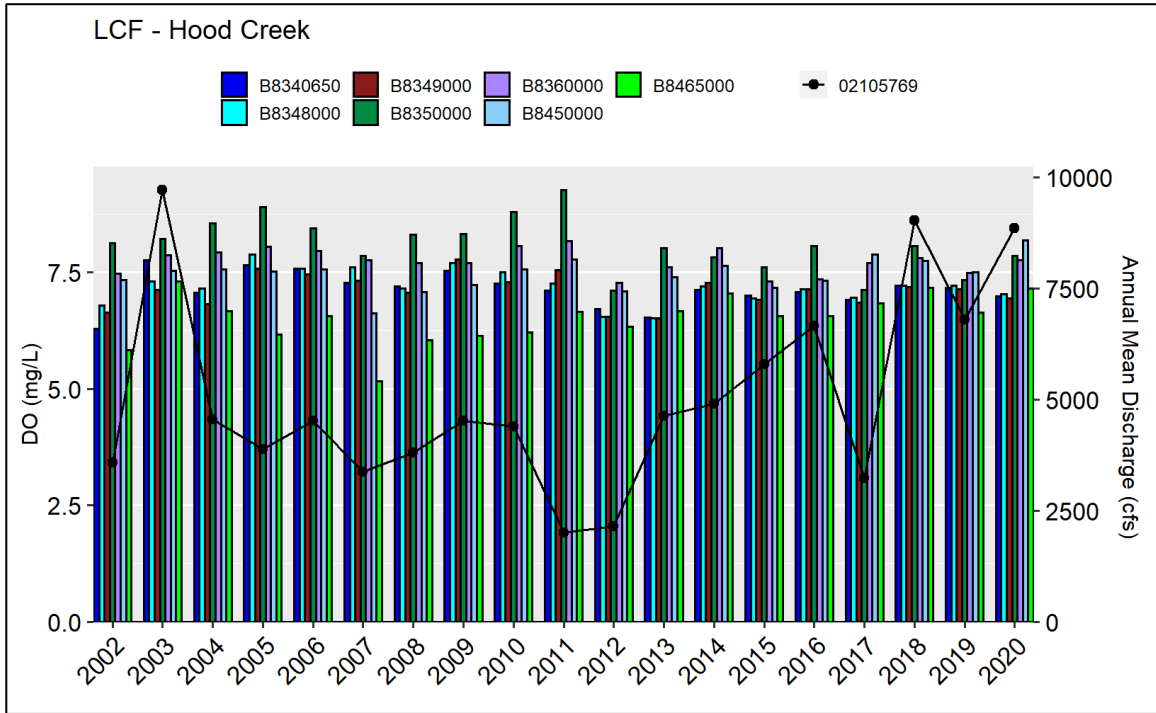
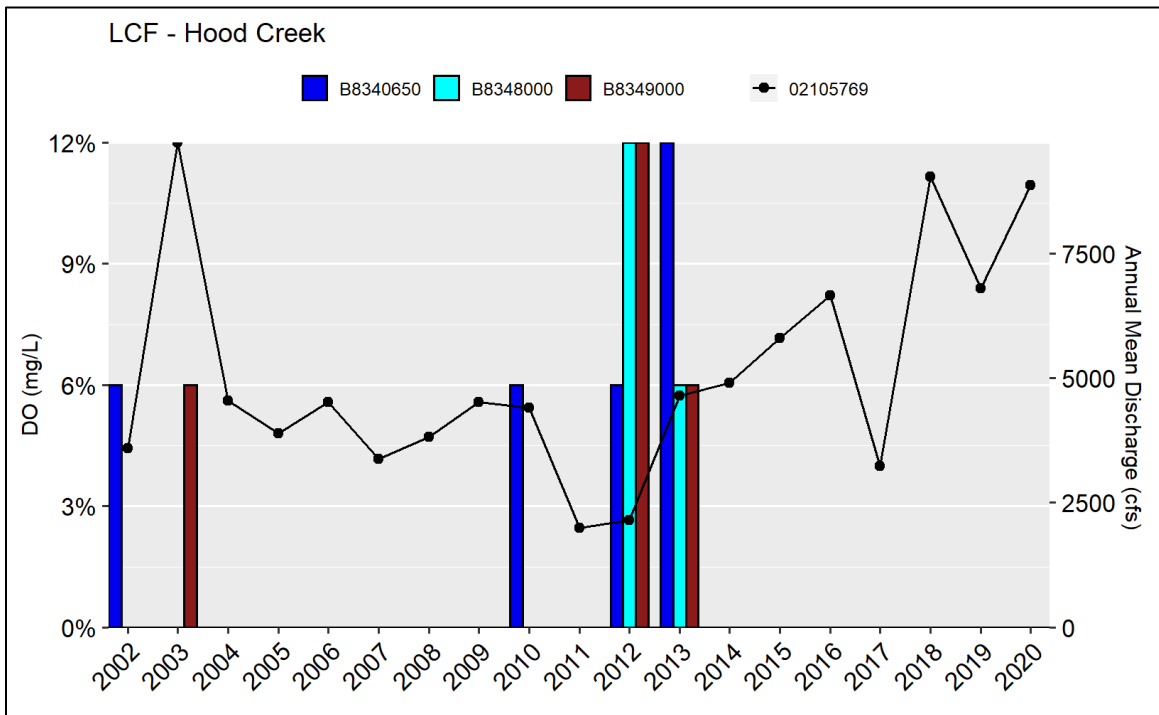


Figure 9-66: Hood Creek Lower Cape Fear Mainstem Stations that exceeded Dissolved Oxygen Water Quality Standard



The DO standard is  $\geq 4$  mg/L for freshwater non Sw stations B8340650, B8348000, B8349000 and there is no standard for freshwater Sw stations, B8350000, B8360000, B8450000, B8465000.

Figure 9-67: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean FCB (400 colonies/100 ml Standard for FCB is shown in graph figure)

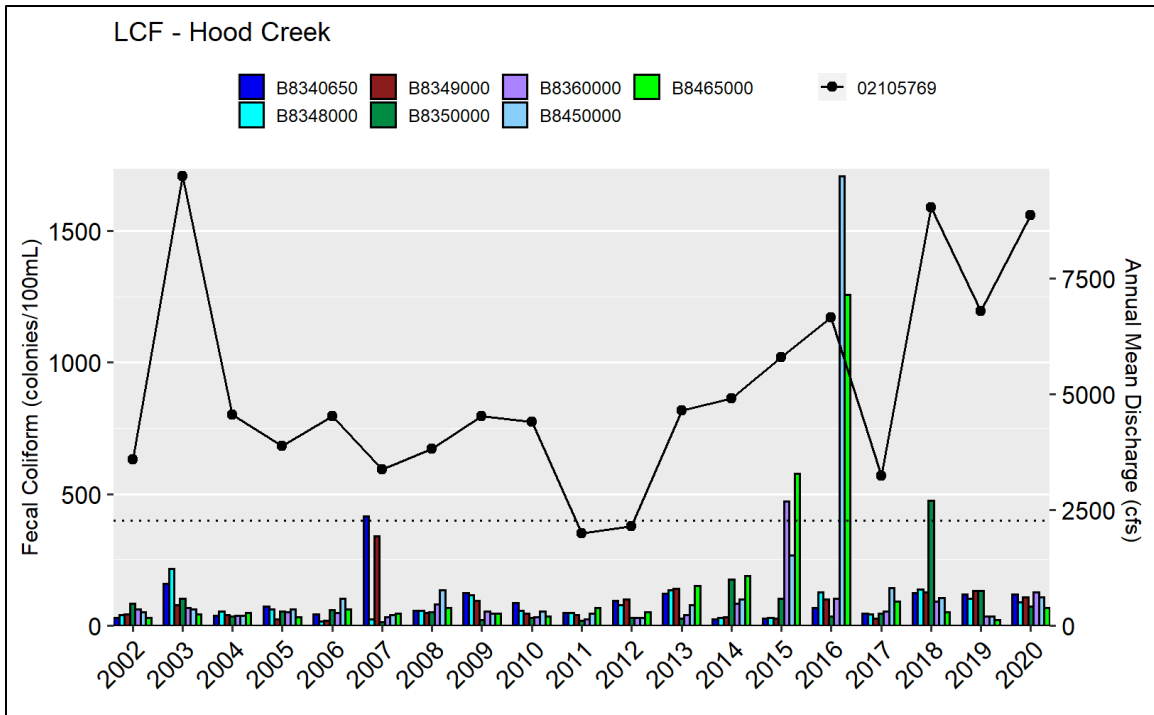


Figure 9-68: Hood Creek Lower Cape Fear Mainstem Stations Sample Percentages that exceeded the 400 colonies/100 ml Standard for FCB

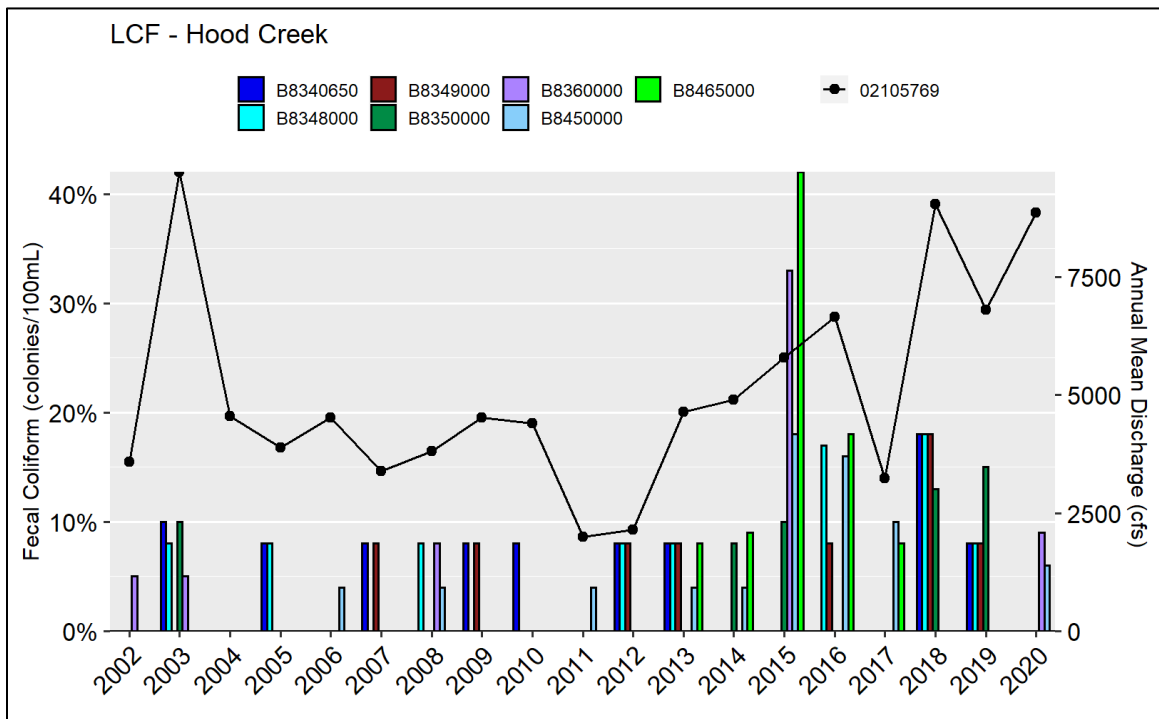


Figure 9-69: Hood Creek Lower Cape Fear Mainstem Stations FCB Annual Geomeans (Geomean standard is 200 colonies/100 mL)

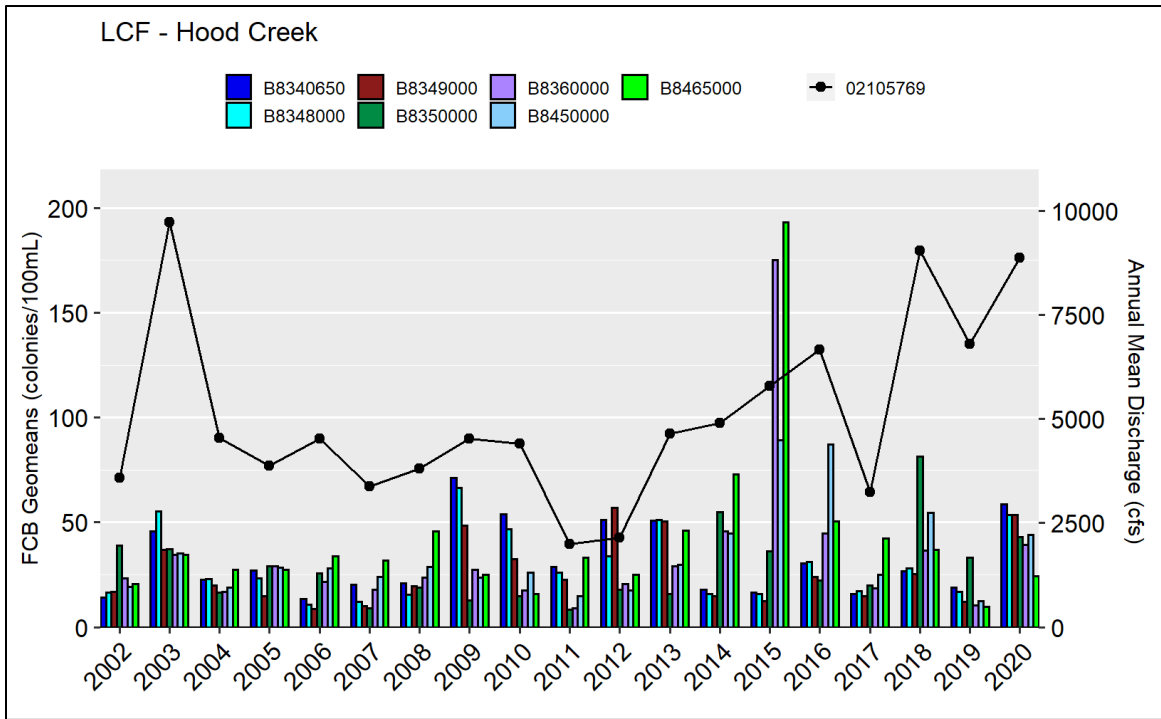


Figure 9-70: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean Specific Conductance

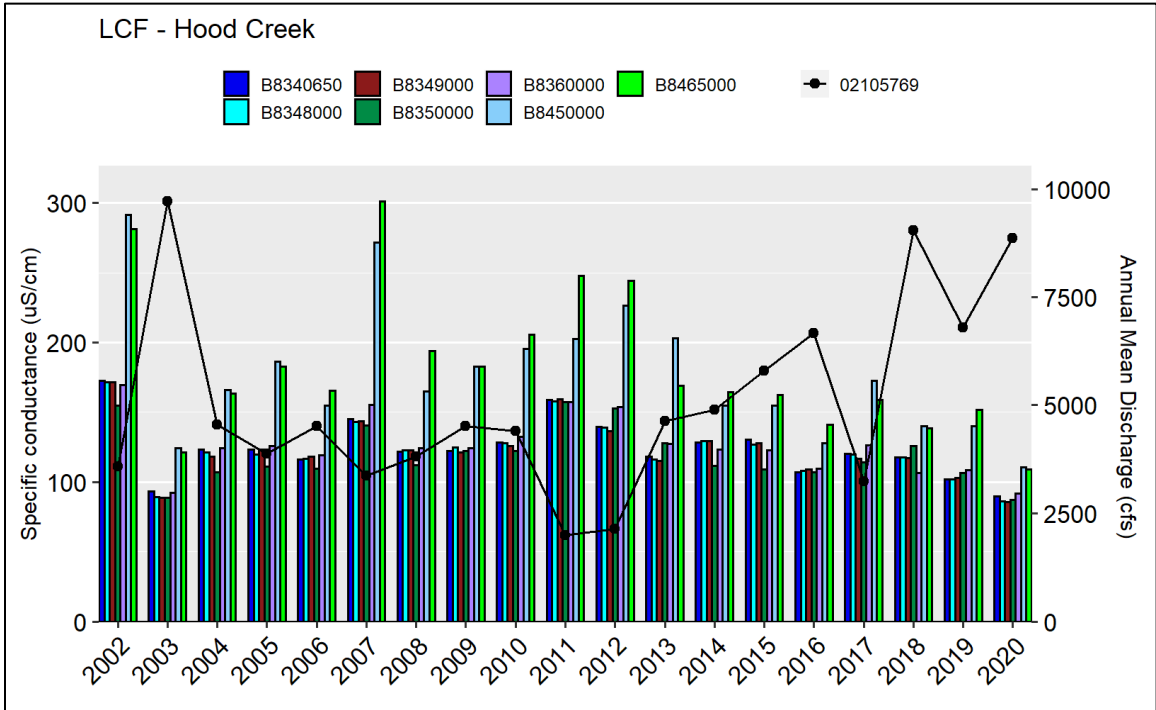


Figure 9-71: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean TKN

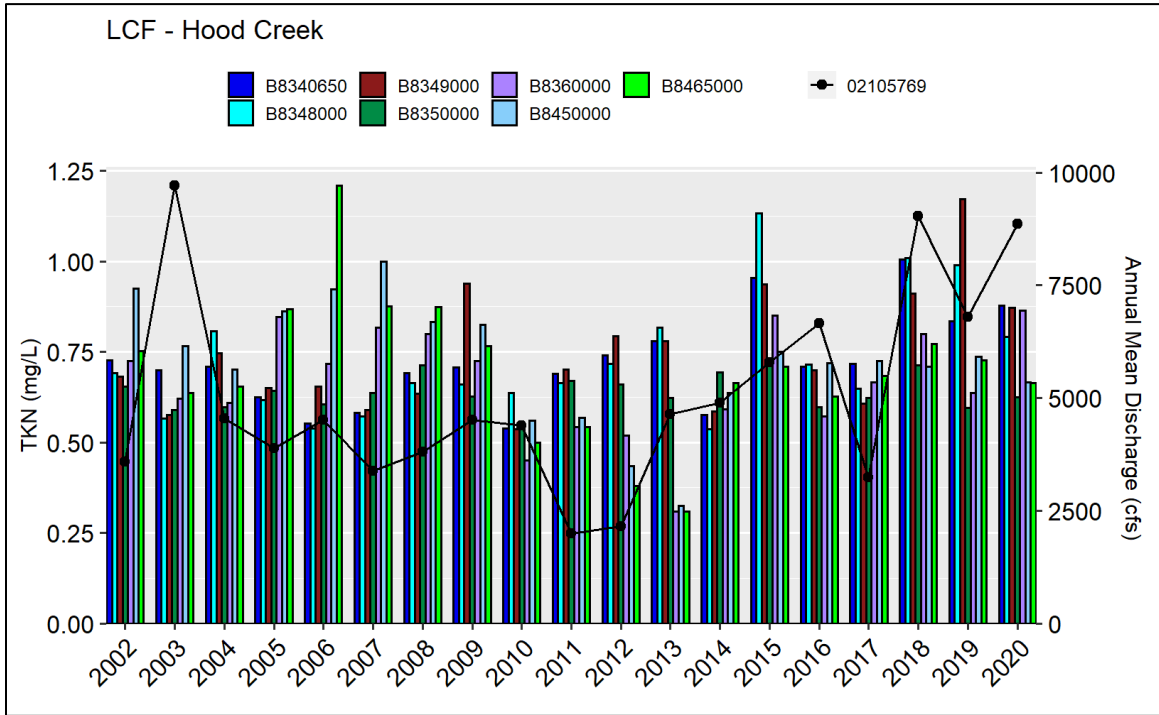


Figure 9-72: Hood Creek Lower Cape Fear Mainstem Stations Annual Means for Ammonia

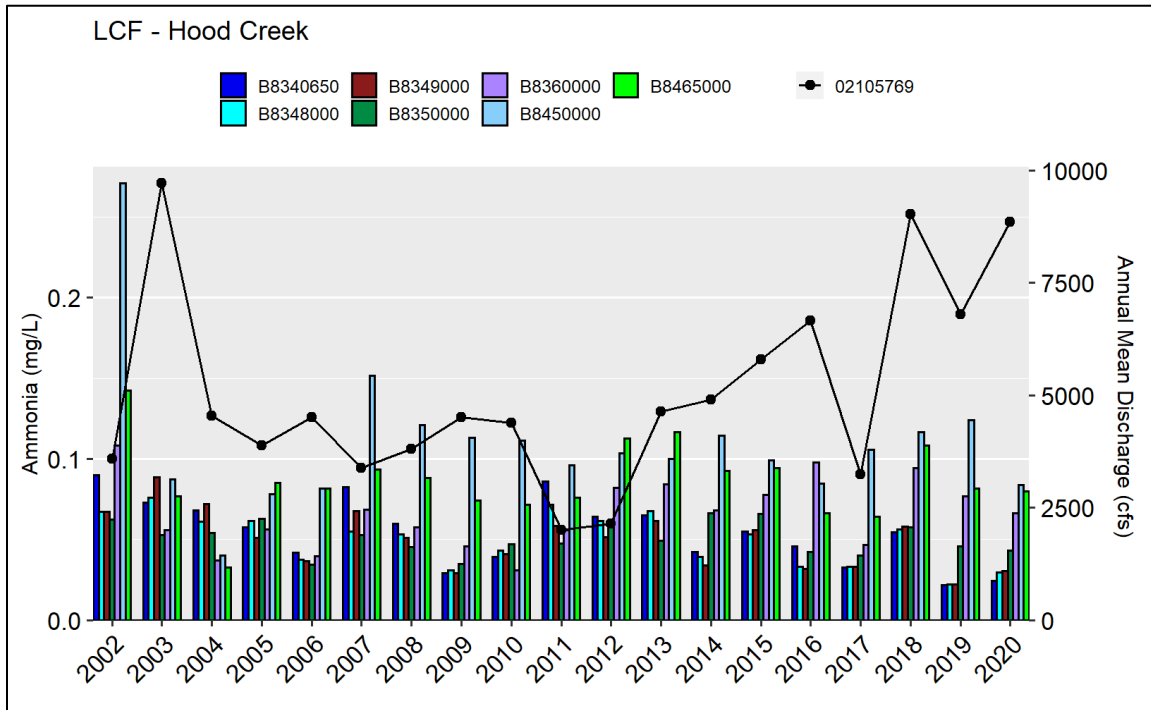


Figure 9-73: Hood Creek Lower Cape Fear Mainstem Stations Five-Year Means for Ammonia

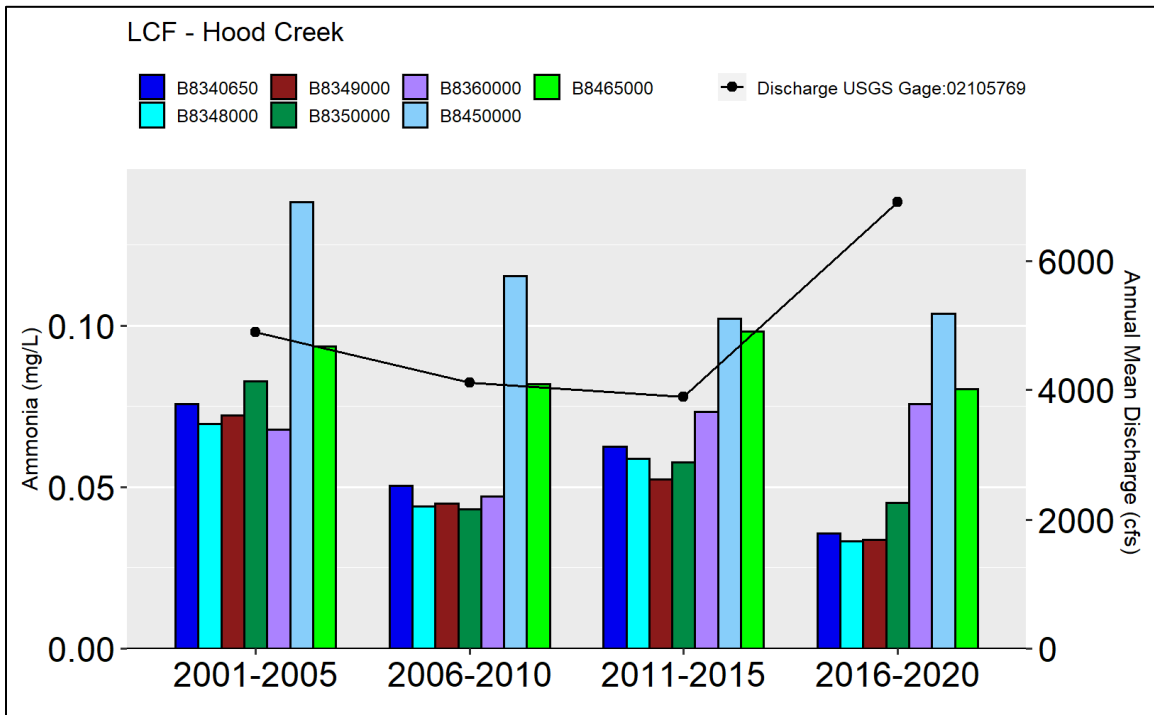


Figure 9-74: Hood Creek Lower Cape Fear River Mainstem Stations Annual Means for NOx

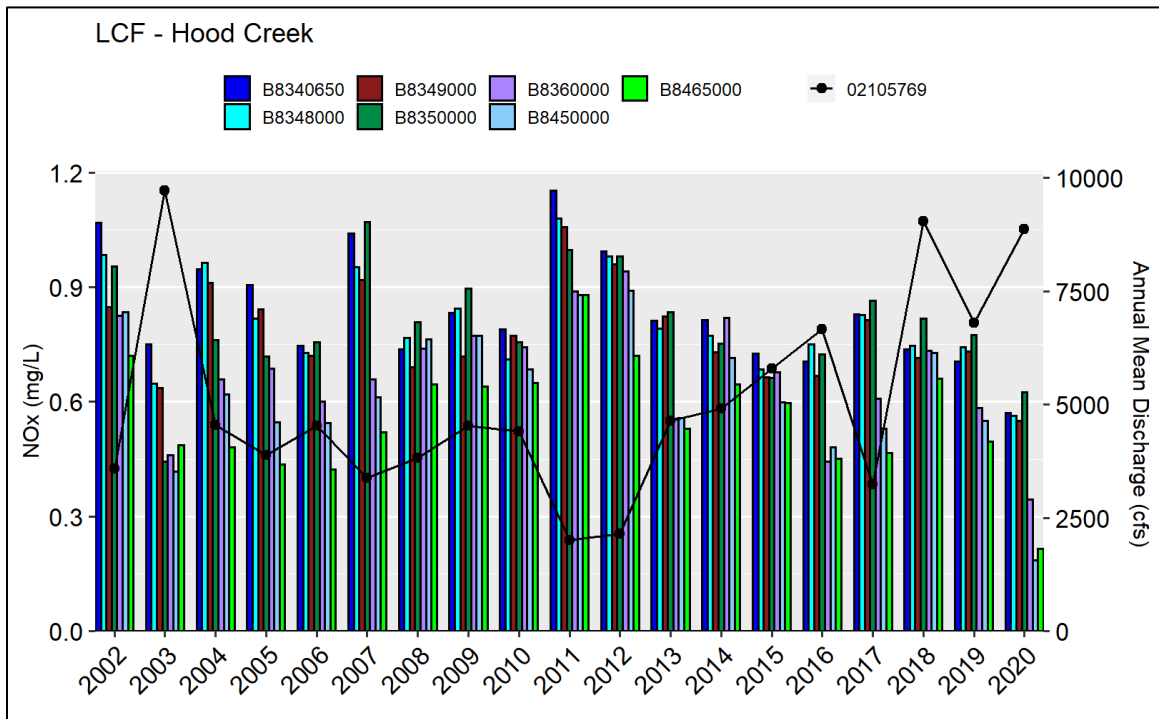


Figure 9-75: Hood Creek Lower Cape Fear River Mainstem Stations Five-Year Means for NOx

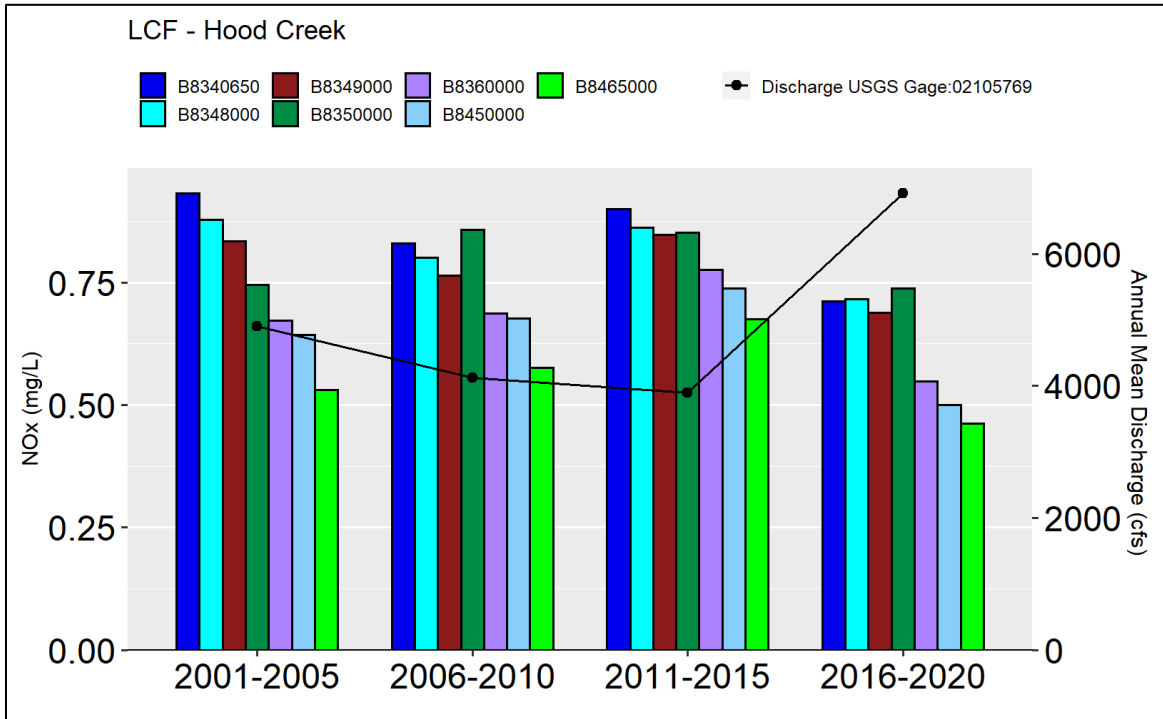


Figure 9-76: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean for TN

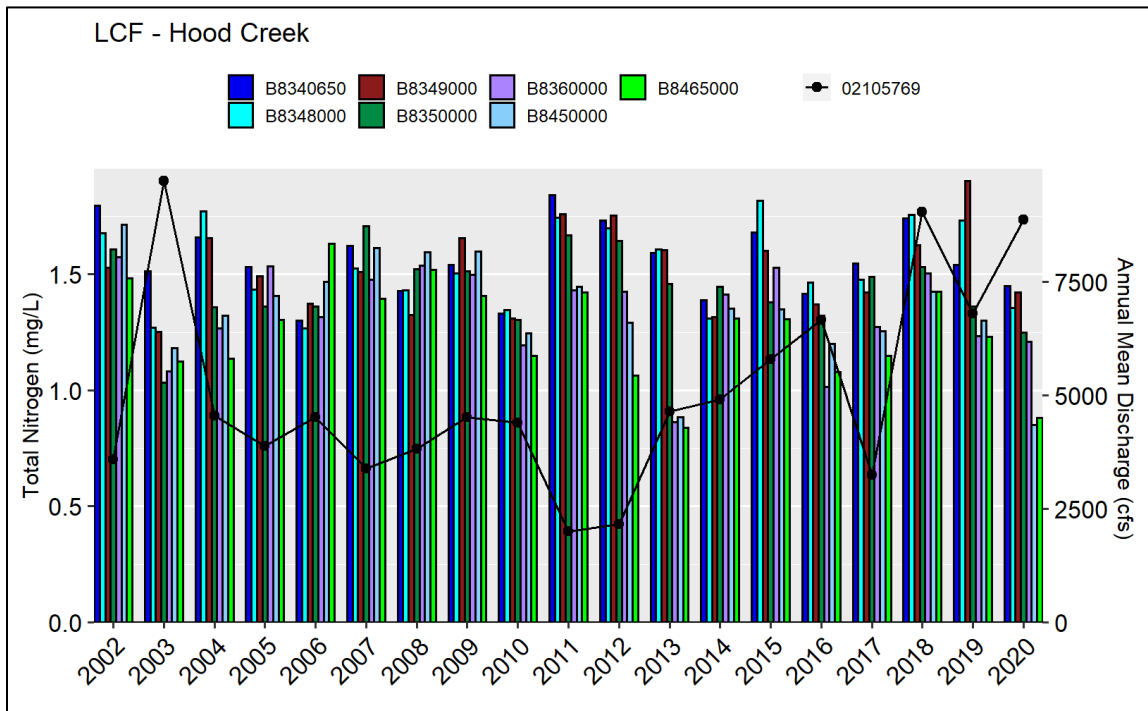


Figure 9-77: Hood Creek Lower Cape Fear Mainstem Stations Annual Mean for TP

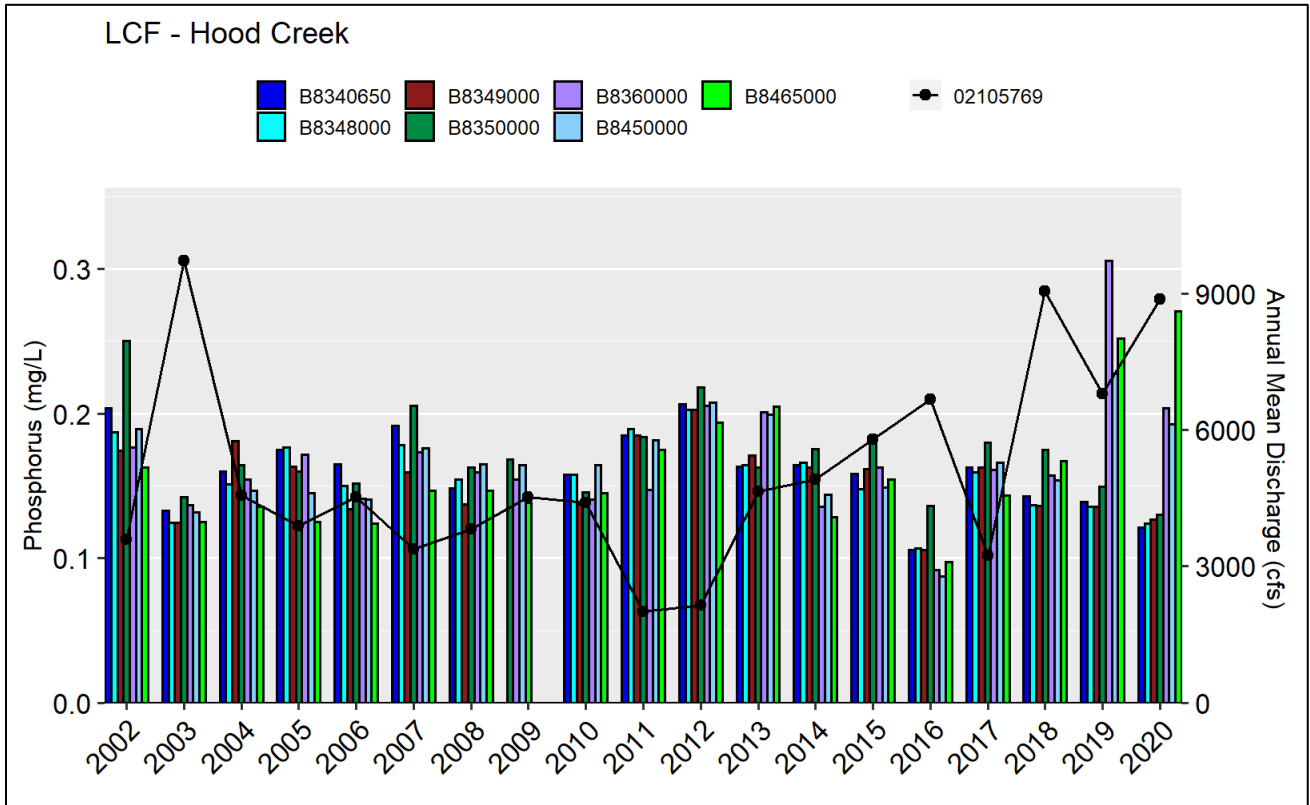


Figure 9-78: Hood Creek TKN and NOx Annual Means

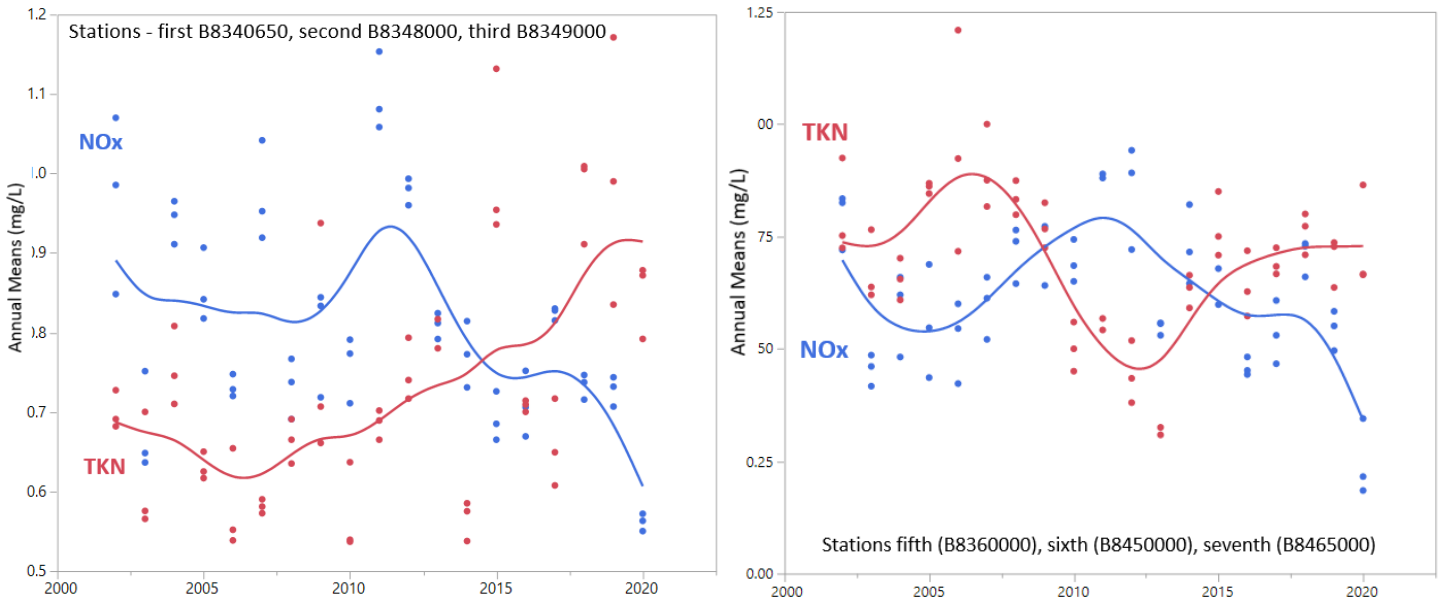


Figure 9-79: Cape Fear River Mainstem B8360000 & Colly Creek Station B8981000 TP mg/L 2000 - 2023

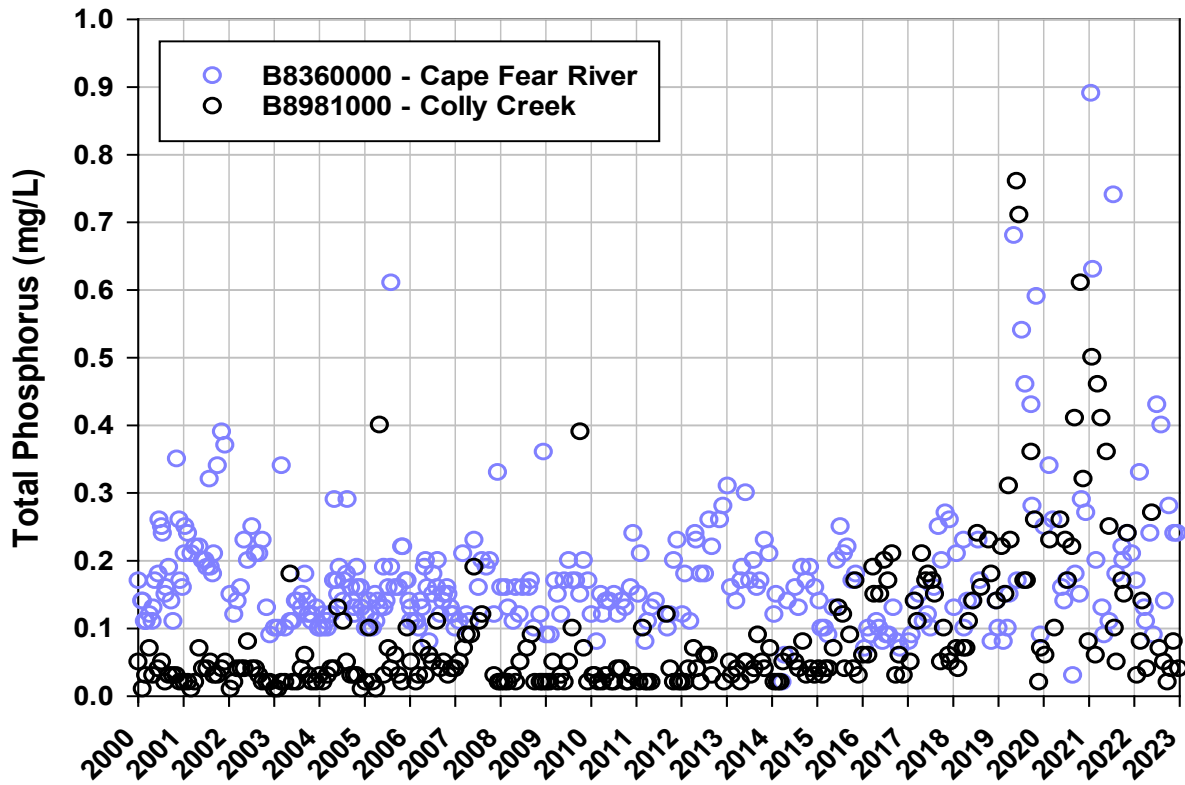


Table 9-17: Hood Creek Cape Fear mainstem station screening level Mann-Kendall tests for significance.

Parameter		TKN		Ammonia		NOx		Total Phosphorus	
Year		2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019
<b>Hammond Creek</b>									
1	B8340650	significant increase	significant increase	significant decrease	significant decrease	not significant	significant decrease	significant decrease	significant decrease
2	B8348000	significant increase	significant increase	significant decrease	significant decrease	not significant	not significant	significant decrease	significant decrease
3	B8349000	significant increase	not significant	significant decrease	not significant	not significant	significant decrease	significant decrease	significant decrease
<b>Lock &amp; Dam #1</b>									
4	B8350000	significant increase	not significant	not significant	not significant	not significant	not significant	not significant	not significant
<b>Natmore Creek</b>									
5	B8360000	not significant	significant increase	not significant	not significant	not significant	not significant	not significant	not significant
<b>Riegelwood Mill Facility (50 MGD)</b>									
<b>Livingston Creek</b>									
6	B8450000	not significant	significant increase	not significant	not significant	not significant	significant decrease	not significant	not significant
7	B8465000	not significant	significant increase	not significant	not significant	not significant	significant decrease	not significant	not significant

Screening level Mann-Kendall tests were conducted by DWR Modeling and Assessment Branch. Stations had a minimum of six months of data ("good year") in the beginning and ending trend year and at least 70% of the years with the trend period have to be "good years." Trends were determined using the nonparametric seasonal and non-seasonal versions of the Mann-Kendall test at 95% confidence.

### 1.9.5.2 Hood Creek-Cape Fear Biology Monitoring

Four sites, two benthos and two fish, have been assessed for biology in the catchment since 2003. Fish community sites BF132 on Hammond Creek and BF122 on Whites Creek were both sampled once in 2008 and were Not Rated, potentially due to drought conditions in the Cape Fear basin at the time.

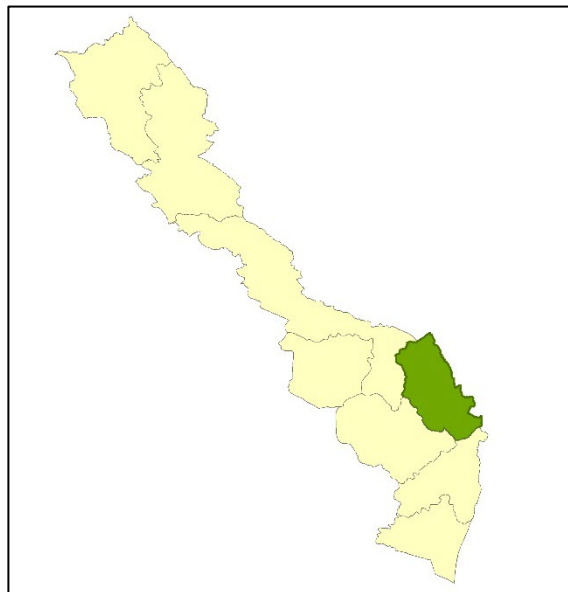
Hood Creek has been sampled during the regular basin cycle since 2003 using Swamp methodology. In the most recent sample taken in 2018, biologists described the substrate as sand, silt, and "other" dominated system with tannic water clarity and the site received a bioclassification of Moderate, which is a decline from the Natural bioclassification received in 2013. While one more EPT taxa was collected in 2018 than in 2013, the overall species total declined from 66 to 44 and BI and EPT BI dropped from 2013. Habitat in 2018 scored 85 out of a possible 100 and wetland was noted as the dominant land use in the sample area, followed by forest. The other benthic community site on Hood Creek,

Year	Bioclassification
<b>Hammond Ck. BF132</b>	
2008	Not Rated
<b>Whites Ck. BF122</b>	
2008	Not Rated
<b>Hood Ck. BB447</b>	
2003	Moderate
2008	Moderate
2013	Natural
2018	Moderate
<b>Hood Ck. BB507</b>	
2009	Moderate

BB507, received a Moderate score the only time it was sampled in 2009 using Swamp methodology. Biologists noted similar conditions as the site further upstream; BB507 was described as a sand and silt-dominated system with a habitat score of 80/100.

### 1.9.6 Brunswick River-Cape Fear River Watershed (0303000505)

The Brunswick River-Cape Fear watershed is located in the lower part of the subbasin spanning 95 square miles in Brunswick and New Hanover counties in the Middle Atlantic Coastal Plain ecoregion. This is a highly urban watershed that includes portions of Wilmington and Leland. The Cape Fear River flows into the Brunswick River-Cape Fear River watershed to the north of Leland right at the confluence with the Black River near the community of Hooper Hill. At this point, the river receives drainage from the Haw, Deep, Upper Cape Fear, and Black River subbasins and the Harrison Creek-Cape Fear, Turnbull Creek-Cape Fear, Livingston Creek, and Hood Creek-Cape Fear watersheds of the Lower Cape Fear River subbasin. The Cape Fear River continues south through wide meanders bordered by swamp forests. Sutton Lake, a man-made cooling reservoir, is located on the eastern shore on the inside of a large meander along this section. Approaching the I-140 bridge (the John Jay Burney Jr Fwy) the river's forested swamp gives way to the expanding coastal marsh habitat. Approximately 1.3 miles below the bridge, the river class changes from C and Sw to SC. Close to this point the river also splits, with the Brunswick River continuing south and the Cape Fear River flowing to the southeast toward Wilmington where the Northeast Cape Fear River confluence is located. Below this major confluence, the river widens and bends southward, merging back with the Brunswick River at the southern tip of Eagle Island, which is formed between the Cape Fear and Brunswick rivers. The Cape Fear River widens even more below the Brunswick River confluence. Other smaller tributaries along the Cape Fear River mainstem from upstream to downstream include Indian, Toomers, Alligator, Barnards, and Mallory creeks. Creeks along the Brunswick River from upstream to downstream include Sturgeon, Alligator, and Jackeys creeks. All of these tributaries are classified as Sw except Toomies Creek which is classified as WS-IV.



In 2019, the Brunswick River-Cape Fear River watershed had 30% development, 32% wetland, 18% forest, 7% grass, and shrub cover, and 10% open water (see [Table 9-6](#) and [Figure 9-6](#)). There is very little agriculture in this watershed. The Brunswick River-Cape Fear River watershed is the most populated and developed watershed in the subbasin. The largest population increase was during the last census period and the highest increase in development since 2001 at 8.4%, which is equivalent to 8 mi<sup>2</sup> ([Table 9-4](#)). Areas to the south of Leland, across the river from Wilmington, have seen rapid development in recent years, including several golf course communities. Primarily forest (4.5 mi<sup>2</sup>) and grassland/shrub cover (3 mi<sup>2</sup>) areas were developed along with some wetland areas (0.9 mi<sup>2</sup>). Studies show that if urbanized areas cover more than 25% of a watershed, there is a point where the decline in the health of the ecosystem is irreversible (Beach, 2002; Galli, 1991).

As of May 2022, there were three major and 11 minor NPDES wastewater discharge facilities permitted for 15.585 MGD total as-built flow, and 45 NPDES and 727 state stormwater facilities in the Brunswick River-Cape Fear River watershed. Two of the major NPDES facilities discharge directly to the Cape Fear River, the Wilmington Southside WWTP (NC0023973) with a permitted as-built flow of 12 MGD and the Northeast Brunswick WWTP (NC0086819) with a permitted as-built flow of 2.475 MGD. The Northeast Brunswick WWTP discharges above the Cape Fear River split with the Brunswick River and the Southside WWTP discharges below Eagle Island where these rivers merge. The other major facility is the Sutton Stream Electric Plant (NC0001422), owned by Duke Energy Progress. The coal-fired Sutton Plant was retired in November 2013, removal of the coal plant and older combustion turbines was completed in 2017. The Sutton Plant has been renovated into a natural gas combined-cycle plant that does not have a permitted-as-built discharge flow. There is a concentration of stormwater facilities in Wilmington and the community of Clairmont just to the south of Leland. There are no AFOs or non-discharge/land application permitted fields in this watershed. The Northeast Brunswick WWTP had four compliance and enforcement cases in 2013 primarily due to pH exceedances above the 9.0 standard, two in 2017 due to TSS and BOD, and one in 2018 due to flow.

For the years assessed in this plan (2002-2020), there are twelve ambient stream monitoring stations (three AMS, five Coalition, one co-located, three RAMS) and two benthic basin sites used to assess the water quality conditions over this period ([Table 9-12](#), also see the Chapter 2 Appendix). Two lakes were monitored in the Brunswick River-Cape Fear River watershed during the timespan of this plan, Sutton and Greenfield lakes. The Brunswick River-Cape Fear River watershed has more impairments than any other watershed in the Lower Cape Fear River subbasin ([Table 9-18](#)). All of the Cape Fear River and Brunswick River in this watershed are impaired for DO (2,469.04 Saltwater acres (S acres)). The very upper reaches of the Brunswick and Cape Fear rivers (above HWY 17) and Sturgeon Creek, which drains directly to the upper reach of the Brunswick River, have arsenic and hexavalent chromium fish tissue advisories (350.6 S Acres). One large section of the Cape Fear River, from Greenfield to Barnards Creek is impaired for copper (1,274.90 S acres). In Wilmington, Burnt Mill Creek (4.6 FW miles) is impaired for benthos based on monitoring before the timeframe of this plan, and Greenfield Lake (75.3 acres) is impaired for chlorophyll *a*. The [Greenfield Lake 9-Element Plan](#) (Section 9.8) was approved in 2019 to address this chlorophyll *a* impairment through monitoring, education, installation of BMPs, and measurement of the success of each. Widespread flooding from Hurricane Florence and a reported dam breach at Lake Sutton, where coal ash is stored from the Sutton Steam Plant, prompted DWR to monitor the area and evaluate the effects. Low-lying coal ash ponds and WWTPs like the Northeast Brunswick and Wilmington Southside facilities posed a vulnerable risk to water quality during extreme weather flood events. To protect Sutton Lake and the Cape Fear River from future overflows and coal ash contamination, Duke Energy excavated the coal ash basins in 2019 and completed the removal of all coal combustion residuals (CCR) in 2020. The CCR were transported to an onsite double-lined landfill that was synthetically capped to prevent infiltration of precipitation and deemed closed in 2021.

The former Kerr-McGee Chemical Corporation in Navassa was placed on the EPA's superfund programs National Priorities List in 2010 because of contaminated groundwater, soil and sediment caused by the facilities operations ([Kerr-McGee Chemical Corp-Navassa Superfund website](#)). Kerr-McGee Chemical Corporation operated a wood-treatment plant from 1936 to 1980. The site is bordered by Sturgeon

Creek to the south and Brunswick River to the east. EPA is the lead agency on the remedial investigation and cleanup, with DEQ as the supporting agency. The site is divided into five sections referred to as “Operable Units” (OU). As of September 2023, remedial action is underway on OU-2 and expected to be completed in March 2024. Phase II investigations are to start in September/October 2023 in OU-3 and OU-4. For more information on this site see the EPA [Kerr-MeGee Chemical Corp-Navassa Superfund website](#). EPA holds regular meetings with the town and stakeholders to provide updates on the progress of site studies and remediation efforts.

*Table 9-18: 2022 IR Impairments in the Brunswick River-Cape Fear River Watershed*

AU#	Description	Impairments <sup>1,2</sup>	Size	Unit <sup>3</sup>	Class
18-(71)a1	Cape Fear River, From upstream mouth to Toomers Cr. To the Railroad bridge at Navassa	Dissolved Oxygen (5 mg/l, AL, SW)	10.6	S Acres	SC
18-(71)a2a	Cape Fear River, From Railroad bridge to Hwy 17 Bridge <b>(includes monitoring stations B9050025 and B905100)</b>	Dissolved Oxygen (5 mg/l, AL, SW), Arsenic Fish Tissue Advisory (Advisory, FC, NC), Hexavalent Chromium Fish Tissue Advisory (Advisory, FC, NC)	290	S Acres	SC
18-(71)a3	Cape Fear River, From Greenfield to Barnards Creek <b>(includes monitoring station B9800000)</b>	Dissolved Oxygen (5 mg/l, AL, SW), pH (6.8 s.u., AL, SW), Copper (3 µg/l, AL, SW)	1,274.90	S Acres	SC
18-(71)a4	From Barnards Creek to 0.6 miles downstream of Barnards Creek <b>(includes monitoring station B9820000)</b>	Dissolved Oxygen (5 mg/l, AL, SW)	372.9	S Acres	SC
18-(71)a5	From 0.6 miles downstream of Barnards Creek to 1.9 miles downstream of Mott Creek <b>(includes monitoring station B9795000)</b>	Dissolved Oxygen (5 mg/l, AL, SW), Copper (3 µg/l, AL, SW)	2,183.7	S Acres	SC
18-(71)a2b	From Hwy 17 Bridge to Greenfield Creek	Dissolved Oxygen (5 mg/l, AL, SW)	149.8	S Acres	SC
18-77a <sup>4</sup>	Brunswick River, From source to Hwy 17 Bridge	Dissolved Oxygen (5 mg/l, AL, SW), pH (6.8 s.u., AL, SW), Arsenic Fish Tissue Advisory (Advisory, FC, NC), Hexavalent Chromium Fish Tissue Advisory (Advisory, FC, NC)	60.6	S Acres	SC
18-77b <sup>4</sup>	Brunswick River, From Hwy 17 Bridge to Cape Fear River	Dissolved Oxygen (5 mg/l, AL, SW), pH (6.8 s.u., AL, SW)	683.1	S Acres	SC
18-77-1	Sturgeons Creek, From source to Brunswick River	Arsenic Fish Tissue Advisory (Advisory, FC, NC), Hexavalent Chromium Fish Tissue Advisory (Advisory, FC, NC)	5.1	FW Miles	C;Sw
18-74-63-2	Burnt Mill Creek	Benthos (Nar, AL, FW)	4.6	FW Miles	C;Sw
18-76-1	Greenfield Lake	Chlorophyll <i>a</i> (40 µg/l, AL, NC)	75.3	FW Acres	C;Sw

<sup>1</sup> AL – Aquatic Life, FC – Fish Consumption, SH - Shellfish Harvesting.

<sup>2</sup> Waterbody Type: FW – Freshwater, SW - Saltwater, Sw - Swamp Waters, SA - Shellfish Area, NC - All North Carolina waters.

<sup>3</sup> Unit – S Acres – Saltwater Acres; FW Miles – Freshwater Miles; FW Acres – Freshwater Acres

<sup>4</sup> Added Brunswick River's (18-77a and 18-77b) 743.7 SW acres not originally captured on the 2022 IR category 5 list or total classified SW acres.

### 1.9.6.1 Brunswick River-Cape Fear River Physical and Chemical Monitoring Lake Monitoring

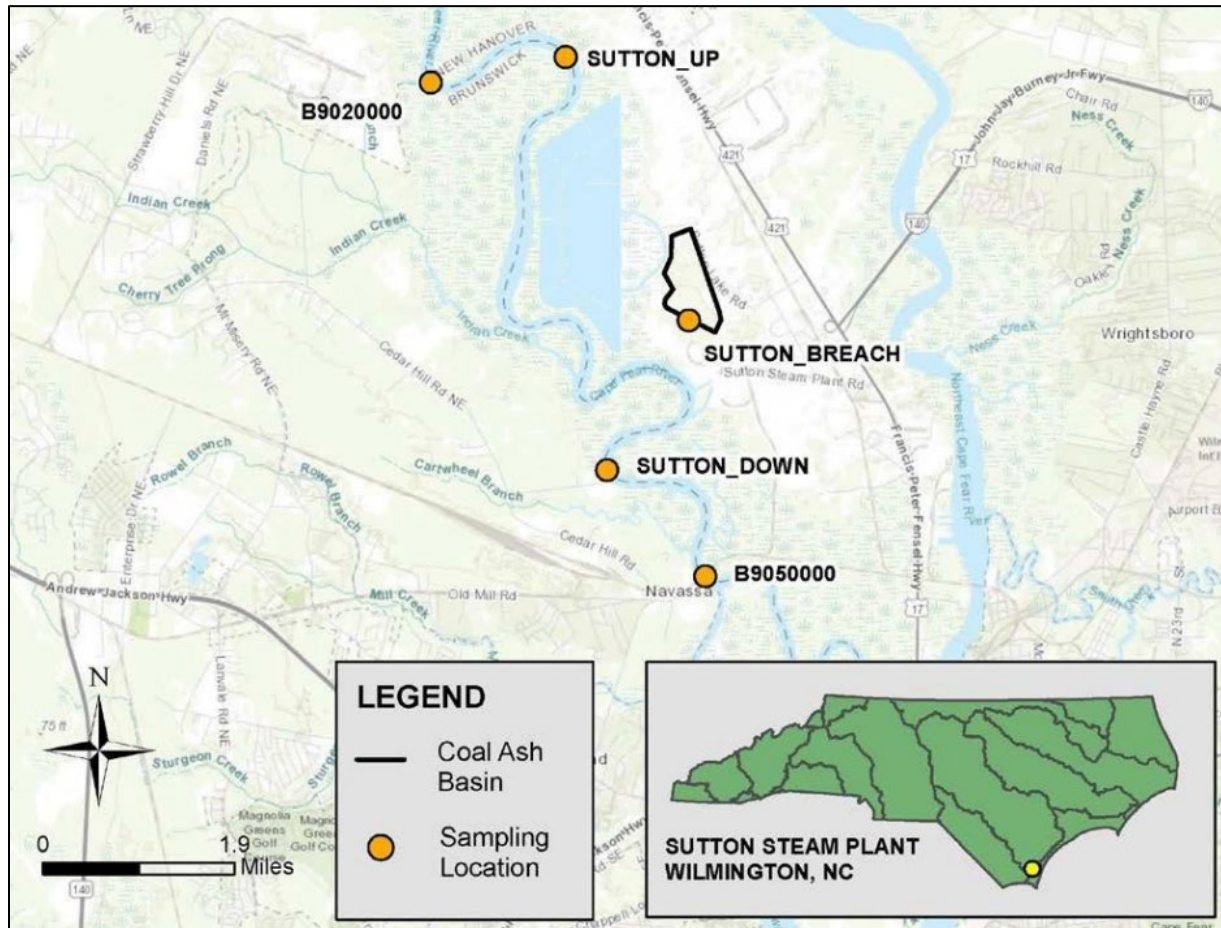
Sutton Lake (AU# 18-69) is a 1,099-acre cooling reservoir, constructed in 1972, to provide condenser cooling water to the former coal-fired Sutton Steam Electric Plant. Coal-fired units were retired in November 2013, with the removal of the coal plant and older combustion turbines and the conversion to natural gas completed in 2017 (Duke Energy n.d.). The lake consists of a 2.3 mile central main dike that bisects the lake and six wing dikes that maximize water circulation and increase the power plant cooling efficiency. This lake is open to the public for recreational fishing. An NC WRC boat ramp is located off US 421 on Sutton Lake Road. Aquatic vegetation growth in Sutton Lake is controlled using introduced triploid grass carp. The 2018 lake sampling showed surface DO ranged from 6.7 to 8.0 mg/L and surface water temperatures ranged from 27.9 °C to 33.5 °C. Surface pH values in Sutton Lake ranged from 7.3 to 7.7 s.u. and conductivity ranged from 183 to 237 µS/cm. Total phosphorus concentrations in Sutton Lake ranged from 0.03 to 0.04 mg/L, TKN from 0.50 to 0.66 mg/L, ammonia from <0.02 to 0.02 mg/L and NO<sub>x</sub> ranged from <0.02 to 0.07 mg/L (NC DWR 2018).

Coal ash stored on-site at the Sutton Plant in two impounded basins posed a risk to Lake Sutton, and more importantly, to the Cape Fear River and downriver communities during severe storm events. The older of the two coal ash basins was unlined and built in 1971 while the newer was clay-lined and built in 1984. Under normal conditions, Sutton Lake provided a buffer between these coal ash basins and the Cape Fear River. However, Hurricane Florence made landfall on September 14, 2018, delivering sustained winds of up to 90 mph and dropping record amounts of rain as it moved west along the North and South Carolina border, resulting in widespread flooding. Flooding at the Sutton Plant inundated the older 1971 coal ash basin, resulting in the submergence of a steel wall that separated the coal excavation area from Lake Sutton. The earthen portion of the coal ash basin dam did remain above water (Fink 2018). Of greater concern was the breach of the Sutton Lake dam at several points on the southern side that sent floodwaters into the Cape Fear River and potentially coal ash downstream to nearby communities and the sensitive aquatic environment of the river. Reports of gray sludge seen washing into the Cape Fear River reached DEQ (Biesecker and Sudermand 2018). In the aftermath of Hurricane Florence, when conditions were deemed safe for fieldwork, DWR conducted supplemental monitoring of surface waters to help quantify and characterize potential impacts that a storm of Florence's size and intensity may have had on these resources. Due to the unprecedented precipitation across parts of eastern and central North Carolina, flood conditions caused major issues for wastewater treatment facilities, as well as extensive flooding of urban and agricultural areas. The complete results of this supplemental monitoring effort are available in the [Survey of Surface Water Quality Associated with Hurricane Florence, September 2018](#) (NC DWR 2019).

The reports of flooding in and around coal ash basins prompted surface water monitoring for a suite of total and dissolved metals at the two coal ash facilities, the Sutton Steam Plant near Wilmington and H.F. Lee Power Plant near Goldsboro. At the Sutton Steam Plant, metals were sampled at two upstream stations, the Sutton Lake breach, and two downstream stations from September 22 through November 26, 2018 (*Figure 9-80*). Visual inspections showed no loss of coal ash or overlying soils in or near the coal ash basin at the Sutton Steam Plant facility.

At the Sutton Lake breach site (*Figure 9-80*), 15 of 48 total arsenic and 26 of 96 dissolved arsenic samples had detections and just one of 48 total and two of 96 selenium samples had detections. All samples were below NC water quality standards and no detections occurred at the upstream and downstream stations. None of the detected zinc values were over the zinc standard, which is based on the concentration of the dissolved fraction of the metal. Total zinc was detected once at the Sutton Lake breach site at a concentration of 15 µg/L on September 30, 2018. Calculated hardness-based dissolved zinc standards at the breach site were 22 µg/L (acute) and 29 µg/L (chronic) on that date, and dissolved zinc was not detected above the analytical reporting level of 10 µg/L. Both total and dissolved zinc were detected once at B9050000 (*Figure 9-80*), at 12 and 13 µg/L, respectively, on September 26, 2018. Applicable standards at B9050000 (stream classification SC) were 81 µg/L (chronic) and 90 µg/L (acute) dissolved zinc. Zinc was not detected in any other samples during the monitoring period.

*Figure 9-80: NC DWR Post-Florence Sutton Steam Plan Sampling Locations for Total and Dissolved Metals*



Copper was the only metal measured at concentrations greater than the NC water quality standard. This occurred at the upstream site (max total = 2.8 µg/L, max dissolved = 2.9 µg/L), breach site (max total = 6.7 µg/L, max dissolved = 6.4 µg/L), and downstream site (max total = 3.2 µg/L, max dissolved = 2.7 µg/L) monitoring locations (*Figure 9-80*). The standard for dissolved copper varies depending on surface water

hardness. Other metals sampled had no detection, including antimony, beryllium, boron, cadmium, chromium, cobalt, lead, molybdenum, nickel, silver, thallium, and vanadium. See the [Survey of Surface Water Quality Associated with Hurricane Florence, September 2018](#) (NC DWR 2019) for more information on metals monitoring and results at and around Lake Sutton.

Extreme precipitation events are predicted to become more common with climate change (see Chapter 1). To protect Sutton Lake and the Cape Fear River from future overflows and coal ash contamination, Duke Energy excavated the coal ash basins in 2019 and completed the removal of all coal combustion residuals (CCR) in 2020. The CCR were transported to an onsite double-lined landfill that was synthetically capped to prevent infiltration of precipitation and deemed closed in 2021. However, an after-study of Sutton Lake by Duke University has found legacy coal ash in the lake's sediments and pore water within the sediment, indicating there have been previous undetected spills from the coal ash basins (Vengosh et al, 2022). DEQ has found no significant pollution in the Cape Fear River since Hurricane Florence.

Greenfield Lake (AU# 18-76-1) is a 2,551-acre lake that was originally a cypress swamp, impounded in 1750 to provide water for milling and irrigation of the Greenfields Plantation, which surrounded it. Greenfield Lake is now owned by the City of Wilmington, which encompasses the lake and its watershed. This lake is swampy and cypress-filled, with a maximum depth of 12 feet (four meters). This urban lake is the central feature of Greenfield Lake Park, which is also managed by Wilmington (NC DWR 2018). Greenfield Lake is located in a populated watershed with 37% impervious pavement. Greenfield Lake has experienced noxious phytoplankton and macrophyte blooms, anoxia and hypoxia (decrease in oxygen to blood tissue), and fish kills for many years (Mallin et al. 2016) and has been impaired for chlorophyll *a* since 2014.



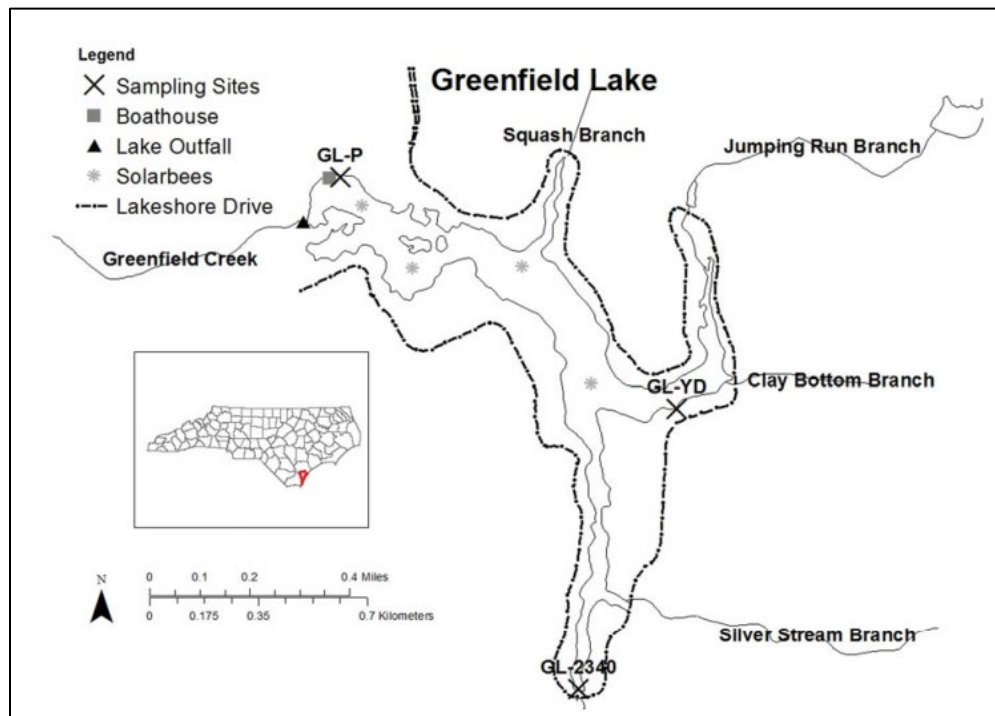
DWR staff monitored Greenfield Lake in 2013 and 2018, both years had an overall NCTSI score that was eutrophic; however, two months in 2013 (August and September) and one month in 2018 (May) had exceptionally elevated biological productivity, rating hypereutrophic on the NCTSI scale (NC DWR 2013 and NC DWR 2018). In 2018, surface DO ranged from 6.5 to 10.0 mg/L, with the highest reading observed for both sampling sites on August 7th. Surface percent DO on August 7th ranged from 106.9% to 128.6%. Surface water temperature in Greenfield Lake ranged from 26.0 °C to 31.5 °C and pH values ranged from 6.8 to 8.8 s.u. Surface conductivity measurements ranged from 70 to 231 µmhos/cm on August 28th. TP concentrations ranged from 0.08 to 0.18 mg/L, TKN ranged from 0.60 to 1.60 mg/L, ammonia ranged from <0.2 to 0.27 mg/L and NO<sub>x</sub> ranged from 0.02 to 0.11 mg/L. In response to available phosphorus and

nitrogen, algal productivity in Greenfield Lake was elevated with chlorophyll *a* values ranging from 10 to 62 µg/L in 2018 (NC DWR 2018).

Mallin et al. (2016) found that chlorophyll *a* and BOD are strongly correlated within Green Field Lake, indicating that decaying algal blooms are an important source of oxygen demand, resulting in low DO. Nutrient addition bioassays indicated that N is a key nutrient that requires control. However, the frequently-occurring blooms of the nitrogen-fixing cyanobacterium, *Dolichospermum* sp. (previously *Anabaena*) also show there is a reservoir of phosphorus in the system that potentially needs removal or reduction. Ammonia, NO<sub>x</sub>, and N/P ratios were higher in the upper lake compared with the lower lake, indicating tributary input of inorganic N (i.e., NO<sub>x</sub>), whereas phosphorus was highest in the lower lake. A year-long survey indicated that waterfowl, especially cormorants, contributed somewhat to the lake's total N load but a considerable amount of phosphorus as well, particularly in winter. Phosphorus in the lake's sediment contributes to the water column, setting the stage for runoff-induced nitrate pulses and subsequent algal blooms. Lake restoration efforts initiated in 2005 included the installation of solar-powered circulators, the introduction of grass carp, and herbicide treatments. These efforts produced a loss of surface macrophyte and algal mats, and reduced DO violations, but led to a significant increase in phytoplankton chlorophyll *a* and a tripling of chlorophyll *a* standard violations in comparison with pre-restoration years (Mallin 2016). During the period March 2005 to December 2013, chlorophyll *a* within the lake exceeded the state standard of 40 µg/L 31% of the time sampled (52/168 measurements, state-certified laboratory data). Visible cyanobacterial (i.e., blue-green algal) blooms continued to appear in the lake (Mark Vander Borgh, NCDWQ, email communication to the City of Wilmington, 2014). The lake has had episodic blooms reported nearly every year since 2013. (See the 2014 Greenfield Lake picture to the right.) *Dolichospermum* sp., a potential component of an HAB (harmful algal bloom), has been identified in episodic and routine sampling; however, microcystin, a known toxin, was only detected once in 2021. Routine physical, chemical, and algal monitoring, including testing for microcystin, occurred in 2023. The lake has been on the North Carolina 303(d) list since 2014 for excessive chlorophyll *a* violations.

A University of North Carolina Wilmington study assessed the nutrient loading to the lake from five tributary streams. Nutrients, chlorophyll *a*, BOD, and Total Suspended Solids (TSS) were collected during dry and wet periods. This effort found that two streams in particular, Squash Branch and Jumping Run Branch contributed the highest loads of inorganic nutrients to the lake and should be prioritized for nutrient reductions (*Figure 9-81*). Nutrient loading from Jumping Branch was largely stormwater-driven, whereas considerable loads of ammonia and NO<sub>x</sub> entered the lake from Squash Branch during dry periods which suggests more of a point source. The [City of Wilmington's Greenfield Lake 9-Element Restoration Plan](#) has recommended installing constructed wetlands as an effective method for nutrient reduction at Greenfield Lake. This type of restorative measure could work at Squash Branch. Another type of BMP recommended in the plan is the installation of floating macrophyte islands in selected tributaries where space is more limited near Jumping Run.

Figure 9-81: Greenfield Lake Wilmington, NC, showing water sampling stations and major tributaries (from Mallin 2016)



### Ambient Stream Monitoring

At the HUC10 level, the Brunswick River-Cape Fear River watershed had the highest mean levels of specific conductivity and TP in the Lower Cape Fear River subbasin from 2016 to 2020 (see [Table 9-13](#)). The Brunswick River station, B9790000, and seven mainstem stations, 9020000, B9030000, B9050025, B9050100, B9800000, B9820000, and B9795000 stations were monitored for the 2022 IR.

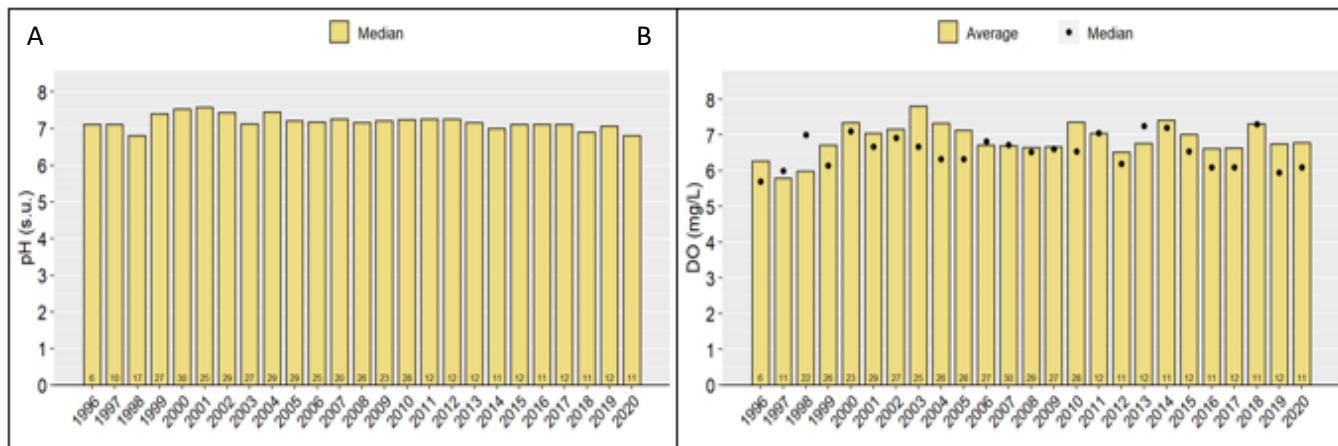
As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Saltwater station B9790000 was monitored by LCFRP all years from 2002 to 2020 along the Brunswick River, which diverges from the Cape Fear River approximately three miles upriver, flowing to the west side of Eagle Island. The Brunswick River assessment unit (AU# 18-77b) is 631.1 S acres of estuarine waters (class SC). [USGS StreamStats](#) mapped the B9790000 watershed at 18.8 mi<sup>2</sup>, although this station does receive drainage from the upper three subbasins and the Lower Cape Fear River subbasin above its location. A raised train track bed appears to have altered the watershed boundary delineation. Within this 18.8 mi<sup>2</sup> delineated watershed for B9790000, there is one minor NPDES discharge permit nearby with no permitted as-built flow. The 18.8 mi<sup>2</sup> watershed was 34.5% developed, 22% forested, 7% grassland/shrub, and 32% wetland in 2019. Development increased by 9.5% while forest and grassland/shrub declined by 4.4% and 3.7%, respectively (see Chapter 2 Appendix, Land Use and Land Cover for AMs and Coalition

Station Watersheds table). On the 2022 IR, AU# 18-77b was impaired for DO and pH (*Table 9-18*) but meeting criteria for other parameters.

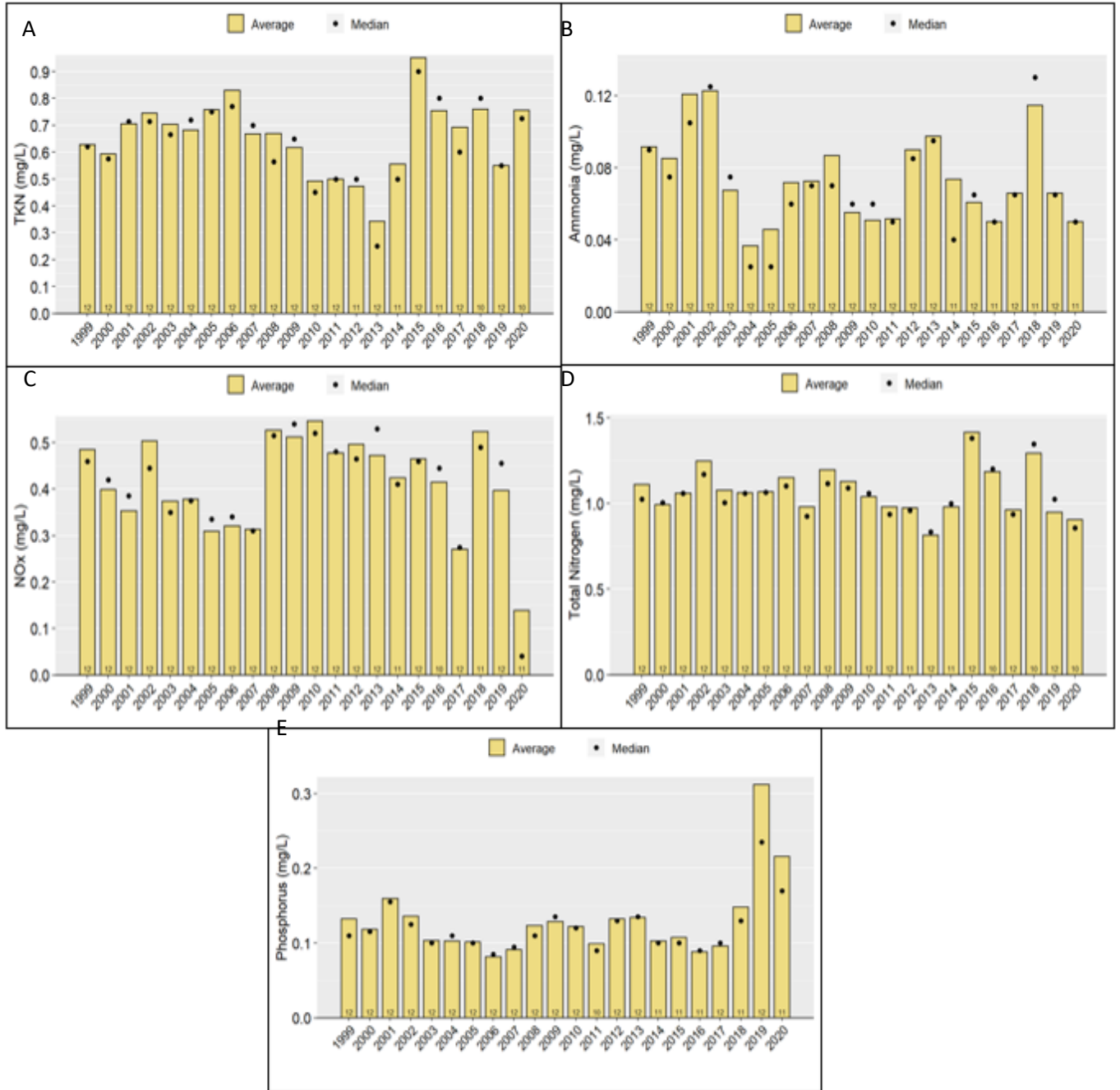
Mean concentrations at station B9790000 over the last five years (2016-2020) were 7.0 s.u. for pH and 6.81 mg/L for DO. Fecal coliform was only collected through 2011 and specific conductivity and turbidity were not collected. Fecal coliform means ranged from 38 to 108 colonies/100mL; however, there is no saltwater standard for fecal coliform bacteria except in shellfish harvesting waters (SA). The exceedance rate for pH was 26% from 2016-2020, 7% from 2011-2015, and 18% from 2001-2006. All pH exceedances were below the saltwater 6.8 s.u. standard. DO has had consistent issues with exceedance of the 5.0 mg/L saltwater standard, 28% for three of the last four five-year periods (2016 to 2020, 2011 to 2015, and 2001 to 2006). The exceedance rate was a little higher--35% from 2006 to 2010--which included drought years. Yearly mean pH levels indicate water quality is becoming more acidic at this station. DWR conducted a screening level Mann-Kendall trend seasonal tests with station B9790000 data years 2000 to 2019 and 2010 to 2019 that showed significant decreasing trends calculated at 95% confidence for pH (*Figure 9-82A*). Mean yearly data for DO shows consistency from 2002 to 2020, there were no significant trends for DO (*Figure 9-82B*).

Figure 9-82: Station B9790000 Mean Yearly DO and pH

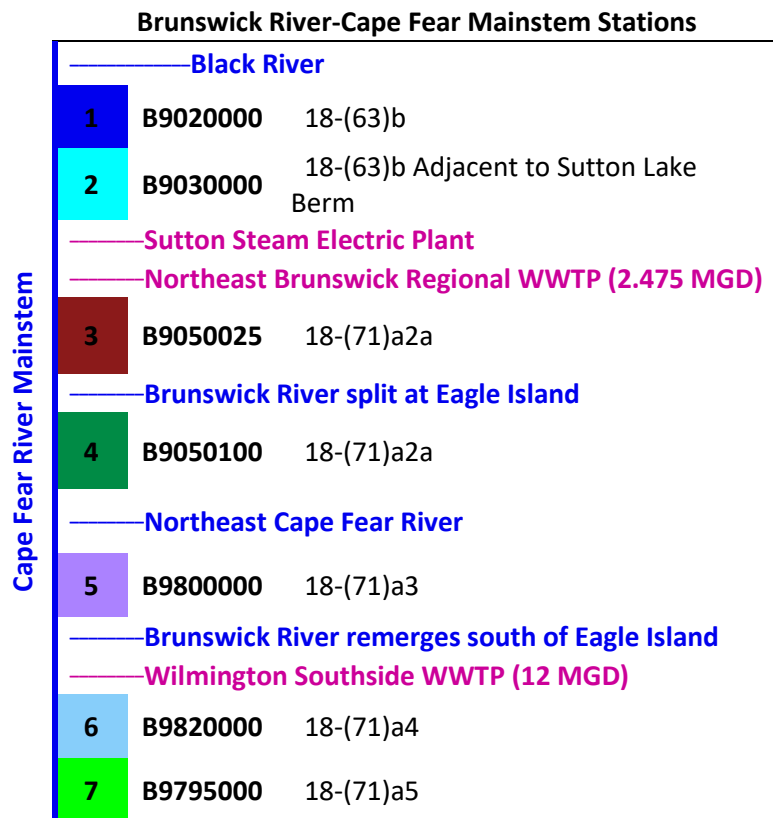


Mean concentrations for nutrients over the last five-years at station B9790000 were 0.70 mg/L TKN, 0.07 mg/L ammonia, 0.35 mg/L NOx, 1.05 mg/L TN, and 0.17 mg/L TP. Nutrient yearly means for B9790000 are shown in *Figure 9-83*. TP is extremely high, ranging from 0.02 to 0.73 mg/L with a 75<sup>th</sup> percentile of 0.185 mg/L (*Figure 9-83E*). The highest concentrations of TP occurred in 2019. A comparison of these five-year nutrient means to DWR’s WSS-ISB special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) shows TP concentrations are more than three times the recommended <0.05 mg/L. TKN and ammonia are both 40% over the recommended Coastal Plan levels (0.5 mg/L for TKN and 0.05 mg/L for ammonia) (*Figure 9-83A, B*). NOx is comparable to the 0.3 mg/L recommendation and TN is about 30% over the recommended 0.8 mg/L (*Figure 9-83C, D*). Screening level Mann-Kendall tests found TKN significantly increased, and NOx significantly decreased from 2010 to 2019 at 95% confidence. Water quality data along the mainstem stations indicates TP sources are likely coming from the mainstem Cape Fear River above station B9050025 which will be discussed next.

Figure 9-83: Station B9790000 Yearly Nutrient Mean Concentrations



The Brunswick River-Cape Fear River mainstem evaluation included seven stations located in five assessment units (see diagram to right and *Table 9-14* for AU descriptions). All stations are in the Middle Atlantic Coastal Plain ecoregion. The first two stations (B9020000 and B9030000) are located along 18.1 FW miles classified as Sw, the lower five stations (B9050025, B905100, B9800000, B9820000, and B9795000) are in 4,121.5 S acres of estuary waters. The diagram to the right shows the Brunswick River-Cape Fear River mainstem station locations relative to major NPDES dischargers and the main tributaries: Black River (Chapter 10); Northeast Cape Fear River (Chapter 11); and Brunswick River. The Black River merges with the Cape Fear River



between the last station (B8495000) of the upriver Hood Creek-Cape Fear River mainstem segment and the first station of this segment (B9020000 – dark blue). The Northeast Cape Fear River confluence is located between the fourth (B9050100 – dark green) and fifth (B9800000 – lavender) stations of this segment. Sutton Lake, described earlier in this section, is located adjacent to the second station (B9030000 - aqua). All AUs along this segment, except 18-(63)b, had impairments on the 2022 IR (*Table 9-18*). AU# 18-(63)b was data inconclusive for chloride (230 mg/L, AL, FW), fluoride (1.8 mg/L, AL, FW), chlorophyll *a* (40 ug/L, AL, NC), and a suite of dissolved metals. AU# 18-(71)a3 was data inconclusive for cyanide (5 mg/L, AL, FW). The data inconclusive rating was due to an insufficient number of samples to rate (< 10), not due to elevated concentration found. The only metal that exceeded the standard was one of four samples tested for dissolved copper.

Between the last station of the upriver segment and the first station of this segment (B9020000), which includes drainage from the Black River subbasin, there are one major and 13 minor dischargers totaling 7.991 MGD as-built flow, 57 NPDES stormwater facilities, 3,387.1 acres non-discharge and residual solids application fields, and 490 AFOs (primarily swine) with 1,087 lagoons, permitted for 333.1 million pounds. These permitted facilities and fields are primarily located in the Black River subbasin. Along this segment of the Cape Fear River, which includes drainage from the Northeast Cape Fear River subbasin, from the first station (B9020000) to the last station (B9795000), there are 10 major and 40 minor NPDES dischargers with a collective as-built flow of 46.031 MGD, 124 NPDES stormwater facilities, 3,712 acres of non-discharge and residual solids application fields, and 558 AFOs (primarily swine) with 912 lagoons and a permitted 316.3 million pounds of live weight. All AFO facilities and permitted fields are in the Northeast

Cape Fear River subbasin. Three of the 10 major NPDES discharge facilities are located directly along the Cape Fear River (two that currently have discharge, see diagram above). Additionally, most of the NPDES stormwater facilities are also located within this HUC10 and closer to the mainstem Cape Fear River. It should be noted that there are also many non-permitted poultry facilities in the Black and especially the Northeast Cape Fear River subbasin where Duplin County is located (see Chapter 1). Also see Chapter 3, Section 3.9.1 Ambient Water Quality Station Drainage Area Permit Analysis for the Cape Fear River Basin.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Yearly means and exceedance rates from 2002 to 2020 for the Brunswick River-Cape Fear River mainstem evaluation were graphed for the eight stations located along this segment (*Table 9-14*). Five-year means were also graphed for DO and NO<sub>x</sub>, a full set of five-year graphics is available in the Subbasin Chapter Appendix. The collection years by DWR and the LCFRP coalition varied for the different stations and parameters. The first station, B9020000 (dark blue), and the sixth station, B9820000 (light blue), were monitored by DWR. The second, B9030000 (aqua), third, B9050025 (brown), fourth B9050100 (dark green), and seventh, B9795000 (lime green) stations were monitored by the LCFRP. The fifth station, B9800000 (lavender), was co-monitored. The upper two freshwater stations and the lower five saltwater stations have different turbidity, pH, DO, and bacteria water quality standards.

Turbidity was collected at just four stations along this segment of the Cape Fear River, the first (B9020000), third (B9050025), fifth (B9800000), and sixth (B9820000) (*Table 9-14*). The annual turbidity means for the four stations ranged from 6 to 20 NTUs (*Figure 9-84*). All annual means were below the DWR turbidity standards: 50 NTU for freshwater and 25 NTU for saltwater stations. Turbidity annual means varied at the four stations with the first and third stations being relatively higher than the other two stations over multiple years. The graphical pattern of the first station (B9020000) was similar to the lowest turbidity monitored station below Hood Creek, B8450000, of the upriver segment (*Figure 9-61*), suggesting it was likely affected by an upstream source like Riegelwood Mill Facility or Livingston Creek watershed. However, overall turbidity levels declined in the Brunswick River-Cape Fear River segment. The first station was relatively higher than the other stations in 2002, 2003, 2014, and 2015. The third station, (B9050025), had relatively higher annual means for most of the low-flow years from 2004 to 2012, ranging from 18 to 20 NTUs, suggesting some local activity was influencing the loading. This station is located directly below the Sutton Steam Electric Plant and Northeast Brunswick Regional WWTP. The coal-fired Sutton Plant was retired in 2013, close to the time turbidity levels declined at this station. The third station also had several exceedances, primarily before 2013 (*Figure 9-85*). The fifth, B9800000, and sixth, B9820000, stations generally correlated with discharge. DWR conducted screening level seasonal and non-seasonal Mann-Kendall trend tests at 95% confidence for monitoring data collected from 2000 to 2019 and 2010 to 2020 on the Brunswick River-Cape Fear River stations. Turbidity had no significant change during either period at the four stations.

The pH means generally increased from upstream to downstream and overall appeared to be negatively correlated with discharge (*Figure 9-86*). Freshwater swamp wetlands draining to the Cape Fear River have

more influence on the upriver stations, particularly during wet years while tidal waters have more influence on downriver stations, particularly during dry years. Some years there was a dip from the first station (B9020000), monitored by DWR, to the second station (B9030000) monitored by the LCFRP coalition. The coalition stations are monitored twice a month during the warm season and frequency could impact the overall yearly mean values. The pH annual mean levels for the Brunswick River-Cape Fear River mainstem segment generally ranged from 6.5 to 7.5 (*Figure 9-86*). The pH water quality criteria changes throughout this section of the Cape Fear River with the upper two freshwater swamp classified station using  $\geq 4.3$  and remaining downstream saltwater stations applying the criteria of  $\geq 6.8$  to 8.5. All of the pH exceedances occurred at the lower five saltwater stations, particularly the third (B9050025, dark brown) and fourth (B9050100, dark green), which had some very high exceedances ranging from 40% to 70%, some of the highest exceedances in the basin (*Figure 9-87*). Mann-Kendall screening trend tests for pH caused a significant decrease at five of the seven stations from 2000 to 2019: the first (B9020000); third (B9050025); fourth (B9050100); fifth (B9800000); and seventh (B9795000) stations. Test results for 2010 to 2019 found all but the first station significantly decreased. For a full description of the low pH and DO impairment in the Cape Fear River Estuary, see section 9.11. Section 9.11 also covers the swamp/SC reclassification history in this section of the Cape Fear River.

The DO yearly mean levels generally ranged from 5 mg/L to 7.5 mg/L and were generally higher at the first (B9020000) and last three stations (B9800000, B9820000, B9795000), while there was a dip in the second (B9030000), third (B9050025), and fourth (B9050100) stations (*Figure 9-88*, also see the DO five-year graphed means *Figure 9-89*). The second, third, fourth, and seventh stations are monitored by the LCFRP solely, which includes twice monthly sampling during the warm season when DO levels are generally lower. This, along with many other factors including the amount of swamp drainage, tidal impact, storm events and droughts, influence the overall yearly mean DO levels. Given all the impacts that can affect the DO concentrations, the mean concentrations have remained fairly consistent with some fluctuation in the yearly excursion rates (*Figure 9-90*). The five lower stations along this segment of Cape Fear River had the highest DO exceedances in the entire basin over the 2022 IR five-years period (see Chapter 2). DO standard excursions occurred at all five lower saltwater stations but were generally highest (>50%) at the third (B9050025, brown) and fourth (B9050100, dark green) stations. The dissolved oxygen concentrations like other instream constituents are also impacted by all the upstream point and nonpoint sources of pollutants that drain to the Cape Fear River Estuary. The Northeast Brunswick WWTP has also had some issues with Biological Oxygen Demand (BOD). Mann-Kendall screening trend tests for DO concentration found the fifth (B9800000) station significantly decreasing from 2000 to 2019. There were no significant changes for DO during the 2010 to 2010 period. For a full description of the low pH and DO impairment in the Cape Fear River Estuary, see section 9.11. Five-year mean concentration graphs for most parameters can be found in the Subbasin Chapters Appendix.

Fecal coliform bacteria monitoring data was collected at the seventh station (B9795000) until 2011, the first (B9020000), fifth (B9800000), and sixth (B9820000) stations through 2019, and the second (B9030000), third (B9050025), and fourth (B9050100) stations all monitoring years, 2002 to 2020 (*Table 9-14*). Fecal coliform bacteria annual mean (*Figure 9-91*) and geomean levels (*Figure 9-93*) were substantially higher at the second (B9030000), third (B9050025), and fourth (B9050100) stations in 2014, 2015, and 2016 (*Figure 9-91* and *Figure 9-93*). These three stations are monitored by the LCFRP but not synchronously. The second (B9030000-aqua) station had four samples >1,000 colonies/100mL in 2015 and

2016, with the highest at 13,000 colonies/100mL in March of 2015. The third station (B9050025-brown) had seven samples over 1,000 with the highest at 28,000 colonies/100mL in January 2016. The fourth station (B9050025-dark green) had five over 1,000 with the highest at 60,000 colonies/100mL in January 2014. The  $\leq 400$  colonies/100 mL fecal coliform bacteria standard applies to just the first two freshwater stations (*Figure 9-92*), which usually had 0 to 10% exceedance, except in 2015 when there were 50% at the second station. There are no saltwater standards for fecal coliform bacteria, instead, a monthly geometric mean of 35 colonies/100 mL (5-in-30) for enterococci bacteria is used for the saltwater standard in North Carolina. Enterococcus bacteria were collected at just the fifth (B9800000) and seventh (B9795000) stations from 2011 to 2020. Both stations had annual geomeans over 35 colonies/100 mL several times, including in 2015 (*Figure 9-94*).

The Black River, located above the first station (B9020000), and the Northeast Cape Fear River, located above the fourth station (B9050100), also have many AFOs in watersheds that may be contributing to fecal coliform and enterococcus bacteria levels. Fecal coliform bacteria levels were also elevated in 2015 and 2016 at the lower three stations in the upriver Hood Creek-Cape Fear River mainstem segment, indicating a potential upriver source during these years. Other potential sources include the point sources, malfunctioning septic tanks, and stormwater runoff from both urban and rural watersheds. The Mann-Kendall screening trend tests for fecal coliform bacteria had a significant increase at the first four stations (B9020000, B9030000, B9050025, and B9050100) and significantly decreased at the fifth station (B9800000) from 2000 to 2019. During the 2010 to 2019 timeframe, fecal coliform increased at two of the six stations, the first (B9020000) and sixth (B9820000). Mann-Kendall tests were not performed on the seventh station.

Specific conductivity (*Figure 9-95*) was only measured for this analysis at the first two freshwater stations where it was usually 250  $\mu\text{S}/\text{cm}$  or below. Specific conductivity was extremely high, over 1,000  $\mu\text{S}/\text{cm}$ , in 2002 and 2007 at the second station (B9030000). The influence of saltwater has a stronger effect during lower flow years as freshwater discharge is replaced by saltwater tides that reach higher up in the river system. Screening level Mann-Kendall tests for specific conductivity showed no significant change from 2000 to 2019 and a significant decrease from 2010 to 2019.

Nutrients were collected at the second (B9030000-aqua), third (B9050025-brown), fourth (B9050100-dark green), fifth (B9800000-lavender), and seventh (B9795000-lime green) stations during all years, and the first station (B9020000-dark blue) from 2004 to 2019 and the sixth station (B9820000-light blue) from 2003 to 2019 (*Table 9-14*). The Brunswick River-Cape Fear River yearly and five-year nutrient data are shown in *Figure 9-96* to *Figure 9-101*. The graphical pattern of the upper four stations (B9020000, B9030000, B9050025, and B9050100) for NO<sub>x</sub> (*Figure 9-98*) and TN (*Figure 9-100*) along the Brunswick River-Cape Fear River mainstem suggest concentrations were negatively correlated with discharge, indicating point sources as the main driver. However, the lower three stations (B9800000, B9820000, and B9795000) do not have as strong a negative correlation with discharge. TKN (*Figure 9-96*) has some correlation with discharge particularly more so at the lower three stations in recent years suggesting a nonpoint source influence. Ammonia (*Figure 9-97*), and TP (*Figure 9-101*) concentrations along this segment also did not appear to correlate positively or negatively with discharge. The USGS gage, Cape Fear R. at Lock #1 NR Kelly (02105769), overlaid on the graphs, is located upriver from this mainstem segment near Elizabethtown and may not have been as representative of discharge.

Eighty percent of nutrient concentrations for the Brunswick River-Cape Fear River mainstem stations ranged from 0.5 to 0.8 mg/L for TKN, 0.05 to 0.11 mg/L for ammonia, 0.3 to 0.6 mg/L for NO<sub>x</sub>, 0.9 to 1.3 mg/L for TN, and 0.09 to 0.17 mg/L for TP. DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams recommended <0.5 mg/L for TKN, <0.05 mg/L for ammonia, <0.3 mg/L for NO<sub>x</sub>, <0.8 mg/L for TN, and <0.05 mg/L for TP (*Table 9-13*). The EPA nutrient criteria study for Coastal Plain streams recommended <0.72 mg/L for TN and 0.032 mg/L for TP (*Table 9-13*). TKN, ammonia, and NO<sub>x</sub> had 75% of annual mean concentrations over the recommended values for those parameters, with some of the TKN and ammonia concentrations being twice as high. Most of the TN annual mean concentrations were over the <0.8 mg/L recommendation. All of the TP annual mean concentrations were over the <0.05 mg/L recommendation and over 50% were at least twice as high or greater.

Annual mean TKN concentrations were variable from year to year with the first station (B9020000) followed by the fifth station (B9820000) being the most consistent (*Figure 9-96*). Concentrations were elevated at some of the other stations from 2005 to 2007, 2015, and 2019. Ammonia concentrations were also variable from year to year with 2002 and 2018 having the most concentrated annual means (*Figure 9-97*). Ammonia concentrations were generally higher at the fifth (B9820000) and seventh (B9795000) stations for multiple years. The fifth station is located in the Cape Fear River at the southern end of downtown Wilmington, just upstream of the Brunswick River confluence (see diagram above). There are several dischargers along this stretch of the Cape Fear River as well as urban sources, such as leaky collection systems, that may contribute to the elevated ammonia signature in this section of the Cape Fear River.

The NO<sub>x</sub> annual means (*Figure 9-98*) were elevated during low-flow years, 2007 to 2013, with the highest concentrations generally in the upper two stations (B9020000 and 9030000). As described in the upper segments of this subbasin, the Cape Fear River NO<sub>x</sub> concentrations tended to decline from the upstream to downstream stations. However, the fifth (B9800000), sixth (B9820000), and seventh (B9795000) stations, the lower three stations in this segment, have relatively similar concentrations over the long-term (*Figure 9-99*). This suggests NO<sub>x</sub> levels are likely influenced by the upstream point sources.

TN annual means also varied from year to year with the first station (B9020000) being the most consistent (*Figure 9-94*). The concentrations in the stations downstream have increased with the increased flows in recent years. The ratio of TKN (organic is TKN minus ammonia) to NO<sub>x</sub> (inorganic) at stations along this segment have changed through the monitoring period and appear to be somewhat correlated with the flow. Overall, more years have had a higher organic to inorganic ratio of TN except from 2010 to 2013 when the ratio was more equal (*Figure 9-102*). Biological uptake can play an important role in the concentration of these nitrogen constituents throughout the riverine/estuarine system. Inorganic forms of nitrogen (NO<sub>x</sub> and NH<sub>3</sub>) are generally utilized and converted to organic forms as normal processes in biologically active systems. The Cape Fear River Estuary is unique in NC in that it is the only major NC estuary with direct access to the Atlantic Ocean. This feature allows for the daily exchange of water, limiting the buildup of nutrients, algae, and other pollutants. There is however a strong tidal influence that can reach about 65 miles upstream of the mouth of the river at Southport to LD1. The extent of the tidal influence is highly dependent on the freshwater river discharge rate. The lower segment of the estuary experiences tidal oscillations resulting in upstream flow during incoming tides that can push

contaminants upstream for a tidal cycle. For more information on tidal flow dynamics and nutrient process in the Cape Fear River Estuary, see section 9.12 below.

TP annual mean concentrations were fairly consistent mostly ranging from about 0.1 mg/L to 0.15 mg/L from 2002 to 2018 (*Figure 9-101*). Before 2018, the first three stations (B9020000, B9030000, and B9050025) were consistently higher than the lower four stations (B9050100, B9800000, B9820000, B9795000), more notably in low-flow years, indicating a point source influence. However, in 2019, TP concentrations shot up, ranging from 0.2 to 0.4 mg/L at several of the stations (*Figure 9-101*). TP concentrations were also elevated during the same years upriver at the lowest three stations in the Hood Creek segment, indicating an upriver source. The dramatic increase in TP in 2019 and 2020 is concerning and needs to be investigated if it remains elevated. The source could be related to nonpoint source runoff; however, there are several point sources upstream that do not have TP or TN limits that could be contributing to the load.

DWR also conducted screening level seasonal and non-seasonal Mann-Kendall trend tests for nutrient monitoring data collected from 2000 to 2019 and 2010 to 2020 at the seven Brunswick-Cape Fear stations (*Table 9-19*). TKN was of particular concern as there was a significant increase at six of the seven stations from 2010 to 2019 and two stations from 2000 to 2019. Ammonia decreased significantly at the first station (B9020000) during both periods and at the sixth station (B9820000) from 2000 to 2019, while it significantly increased at the third (B9050025) and fourth (B9050100) stations from 2010 to 2019. All other ammonia analyses were insignificant. NOx had no significant change from 2000 to 2019 at all of the stations but significantly decreased at the second (B9030000), third (B9050025), and fourth (B9050100) stations from 2010 to 2019. Other stations had no significant change in NOx during 2010 to 2019. Similar to NOx, TP had no significant change from 2000 to 2019 at all stations. However, from 2010 to 2019, TP increased significantly at the fifth (B9800000) and seventh (B9795000) stations, while having no change at the other stations.

Figure 9-84: Brunswick River Mainstem Stations Annual Mean Turbidity

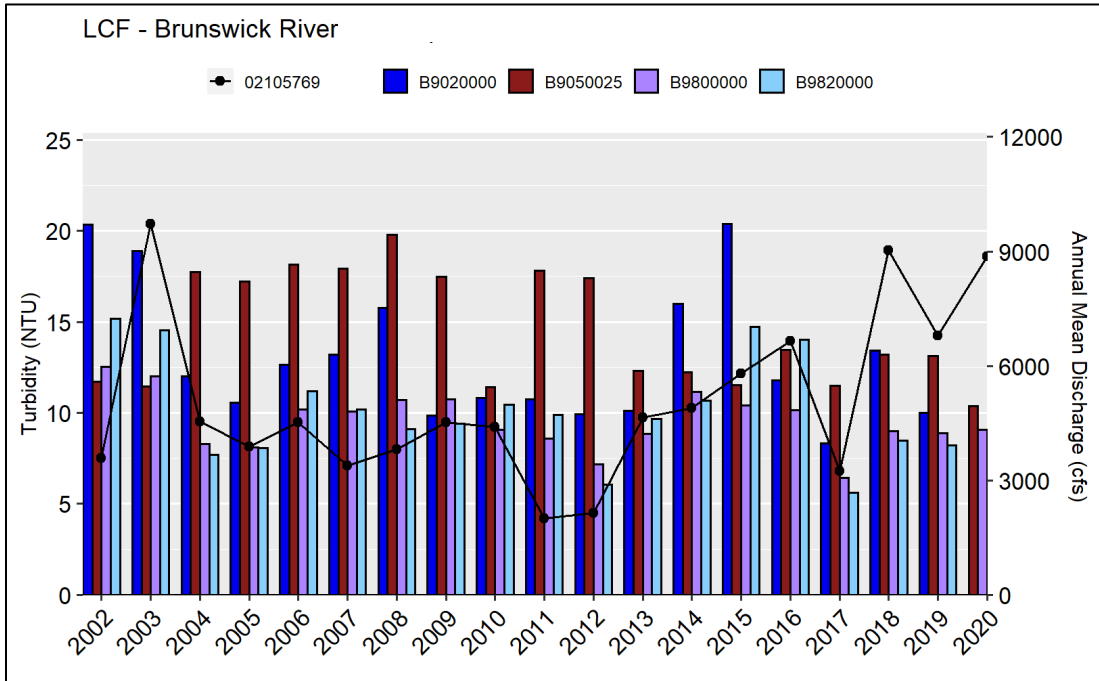
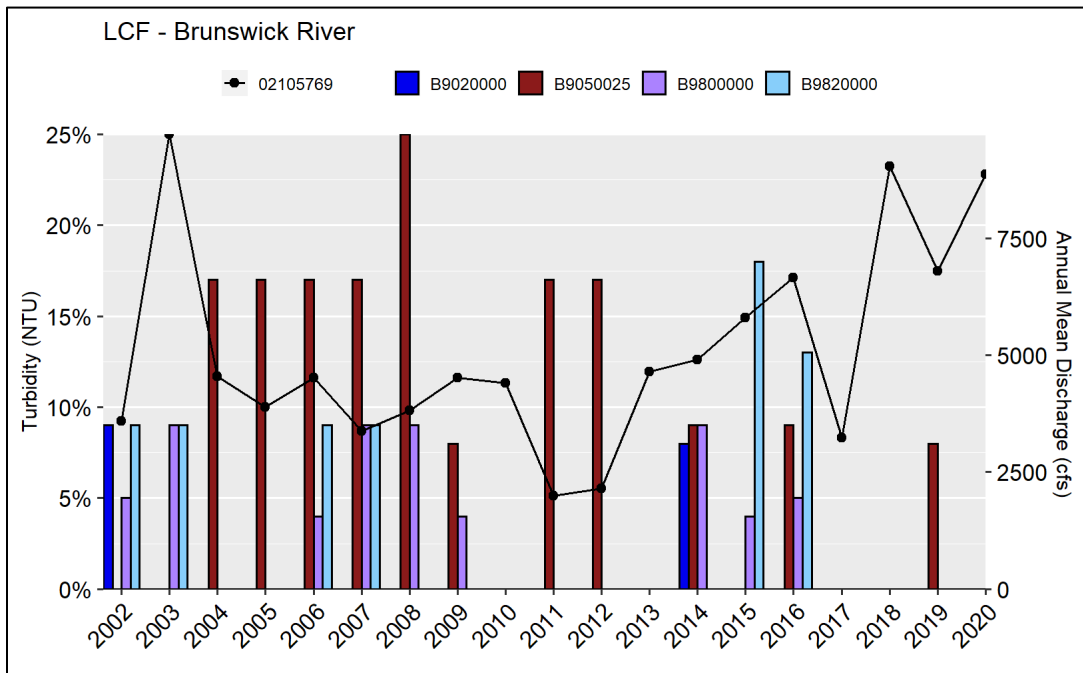


Figure 9-85: Brunswick River Mainstem Stations Sample Percentages that Exceed Water Quality Standard for Turbidity



The turbidity standard is  $\leq 50$  NTU for freshwater stations B9020000, B9030000 and  $\leq 25$  NTU for saltwater stations B9050025, B9050100, B9800000, B9820000, B9795000.

Figure 9-86: Brunswick River Mainstem Stations Annual Mean pH

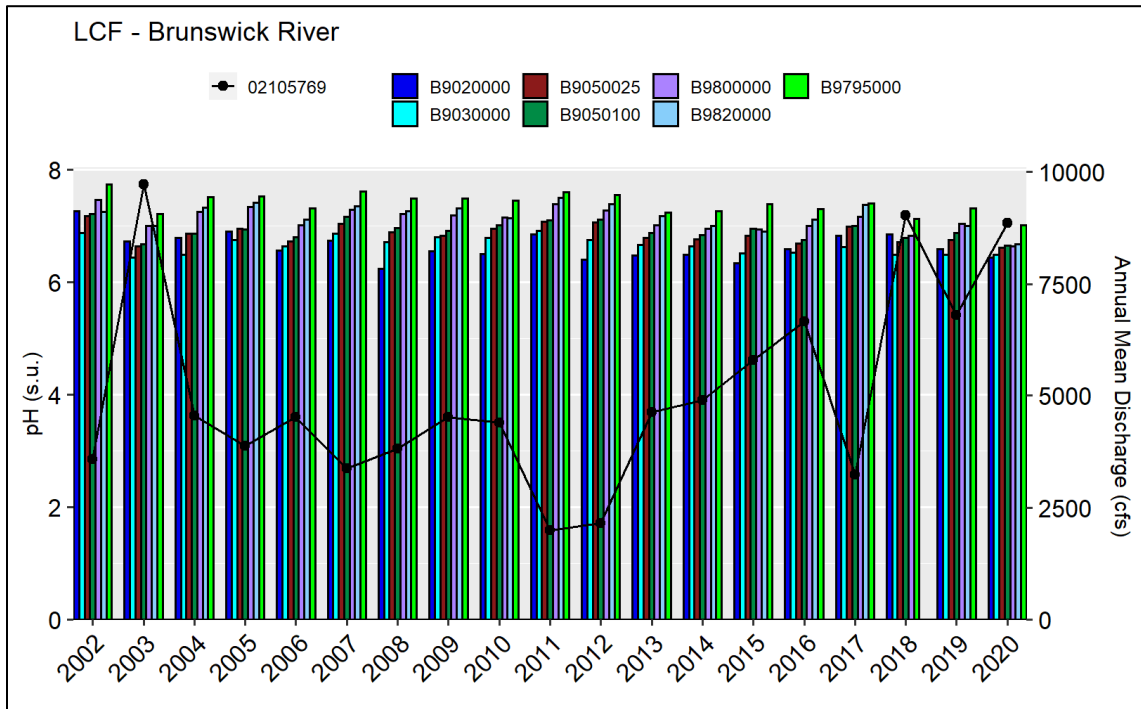
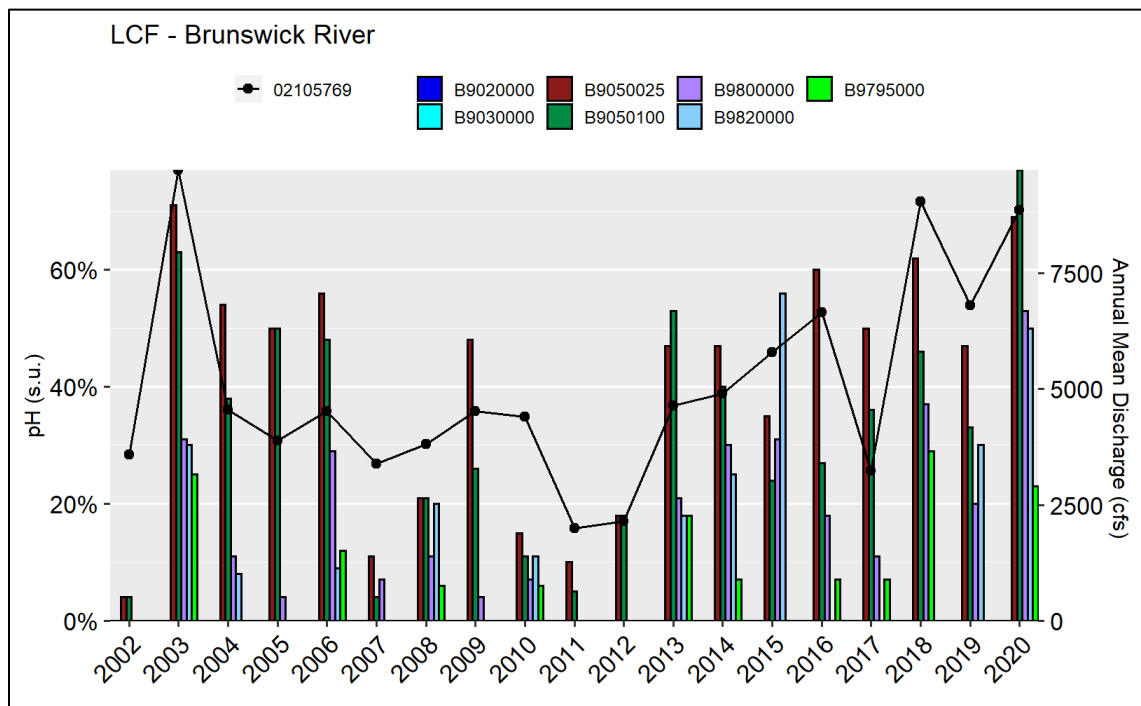


Figure 9-87: Brunswick River Mainstem Stations Percentages that Exceeded Water Quality Standard for pH



The pH standard is >4.3 S.U. for freshwater Sw stations B9020000, B9030000 and 6.8 to 8.5 for saltwater stations B9050025, B9050100, B9800000, B9820000, B9795000.

Figure 9-88: Brunswick River Mainstem Stations Annual Mean Dissolved Oxygen

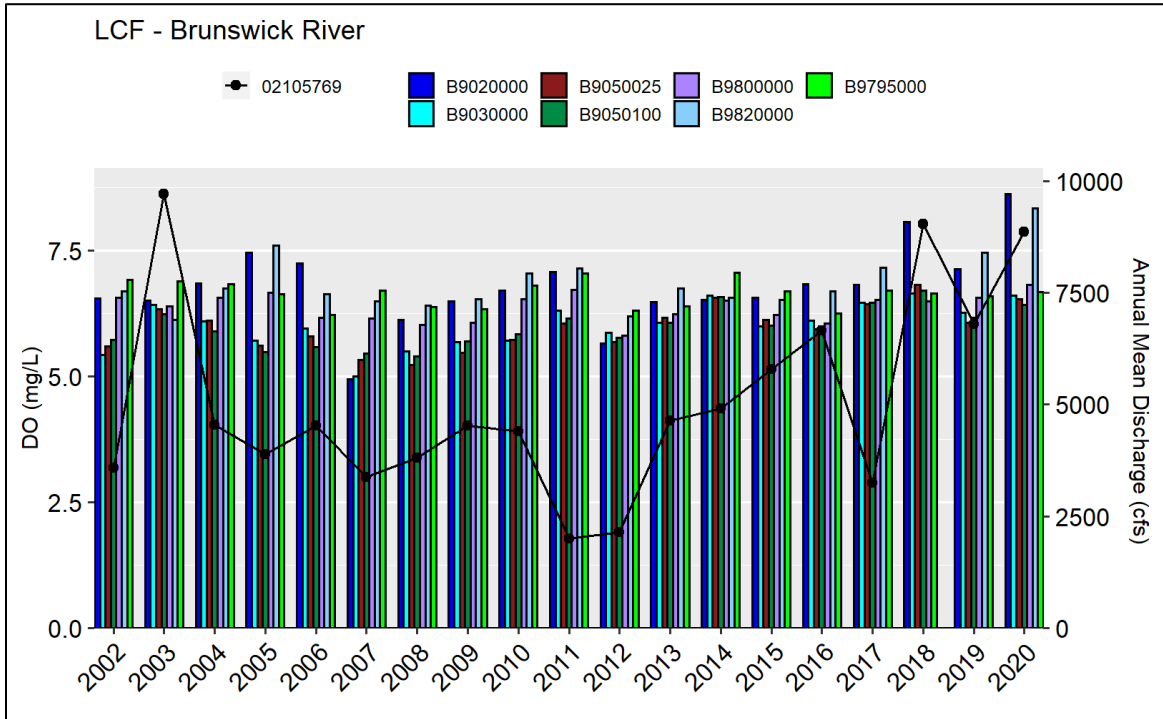


Figure 9-89: Brunswick River Mainstem Stations Five-Year Mean Dissolved Oxygen

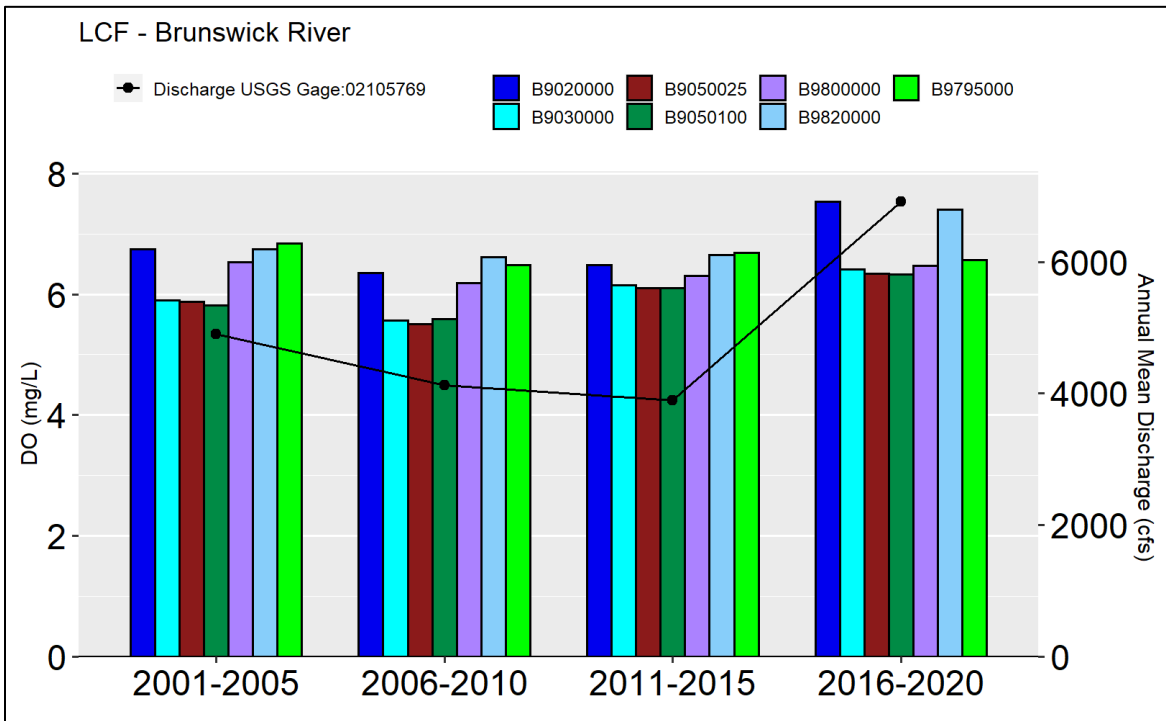
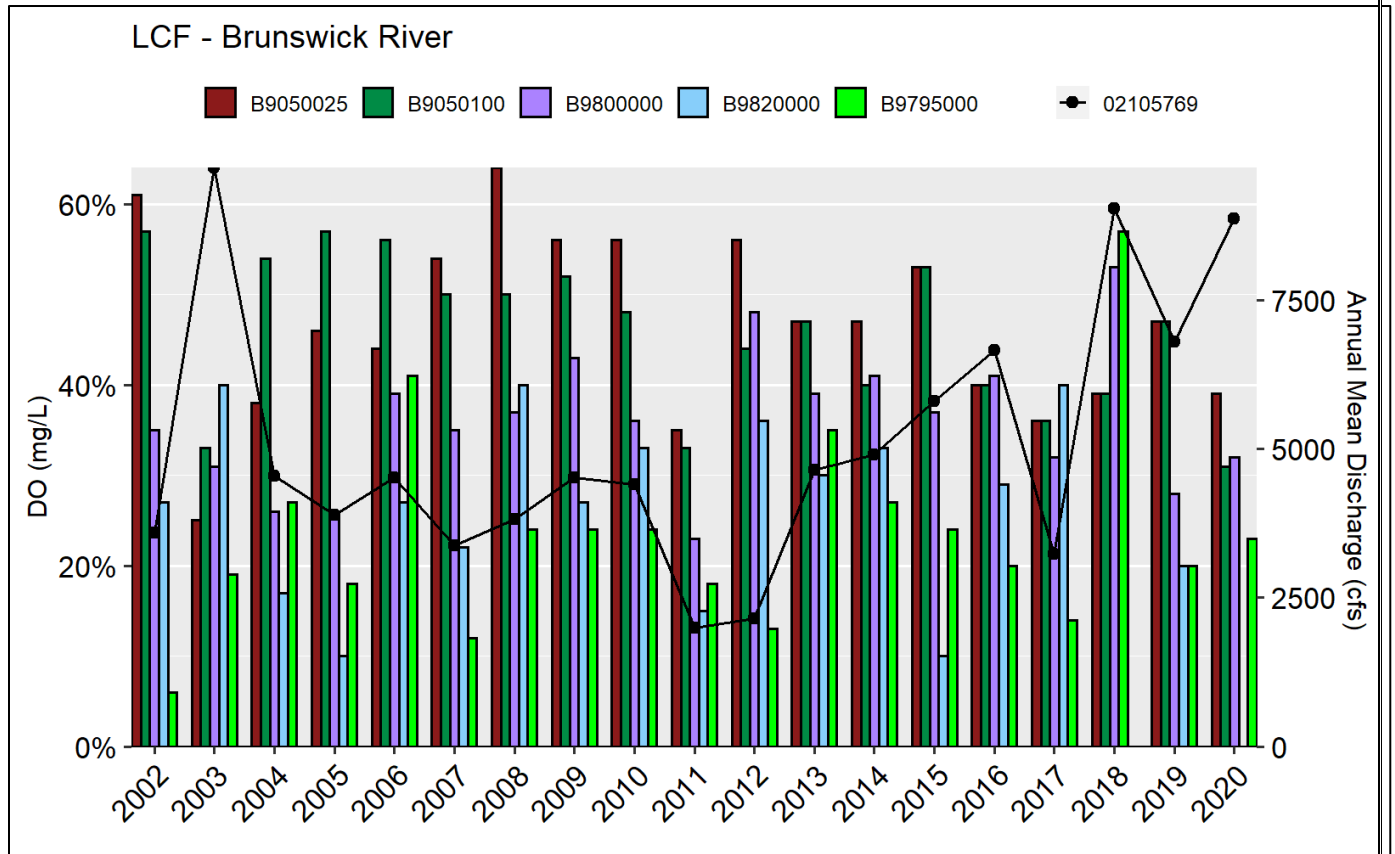


Figure 9-90: Brunswick River Mainstem Stations that exceeded the Dissolved Oxygen Water Quality Standard



The DO standard = no DO standard for freshwater, Sw stations B9020000, B9030000 and  $\geq 5$  mg/L for saltwater stations B9050025, B9050100, B9800000, B9820000, B9795000.

Figure 9-91: Brunswick River Mainstem Stations Annual Mean FCB (400 colonies/100 ml Standard for FCB is shown in graph figure)

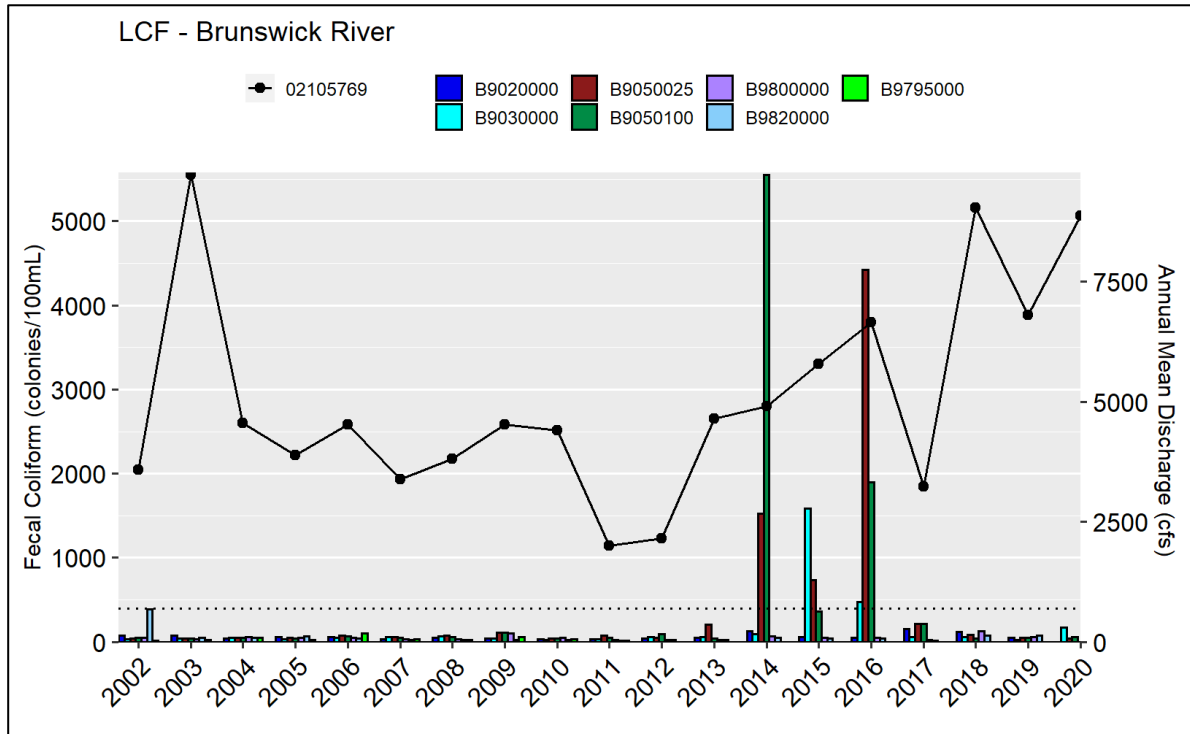


Figure 9-92: Brunswick River Mainstem Stations Sample Percentages that exceeded the 400 colonies/100 ml Standard for FCB

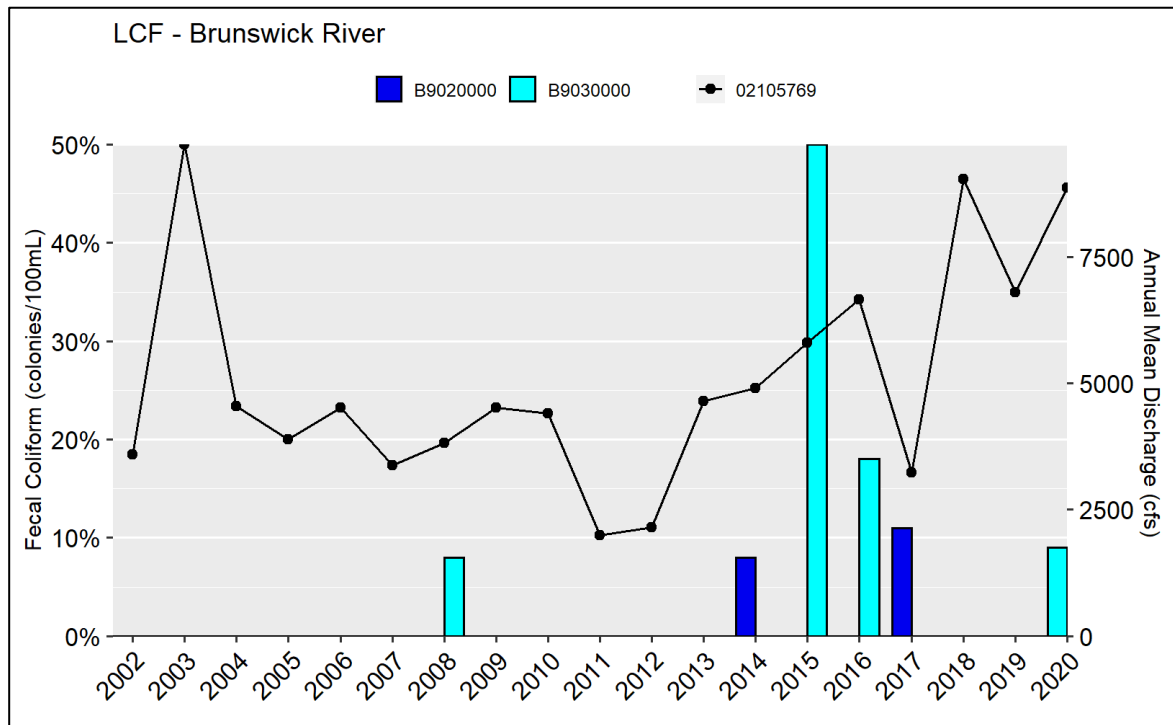


Figure 9-93: Brunswick River Mainstem Stations FCB Annual Geomeans (Geomean standard is 200 colonies/100 mL)

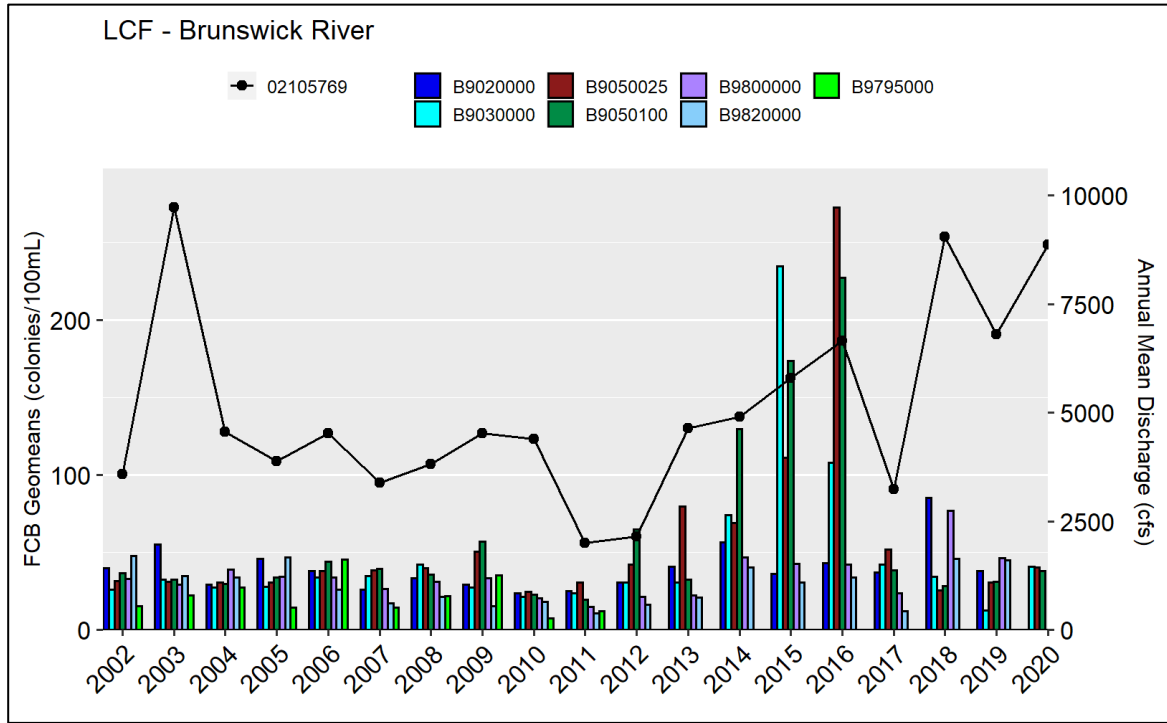


Figure 9-94: Brunswick River Mainstem Stations Enterococcus Bacteria Annual Geomeans (Geomean Standard is 35 colonies/100 mL)

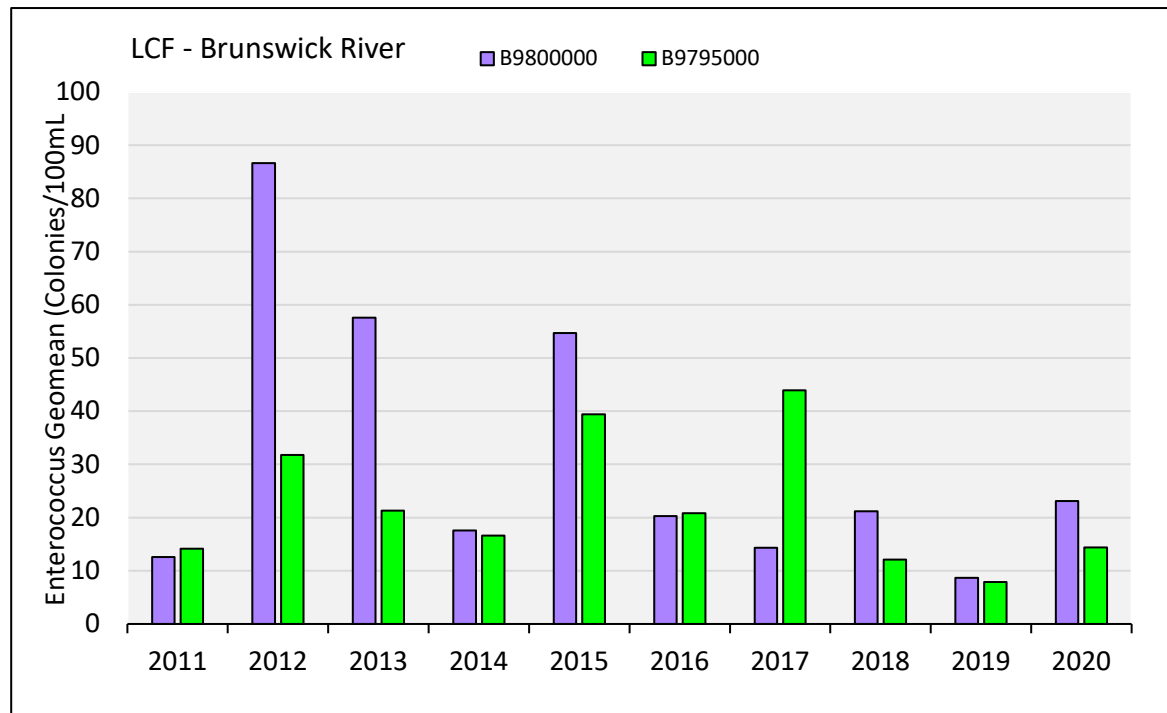


Figure 9-95: Brunswick River Mainstem Stations Annual Mean Specific Conductance

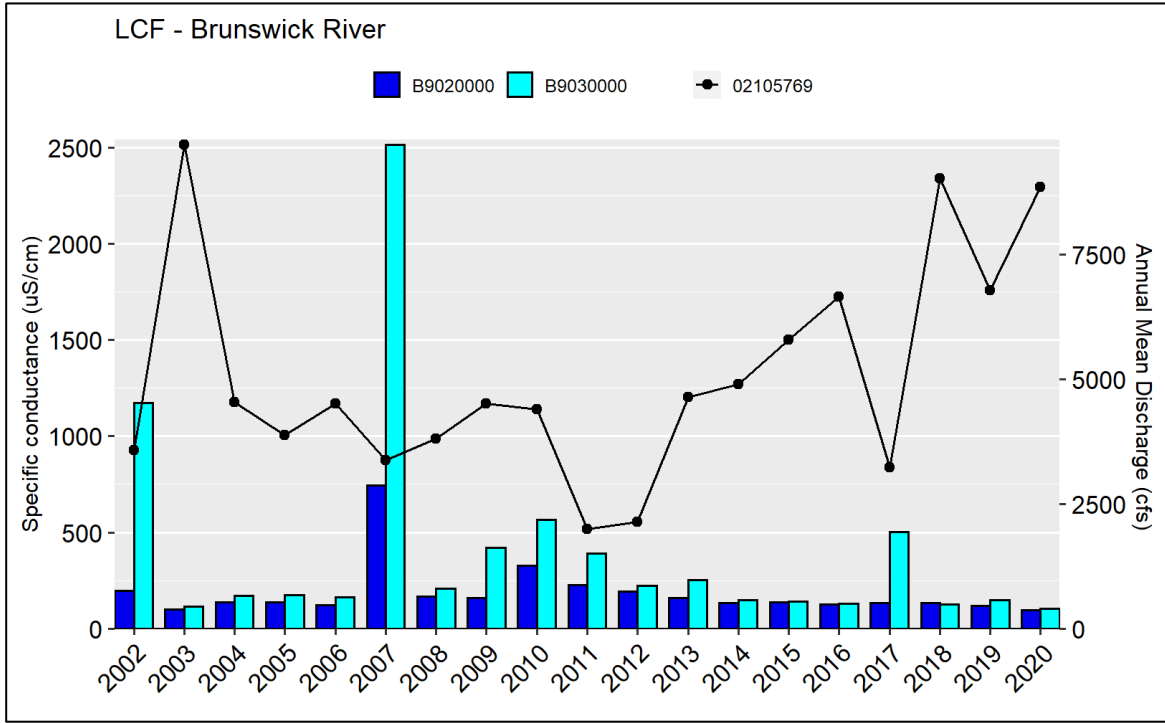


Figure 9-96: Brunswick River Mainstem Stations Annual Mean TKN

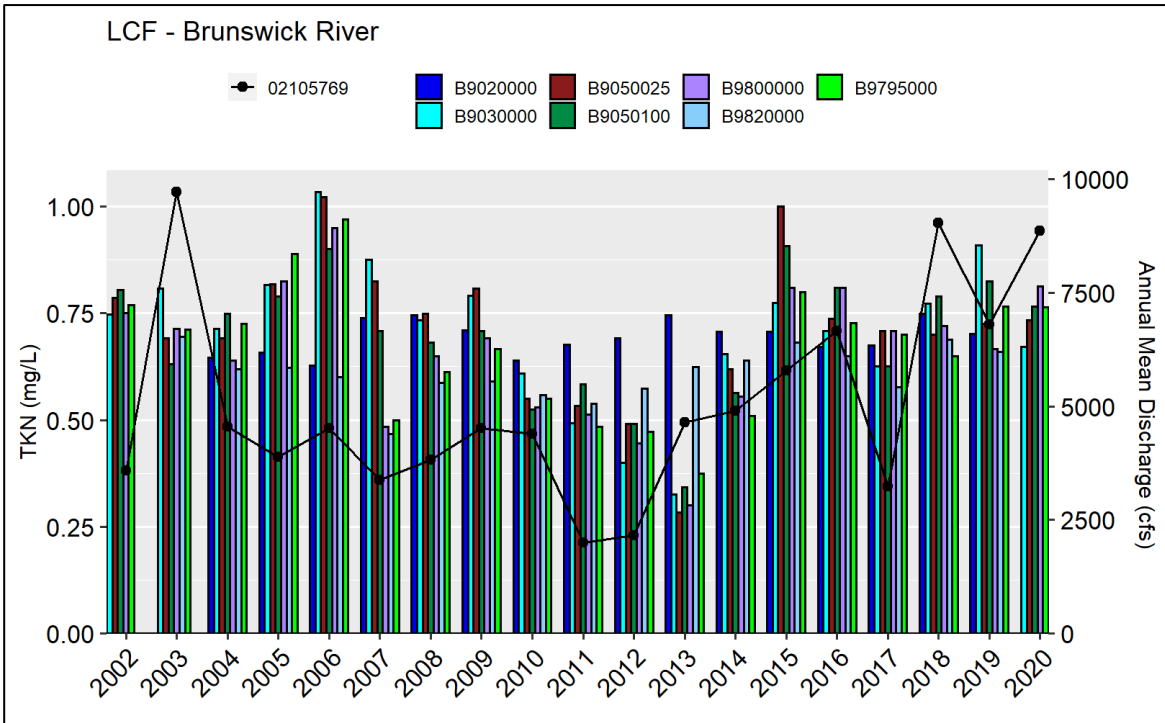


Figure 9-97: Brunswick River Mainstem Stations Annual Mean Ammonia

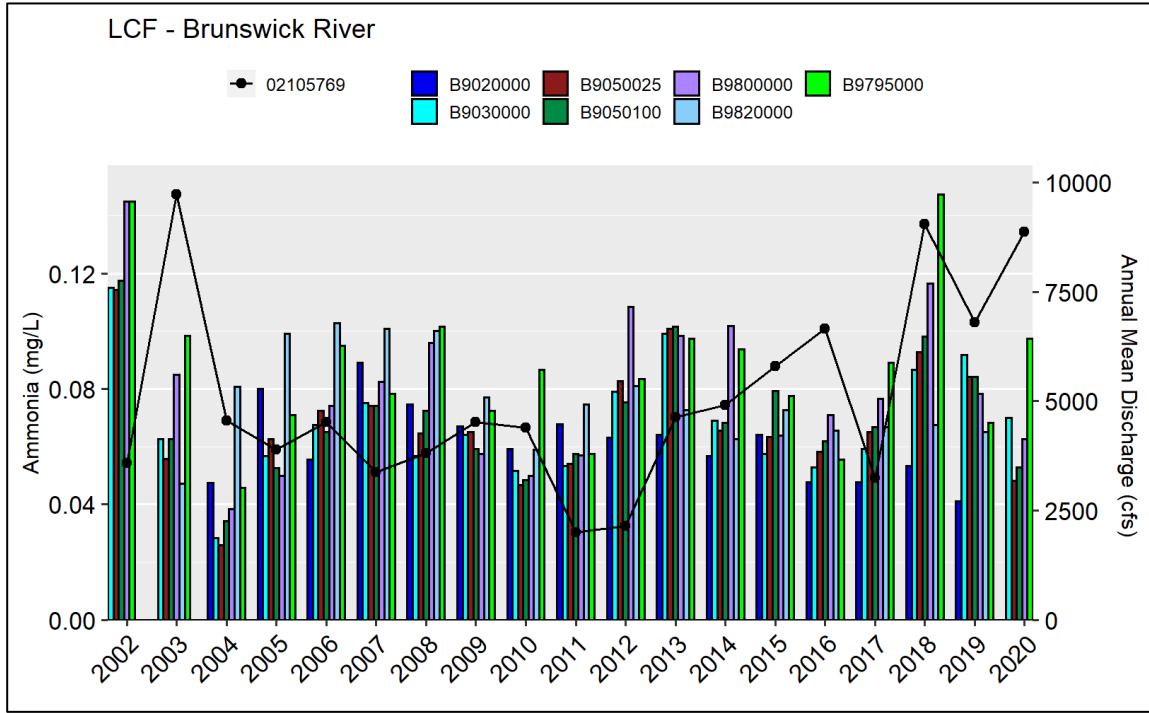


Figure 9-98: Brunswick River Mainstem Stations Annual Mean for NOx

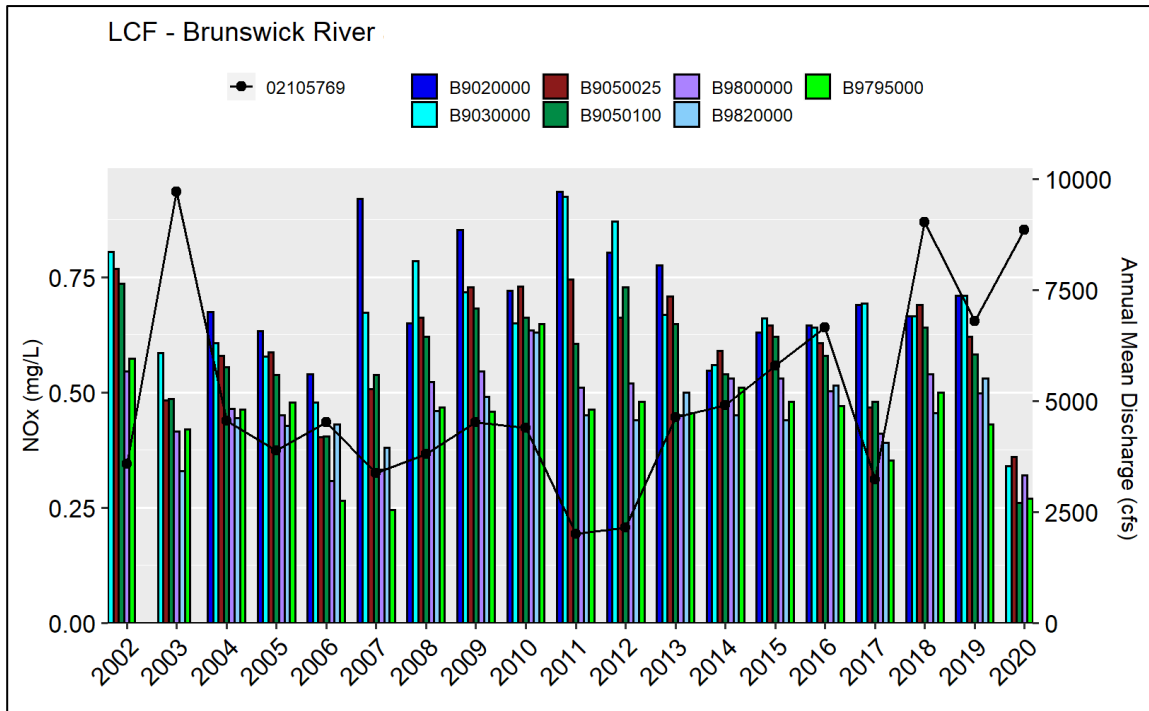


Figure 9-99: Brunswick River Mainstem Stations Five-Year Mean for NOx

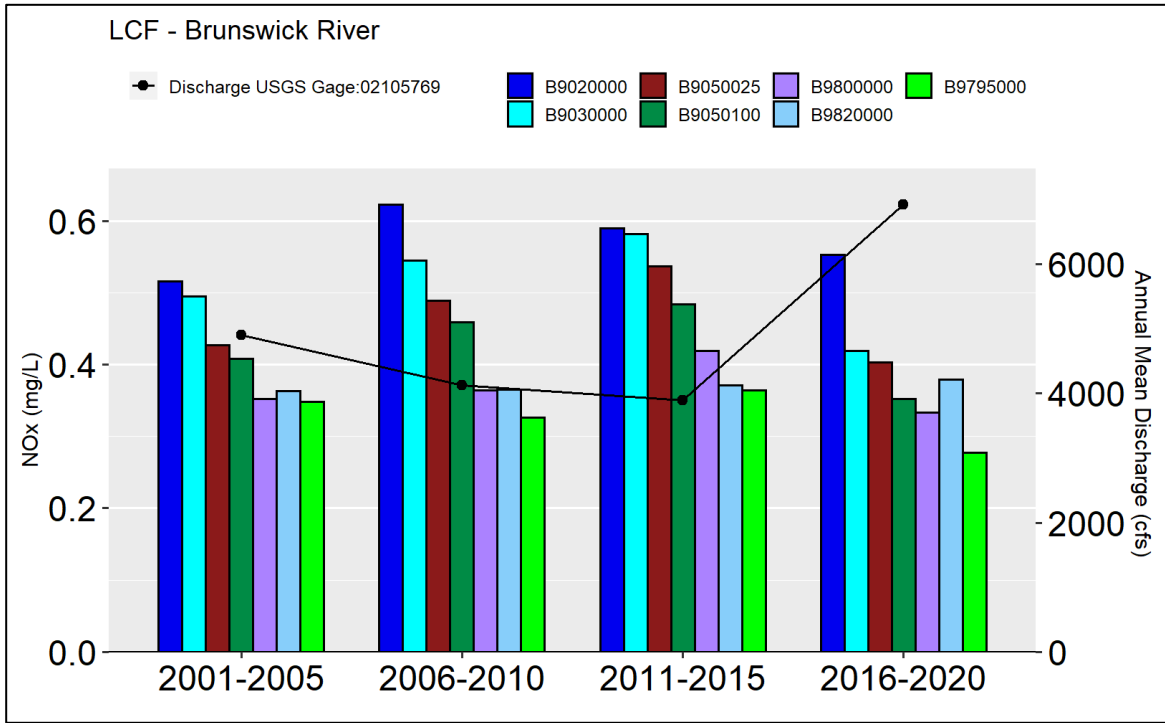


Figure 9-100: Brunswick River Mainstem Stations Annual Mean for TN

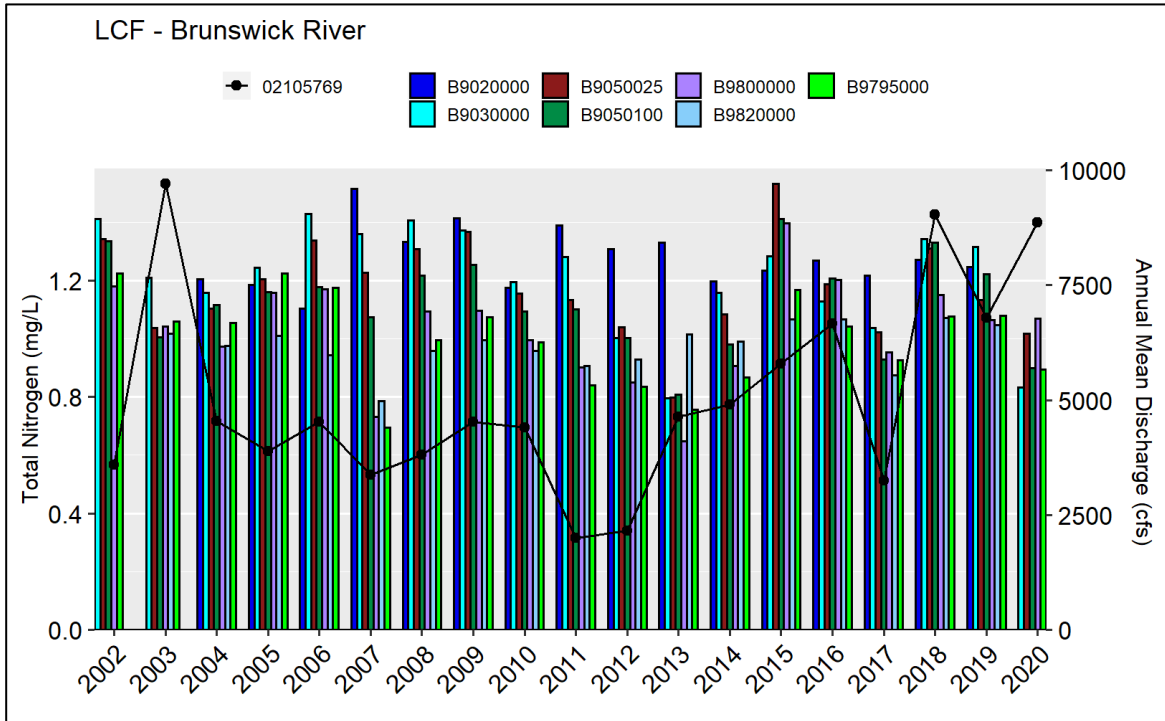


Figure 9-101: Brunswick River Mainstem Stations Annual Mean for TP

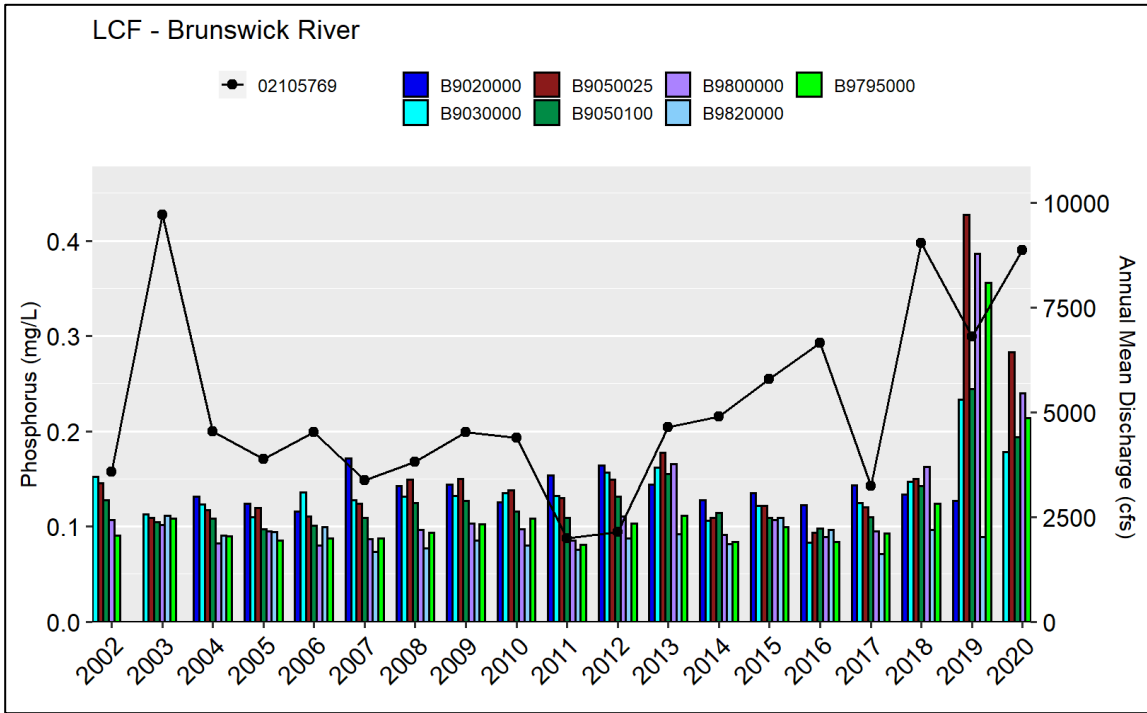


Figure 9-102: Brunswick River-Cape Fear Mainstem TKN and NOx Annual Means

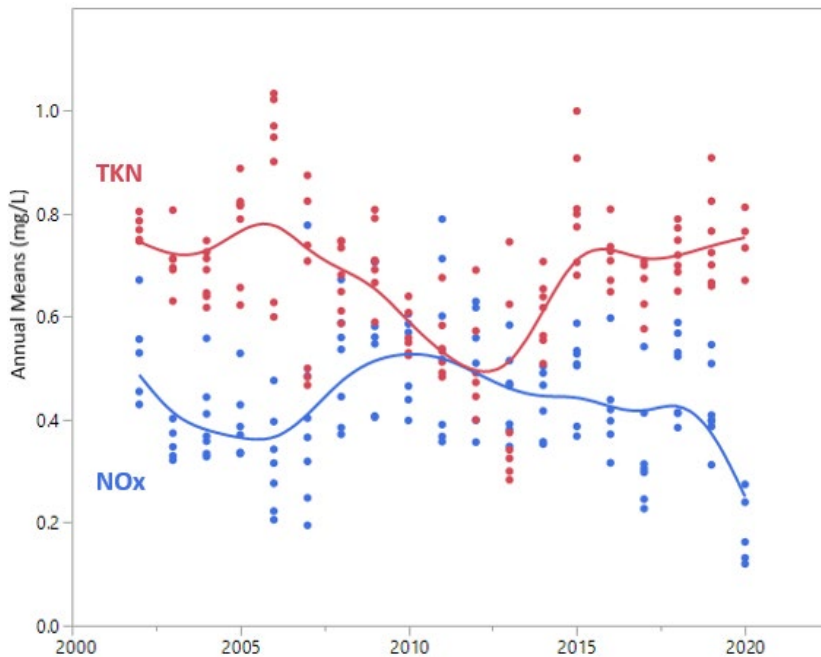


Table 9-19: Brunswick River-Cape Fear mainstem station screening level Mann-Kendall tests for significance.

Parameter	TKN		Ammonia		NOx		Total Phosphorus		
	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	
<b>Black River</b>									
1	B9020000	significant increase	not significant	significant decrease	significant decrease	not significant	not significant	not significant	not significant
2	B9030000	not significant	significant increase	not significant	not significant	not significant	significant decrease	not significant	not significant
<b>Sutton Steam Electric Plant</b>									
<b>Northeast Brunswick Regional WWTP (2.475 MGD)</b>									
3	B9050025	not significant	significant increase	not significant	significant increase	not significant	significant decrease	not significant	not significant
<b>Brunswick River split at Eagle Island</b>									
4	B9050100	not significant	significant increase	not significant	significant increase	not significant	significant decrease	not significant	not significant
<b>Northeast Cape Fear River</b>									
5	B9800000	not significant	significant increase	not significant	not significant	not significant	not significant	not significant	significant increase
<b>Brunswick River remerges south of Eagle Island</b>									
<b>Wilmington Southside WWTP (12 MGD)</b>									
6	B9820000	significant increase	significant increase	significant decrease	not significant	not significant	not significant	not significant	not significant
7	B9795000	not significant	significant increase	not significant	not significant	not significant	not significant	not significant	significant increase

Screening level Mann-Kendall tests were conducted by DWR Modeling and Assessment Branch. Stations had a minimum of six months of data ("good year") in the beginning and ending trend year and at least 70% of the years with the trend period have to be "good years." Trends were determined using the nonparametric seasonal and non-seasonal versions of the Mann-Kendall test at 95% confidence.

1.9.6.2 Brunswick River Biology Monitoring

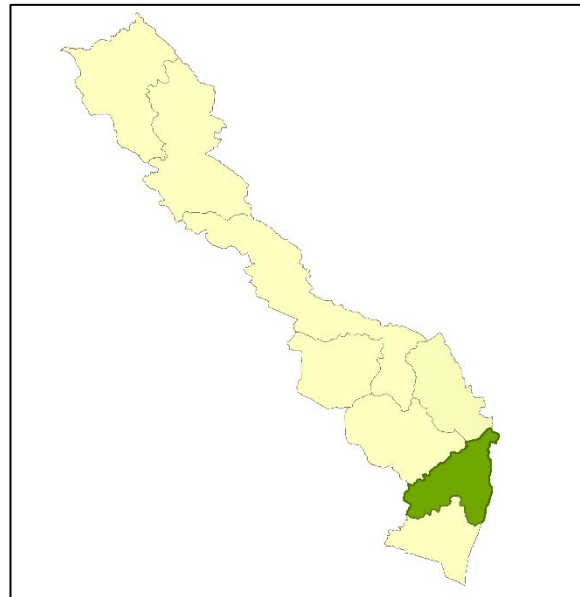
Two benthic community sites have been monitored in this catchment since 2003, Sturgeon Creek (BB483) and Barnards Creek (BB438). Sturgeon Creek was sampled once in 2008 and was not rated. Biologists noted a sand-dominated system with tannin-stained substrate. Elevated specific conductance is likely a result of the highly developed nature of the watershed.

Year	Bioclassification
<b>Sturgeon Ck. BB483</b>	
2008	Not Rated
<b>Barnards Ck. BB438</b>	
2003	Moderate
2013	Moderate

Barnards Creek (BB438) was sampled with Swamp methodology in 2003 and 2013 and received a bioclassification of Moderate both times. The biologists noted silt-dominated instream substrate and a total habitat score of 48/100. EPT taxa richness has declined every sampling year, from five taxa collected when the site was first sampled in 1998 to two taxa collected in 2013. The total species collected has also continuously declined, from 44 in 1998 to 25 in 2013. This watershed is in a highly suburbanized area of Wilmington and the stream is likely exhibiting the effects of the impervious nature of the catchment.

1.9.7 Lilliput Creek-Cape Fear River 0303000507

The Lilliput Creek-Cape Fear River watershed is located in the lower part of the subbasin spanning 89 mi<sup>2</sup> in Brunswick and New Hanover counties in the Middle Atlantic Coastal Plain ecoregion. The Cape Fear River flows into the Lilliput Creek-Cape Fear River watershed right at the confluence with Old Town Creek near the most upstream point of the watershed. The Lilliput River-Cape Fear River watershed receives drainage from all other subbasins and the Harrison Creek-Cape Fear, Turnbull Creek-Cape Fear, Livingston Creek, Hood Creek-Cape Fear, Brunswick River-Cape Fear River, and Town Creek watersheds of the Lower Cape Fear River subbasin. The Cape Fear River in this watershed is classified as SC. As noted above, the flow in the lower Cape Fear River Estuary is highly impacted by the direct connection to the Atlantic Ocean and the tidal oscillations that change flow direction several times a day.



The river is wide along this section of the Cape Fear River, ranging from one to two miles across, with several small islands interspersed. There are also several Sw classified tributaries that drain to the Cape Fear River Estuary from the west, including Sand Hill Creek, Lilliput Creek, and Orton Creek. The lower portion of these tributaries are tidally influenced as coastal marshes have formed, but these waterways are not classified as SC. The City of Boiling Spring Lakes surrounds the lake and is located in the headwaters of Lillington Creek. This lake drained in September 2018 when Hurricane Florence destroyed the dam. The municipality received a grant to restore the dam in 2022. To the south, Orton Creek is connected to Orton Pond, another man-made reservoir not monitored by DWR. On the east side of the river, Snows Cut, classified as SC, crosses basin boundaries, connecting the Cape Fear River to Myrtle Sound located in the adjacent White Oak River basin. The towns of Carolina Beach, Wrightsville Beach,

and Kure Beach are densely developed and located east of the Cape Fear River along the coast. The Sunny Point Military Ocean Terminal, which borders the river on both the east and west sides, is also partially located in this watershed.

In 2019, the Lilliput Creek watershed had 18% development, 17% forest, 11% grass and shrub cover, 32% wetland, and 20% open water (see [Table 9-6](#) and [Figure 9-6](#)). There is very little agriculture in this watershed. Development is concentrated along the coast and in the Boiling Spring Lakes municipality. This city, although growing, has hundreds of undeveloped land parcels, many that have been platted since the 1970s, but have not been developed due to a lack of county sewer services (Still, 2019). Outside of the coastal communities and Boiling Spring Lakes, much of the land in this watershed is in a more natural state. Many of the land parcels are conservation properties managed by the state, local government, the military, and The Nature Conservancy. This area around Boiling Spring Lake is ecologically significant with extensive pine flatwoods, pine savannas, pond pine woodlands, and pocosin communities that support several rare plant species (see Chapter 1. Section 1.6.5). Several Carolina bays and lime sinks have also formed on the landscape in this watershed. Some of the lime sinks at the Sunny Point Military Terminal and Carolina Beach State Park properties have been classified as unique wetlands.

As of May 2022, there were three minor and one major NPDES wastewater discharge facilities permitted for 3.745 MGD, three NPDES stormwater facilities, and 268 state stormwater facilities in the Lilliput Creek-Cape Fear River watershed. The major NPDES facility is the Carolina Beach WWTP (NC0023256) with a permitted as-built flow of 3.0 MGD for discharge to the Cape Fear River. There are no AFOs or non-discharge/land application permitted fields in this watershed.

For the years assessed in this plan (2002-2020), there are two coalition ambient monitoring stations and no biology stations used to assess the water quality conditions over this period ([Table 9-12](#), also see the Chapter 2 Appendix). Boiling Spring Lake was the only lake monitored during the period of this plan in the Lilliput Creek-Cape Fear River watershed.

In this watershed, the upper 2,183.66 S acre segment of the Cape Fear River [AU# 18-(71)a5] from 0.06 miles downstream of Barnards Creek to 1.9 miles downstream of Mott Creek is impaired for DO and total copper. Just downstream, the 1,394.11 S acre segment [AU# 18-(71)a6] from 1.9 miles downstream of Mott Creek to a line across the river between Lilliput Creek and Snows Cut is impaired for total copper.

### 1.9.7.1 Lilliput Creek-Cape Fear River Physical and Chemical Monitoring **Lake Monitoring**

Boiling Spring Lake (AU# 18-85-1-(1)), a man-made, coastal, blackwater lake located in eastern Brunswick County, is owned by the Town of Boiling Spring Lakes. This lake was impounded in 1961. Land use upstream of the lake is mostly forested and residential. The lake is used for fishing and boating and is fed by several springs (NC DWR 2018). In 2018, surface dissolved oxygen ranged from 4.2 mg/L in August to 7.0 mg/L in May. Surface water temperatures ranged from 26.1 to 32.6 °C. Field observations by staff indicated that the water of this lake was dark or tannic. Secchi depths were less than a meter and ranged from 0.2 to 0.5m. Surface pH values for the lake ranged from 4.4 to 6.1. Total phosphorus was 0.02 mg/L and TKN ranged from 0.60 to 0.98 mg/L. Ammonia concentrations ranged from <0.02 to 0.09 mg/L and chlorophyll *a* was low from 1.1 to 4.9 µg/L. Based on data collected in 2018, the lake appears to be meeting designated uses. The lake is dystrophic and the NCTSI score could not be accurately calculated (NC DWR 2018). On September 17, 2018, Hurricane Florence made landfall along the coast of North Carolina. Excessive rainfall from the storm caused the breaching of the earthen dam of Boling Spring Lake, resulting in dewatering of the lake (see aerial photo). The town plans to restore the dam and lake with a grant received in 2022 from the U.S. Department of Defense's Defense Community Infrastructure Program.

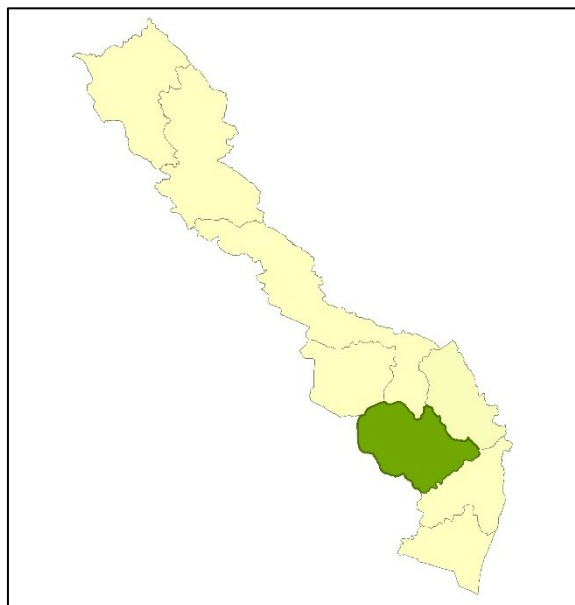


### **Ambient Stream Monitoring**

The one ambient station in this HUC10 used in the 2022 IR, B9850100, is covered in Section 9.9.10 Lower Estuary Mainstem Physical and Chemical Evaluation.

### 1.9.8 Town Creek Watershed (0303000506)

The Town Creek watershed spans 126 square miles of the Middle Atlantic Coastal Plain ecoregion in Brunswick County. This watershed only receives drainage from the network of creeks and streams that drain to Town Creek. Town Creek flows in an easterly direction and merges with the Cape Fear River to the south of Wilmington and the east of the small community of Old Town. Town Creek received drainage from several networks of smaller stream tributaries, which include upstream to down: Turkey Branch, Lewis Swamp, Beaverdam Swamp, Russells Creek, Morgan Branch, Rick Creek, and Dews Creek. All creeks and streams within the Town Creek watershed are classified as C and Swamp waters (Sw) although parts of Old Town Creek are tidally influenced by saltwater as coastal marshes have formed along the lower part of the creek closer to the Cape Fear River confluence.



In 2019, the Town Creek watershed was 37% forest, 37% wetland, 13.5% grassland/shrub, 7% agriculture, and 5% developed (see [Table 9-6](#) and [Figure 9-6](#)). The center of the watershed is a patchwork of forest, grass, and shrub cover, agriculture, wetlands, and development. The north central section of the watershed near the community of Spring Hill and the golf course communities of the adjacent Brunswick River-Cape Fear River watershed have seen development in recent years. The lower section of the watershed, closer to the Cape Fear River confluence, has more forest and wetland cover and appears to be in a more natural state, other than one golf course and the historic ditching in the coastal marsh areas along Old Town Creek. Forested areas, wetlands, and grass and shrub cover are prevalent in the upper portion of the watershed near the headwaters in the wide, flat instream divide areas. Aerial photography indicates some areas in the upper portion of this watershed are managed pineland while other areas are in a more natural state, including a small section of The Nature Conservancy-owned Green Swamp preserve and several pocosin-covered Carolina bays on the south side of the watershed.

As of May 2022, there were five swine AFOs, permitted for 32,770 head with 5,288,150 pounds of live weight and 84 state stormwater facilities in the Town Creek watershed. There are no NPDES dischargers, NPDES stormwater facilities, or non-discharge/land application permitted fields in this watershed.

For the years assessed in this plan (2002-2020), just one RAMS station and one benthos station were used to assess water quality conditions over this period ([Table 9-12](#), also see the Chapter 2 Appendix). There were no impairments on the 2022 IR.

#### 1.9.8.1 Town Creek Physical and Chemical Monitoring

RAMS station B98410000 was sampled at an unnamed tributary (UT) to Lewis Swamp in 2013 and 2014 for turbidity, DO, pH, and specific conductivity. The characteristically low DO and acidic conditions of Sw classified waters existed in this UT. The yearly means for pH were 4.9 and 4.4 and for DO were 4.7 and

3.9 mg/L, in 2013 and 2014, respectively. Specific conductivity was also low, 50.8  $\mu\text{s}/\text{cm}$  in 2013 and 51.2  $\mu\text{s}/\text{cm}$  in 2014. Just one yearly sample was taken for turbidity, both samples were under 10 NTUs. Sampling lower in this watershed along Town Creek closer to the Cape Fear River confluence and including fecal coliform bacteria and nutrients would be more telling of the conditions in this watershed.

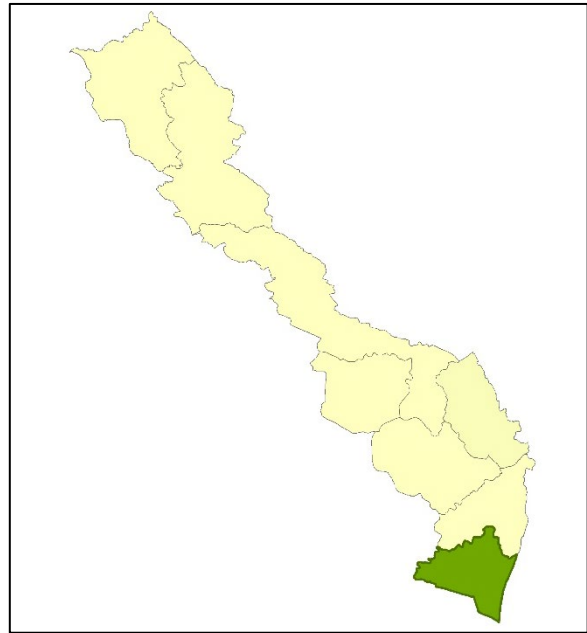
#### 1.9.8.2 Town Creek Biology Monitoring

Benthic community site BB288, Lewis Swamp, was sampled with Swamp methodology in 1998 and 2003. and received a bioclassification of Natural both times. The biologists noted a sand and silt-dominated instream substrate and a total habitat score of 83/100. EPT taxa richness declined slightly in 2003 to 12, down from 14 in 1998. The total species collected has also declined, from 63 in 1998 to 55 in 2013. This watershed is dominated by wetlands and forests, with timbering activity present.

Year	Bioclassification
<b>BB288</b>	
2003	Natural
1998	Natural

#### 1.9.9 Walden Creek-Cape Fear River Watershed 0303000508

The Walden Creek-Cape Fear River watershed is the lowest HUC10 watershed in the basin and therefore receives drainage from the entire Cape River basin. This watershed spans 79 square miles of primarily Brunswick County in the Middle Atlantic Coastal Plain ecoregion. The Cape Fear River Estuary is located on the east side of the watershed and flows in a southwesterly direction, entering the Atlantic Ocean between Fort Caswell on the west bank and Bald Head Island on the east bank. Tributaries and waterways from upstream to downstream on the west side of the estuary include Waldon Creek, Price Creek, the Intercoastal Waterway (ICWW), Dutchman Creek, and the Elizabeth River. On the east side, where Bald Head Island is located, several small tidal marsh creeks drain to the estuary, including Cedar Creek, Cape Creek, and Baldhead Creek. All of the Cape Fear River, the ICWW, and its tidal tributaries are classified as SC. Additionally, most of the Cape Fear River from Fort Fisher downstream, the Baldhead Island creeks and bays, the ICWW and several of its tributaries, Dutchman Creek, and the Elizabethan River are also classified SA.



In 2019, the Walden Creek-Cape Fear River watershed had 20% development, 14% forest, 36% wetland, and 24% open water (see [Table 9-6](#) and [Figure 9-6](#)). There is very little agriculture or grassland/shrub cover in this watershed. There are several densely developed coastal communities, including Coolvale, Yaupon Beach, Long Beach, and Bald Head Island. Other communities include the City of Southport and the Town of St. James, a golf course community incorporated in 1999, which has seen extensive growth in recent years. Development increased by 2.5 square miles (3.1%) since 2001 with a 40% population growth during the last census period in this watershed. Aerial photography indicates the undeveloped areas of the Walden Creek-Cape Fear River watershed are in a fairly natural state. Expansive salt marsh borders the

Cape Fear River Estuary on Baldhead Island and the east side of Oak Island. Several forested wetlands including Carolina bays occur to the north and west of St. James. Forested upland areas, prime areas for development, exist near Southport and Coolvale. The Sunny Point Military Ocean Terminal (U.S. Department of Defense) manages some of the restricted upland and wetland natural areas in this watershed.

As of May 2022, there were three minor and three major NPDES wastewater discharge facilities permitted for 3.51 MGD total as-built flow, 426 acres of non-discharge fields, and 10 NPDES and 359 state stormwater facilities in the Walden Creek-Cape Fear River watershed. The major NPDES facilities include the Archer Daniels Midland Company Southport Manufacturing Facility (NC0027065), which has a permitted as-built flow of 3.51 MGD for discharge to the Cape Fear River, the Duke Energy Progress Brunswick Steam Electric Plant (NC0007064), and the CPI USA-North Carolina Southport Power Plant (NC0065099). Neither the steam electric plant nor the power plant have a permitted as-built discharge flow limit. Non-discharge fields include 48 acres of non-discharge wastewater for the Baldhead Island WWTP (WQ0000193), 177 acres of high-rate infiltration fields for Southeast Brunswick Sanitary District (WQ0013200), 27 acres of reclaimed water for Oak Island's Fish Factory Road WRF (WQ0005790), and 172 acres of high infiltration fields for the West Brunswick Regional WRF (WQ0023693). There are no AFOs in this watershed.

Three minor facilities had issues with limit violations that caused compliance and enforcement action. The Beau Rivage Plantation WWTP (NC0065480), a minor facility that discharges directly to the east side of the Cape Fear River Estuary had 22 compliance and enforcement cases for limit violations for Enterococci and ammonia nitrogen primarily, as well as BOD, chlorine, flow, pH, and TSS between 2012 and 2018. The Cape WWTP with 0.26 MGD (NC0057703) had 13 compliance and enforcement cases for limit violations primarily to Enterococci and several for BOD in 2013, 2015, 2016, 2017, and 2018. The Kure Beach WWTP, with a permitted as-built flow of 0.285 MGD, also had nine compliance and enforcements for limit violations to Enterococci, BOD, chlorine, and TSS that occurred in 2011, 2013, 2015, 2016, and 2017. See the Subbasin Chapter Appendix for more details on these enforcements.

For the years assessed in this plan (2002-2020), there are four ambient monitoring stations--one AMS and three LCFRP coalition. No biology stations were used to assess the water quality conditions over this period (*Table 9-12*, also see the Chapter 2 Appendix). Just ambient two stations were used on the 2022 IR, estuary stations B9910000 and B99210000, and discussed later in Section 9.9.10.

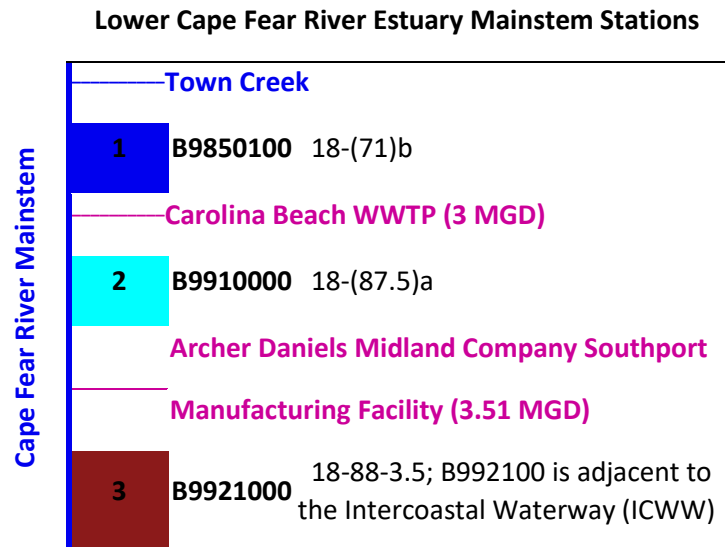
There are 2,408.6 S acres impaired for shellfish harvesting (multiple AUs) within this watershed. For more details, see Section 9.5 on Shellfish Growing Areas. Also impaired are 715.1 S acres of the Cape Fear River Estuary [AU# 18-88-3.5], near Southport, for total arsenic, total copper, and total nickel.

#### 1.9.9.1 Cape Fear River Physical and Chemical Monitoring Ambient Stream Monitoring

The two ambient stations, B9910000 and B9921000, used in the 2022 IR, are covered in Section 9.9.10 Lower Estuary Mainstem Physical and Chemical Evaluation.

### 1.9.10 Lower Estuary Mainstem Physical and Chemical Evaluation

The Cape Fear River estuary evaluation includes three stations located in three assessment units totaling 9,339 S acres, see diagram to right and *Table 9-14* for AU descriptions. All stations are in the Middle Atlantic Coastal Plain ecoregion. The diagram to the right shows the station locations relative to the Town Creek Tributary and three major NPDES dischargers. The third station (B9221000) is also located adjacent to the Intercoastal Waterway (ICWW). The 2022 IR found AU# 18-(87.5)a (station B9910000) was impaired for shellfish harvesting (Fecal, SH, SA), and data inconclusive for fecal coliform bacteria (GM 14 or 43, SH, SA) and arsenic (10 µg/l, HH, NC) and that AU# 18-88-3.5 (station B9921000) was impaired for copper (3 ug/L, AL, SW), nickel (8.3 ug/L, AL, SW), and arsenic. AUs were meeting the criteria for all other assessed parameters.



Between the last station (B979500) of the upstream Brunswick River-Cape Fear River segment and this segment's first station (B9850100), there is one minor NPDES discharger, one NPDES stormwater facility, and five AFOs with nine lagoons, permitted for 5.3 million pounds of live weight. The AFOs are located in the Town Creek tributary watershed. Permitted facilities and fields along this estuarine segment include six minor and four major NPDES dischargers (two with permitted as-built flows), 13 stormwater NPDES facilities, and 426 non-discharge wastewater fields. The Carolina Beach WWTP discharges 3.0 MGD west of the town to the east side of the Cape Fear River Estuary with the outfall located just below the first station (B9850100). The Archer Daniels Midland Company Southport Manufacturing Facility discharges 3.51 MGD to the west side of the Cape Fear River Estuary, with the outfall located just above the Southport and Fort Fisher Terminal between the second (B9910000) and the third (B9921000) stations.

Yearly means and exceedance rates from 2002 to 2020 for the Cape Fear River Estuary mainstem evaluation are shown in *Figure 9-103* to *Figure 9-116* for the three stations located along this segment (*Table 9-14*). All of the stations were monitored by the LCFRP synchronously. Specific conductance was not analyzed at the estuary saltwater stations. As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

Turbidity was only collected at the third station, B9921000 (brown), where annual means ranged from just under 5 NTU to 12.7 NTU (*Figure 9-103*). The annual means were higher in 2006, 2009, and 2018 and were the only years with excursions of the 25 NTU saltwater standard and ranged from 8% to 10% (*Figure*

9-104). DWR conducted screening level seasonal and non-seasonal Mann-Kendall trend tests at 95% confidence for monitoring data collected from 2000 to 2019 and 2010 to 2020 and there was no significant change in turbidity at station B9921000 during either period.

Annual pH means ranged from 7.4 to 8.0. The saltwater pH standard is 6.8 to 8.5 (Figure 9-105). The first station, B9850100 (dark blue), was more acidic than the other two stations and had exceedances below the 6.8 standard ranging from 6% to 15% in 2013, 2016, 2018, and 2020 (Figure 9-106). The uppermost station would receive the most runoff from swamp wetlands, which could lower the pH. Mann-Kendall screening trend tests for pH found a significant decrease during both periods, 2000 to 2019 at the first station (B9850100) and a significant decrease at all three stations from 2010 to 2019.

DO annual mean levels at the three lower estuarine stations ranged from over 6.5 to 7.7 mg/L (Figure 9-107). DO annual exceedances ranged from 6% to 21% with the most exceedances occurring at the uppermost station, B9850100 (Figure 9-108). Mann-Kendall screening tests for DO showed no significant change at any station during either 2000 to 2019 or 2010 to 2019 periods. For an in-depth review of the DO issue in the Cape Fear River Estuary, see section 9.11 below.

Fecal coliform was collected from 2002 to 2011 at all three stations and just at the lower two stations, B9910000 (aqua) and B9921000 (brown), from 2016 to 2020. Before 2012, almost all annual means were <30 colonies/100 mL; however, after 2015, annual means were a little higher (Figure 9-109). Geomeans ranged from <5 to 25 colonies/100 mL (Figure 9-110). The fecal coliform bacteria mean and geomeans were higher for the lower two stations in 2016-2019. There are no saltwater standards for fecal coliform bacteria, instead, a geometric mean of 35 colonies/100 mL (5-in-30) for enterococci bacteria is used for the saltwater standard in North Carolina. Enterococcus bacteria were collected from 2011 to 2020 at all three stations, and annual geomeans are shown in Figure 9-111. Annual enterococci bacteria geomeans were over 35 colonies/100 mL in 2015 and 2017. Mann-Kendall screening tests for fecal coliform were performed on just the lower two estuary stations. Test results found that the second station (B9910000) significantly decreased during both the 2000 to 2019 and 2010 to 2019 periods, and the third station (B9921000) significantly decreased during the 2010 to 2019 period.

The Cape Fear River Estuary mainstem yearly mean nutrient concentrations for 2002 to 2019 are shown in Figure 9-112 to Figure 9-116. The graphical pattern for TKN (Figure 9-112) and TN (Figure 9-115) in the Cape Fear River Estuary mainstem segment suggests yearly mean concentrations were positively correlated with discharge. NO<sub>x</sub> (Figure 9-114) appeared to negatively correlate with discharge, particularly at the upper two stations, indicating a point source influence. Ammonia (Figure 9-113) and TP (Figure 9-116) annual concentrations along this segment did not appear to correlate with discharge.

Eighty percent of nutrient concentrations for the Cape Fear River Estuary mainstem stations ranged from 0.3 to 0.6 mg/L for TKN, 0.02 to 0.10 mg/L for ammonia, 0.07 to 0.26 mg/L for NO<sub>x</sub>, 0.3 to 0.9 mg/L for TN, and 0.03 to 0.13 mg/L for TP, not including the last two years. DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams (Table 9-13) recommended <0.5 mg/L for TKN, <0.05 mg/L for ammonia, <0.3 mg/L for NO<sub>x</sub>, <0.8 mg/L for TN, and <0.05 mg/L for TP. The EPA nutrient criteria study for Coastal Plain streams recommended <0.72 mg/L for TN and 0.032 mg/L for TP (Table 9-13). Forty percent of the TKN and ammonia annual mean concentrations were over DWR's Coastal Plain

recommendations (<0.5 mg/L for TKN and <0.05 mg/L for ammonia). Most of the NOx means were less than the recommended <0.3 mg/L. Over 15% of TN annual means were over the <0.8 mg/L recommendation. About 55% of the TP annual mean concentrations were greater than the recommended 0.05 mg/L, and several were twice as high or greater.

For most years nutrient mean concentrations consistently decreased from the first to the third station with some exceptions and the graphical pattern for TKN (*Figure 9-112*), NOx (*Figure 9-114*), TN (*Figure 9-115*), and TP (*Figure 9-116*) had a similar pattern as the Brunswick River-Cape Fear River annual mean concentrations for those same parameters. This indicates upriver sources are driving the estuary nutrient levels. Ammonia levels decreased from the first to the third station most years also indicating potential upriver sources; however, in 2013, ammonia concentrations spiked, increasing from the first to third station, with the annual mean at the third station at almost 0.25 mg/L, five times over the recommended <0.05 mg/L (*Figure 9-113*). This suggests a more local source influenced ammonia in 2013. The TKN (organic = TKN – ammonia) fraction of TN was higher than the NOx (inorganic) fraction during the 2002 to 2020 monitoring period at these estuary stations (*Figure 9-117*). The organic-to-inorganic ratio has also been highest in recent years (*Figure 9-117*). The five-year mean concentration graphics are available in the Subbasin Chapters Appendix for additional insight to the changes that have occurred in this section of the estuary.

DWR also conducted screening level seasonal and non-seasonal Mann-Kendall trend tests for nutrient monitoring data collected from 2000 to 2019 and 2010 to 2019 at the three Cape Fear River estuarine stations (*Table 9-20*). TP was of the most concern in the estuary as there was a significant increase during both periods at all three stations. TKN was concerning as there was a significant increase at all three stations during the most recent period, 2010 to 2019. From 2000 to 2019, there was no significant change in TKN at any station. Ammonia also significantly increased from 2010 to 2019 at the first (B9850100) and third (B9921000) stations, but not the second (B9910000). There was no significant change in ammonia from 2000 to 2019 and no significant change in NOx during either period at any station.

Understanding the nutrient dynamics in the Cape Fear River Estuary is challenging due to the complex nature of a tidally influenced system as well as all the contributions from local and upstream sources. The use of models that can take many of these variables into play would be helpful in understanding the changes that have occurred and those likely to follow as the climate changes. The increasing tidal range in the Cape Fear River Estuary is resulting in more frequent flooding events including more sunny day high tide flooding as described by Dr. Shew at UNC Wilmington. In 2023, the Wilmington District of the USACE initiated a stakeholder process looking at the feasibility of deepening the Cape Fear River shipping channel from 42 to 47 feet and widening the ports turning basin to accommodate larger shipping vessels (USACE Wilmington Harbor 403 [website](#)). This would certainly impact the estuary, allowing for more saltwater movement upstream and further changing the dynamics of this vulnerable ecosystem. For more information on tidal flow dynamics in the Cape Fear River Estuary, see section 9.12 below.

Figure 9-103: Lower Cape Fear Mainstem Estuary Stations Annual Mean Turbidity

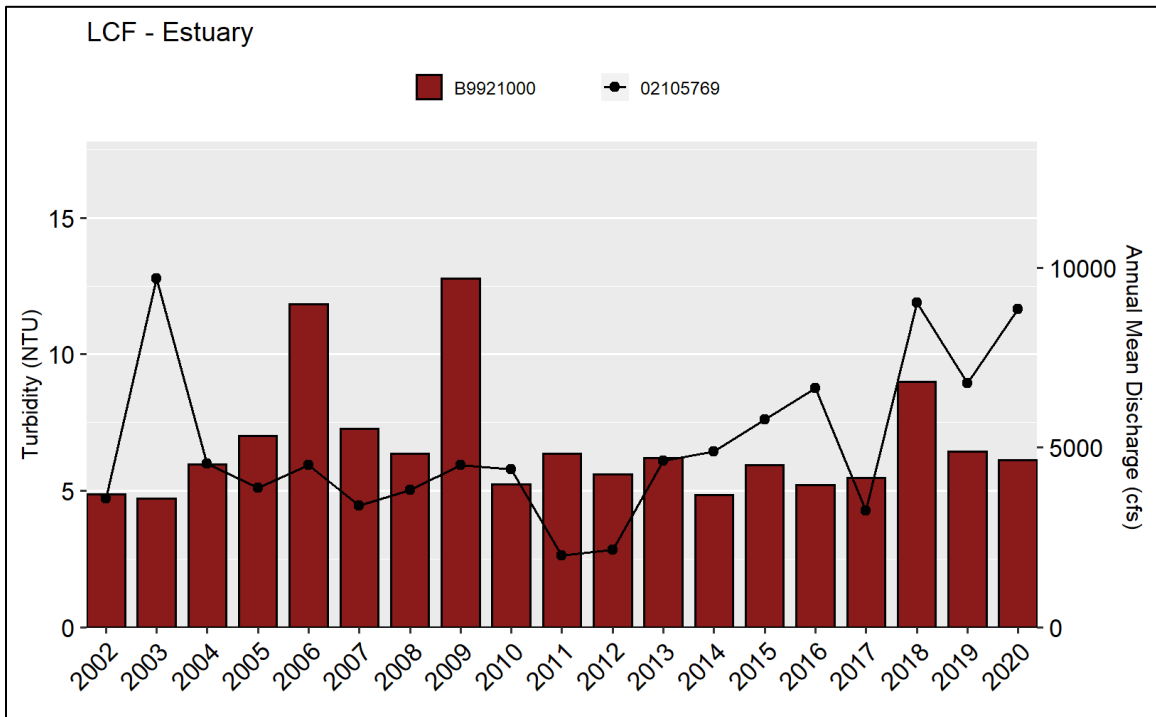


Figure 9-104: Lower Cape Fear Mainstem Estuary Stations Sample Percentages that Exceed the 25 NTU Water Quality Standard for Turbidity

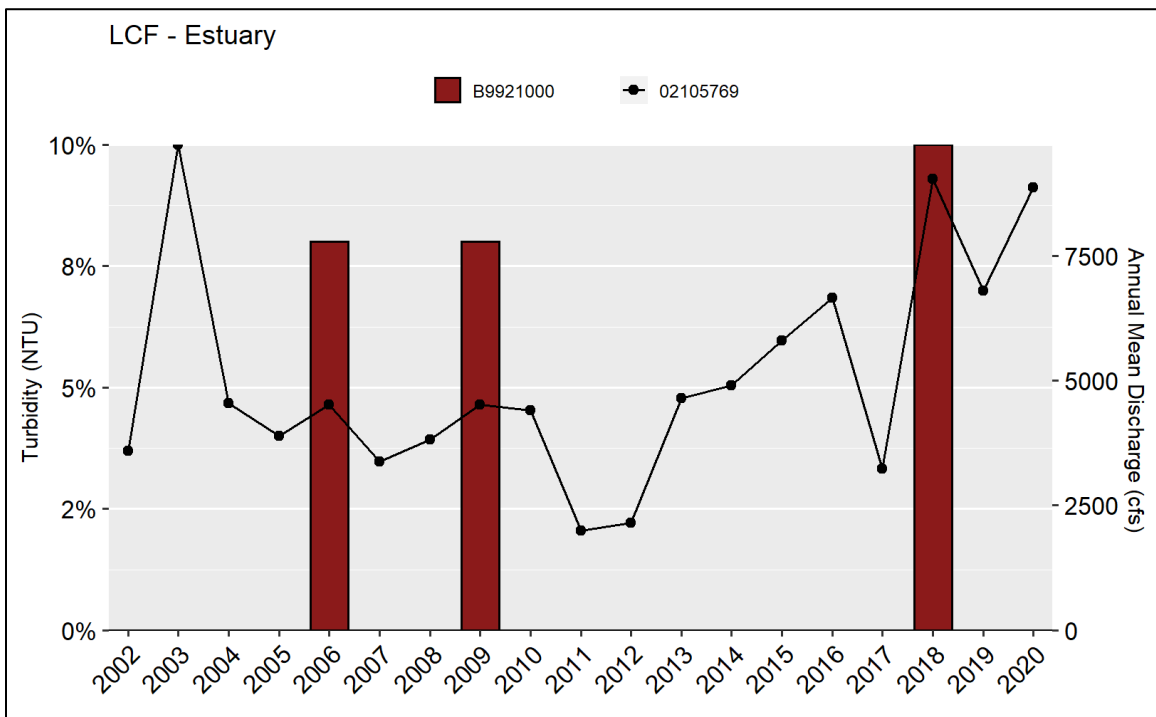


Figure 9-105: Lower Cape Fear Mainstem Estuary Stations Annual Mean pH

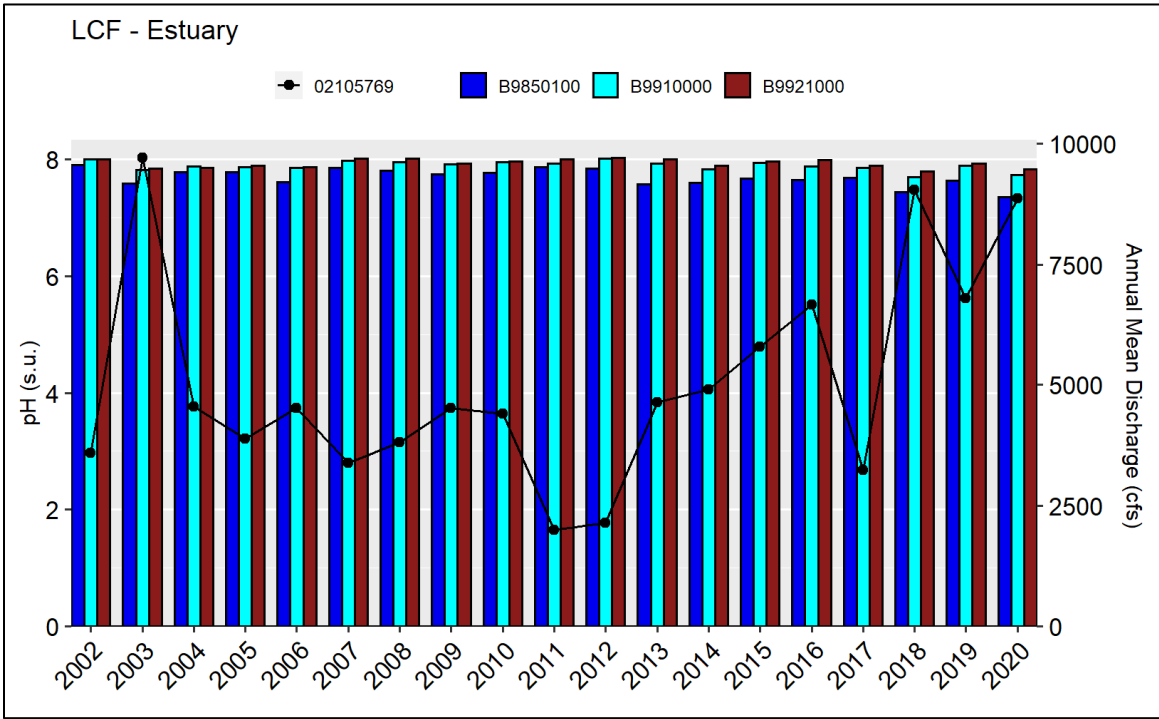


Figure 9-106: Lower Cape Fear Mainstem Estuary Stations Sample Percentages that exceed the 6.8 to 8.5 s.u. Water Quality Standard for pH

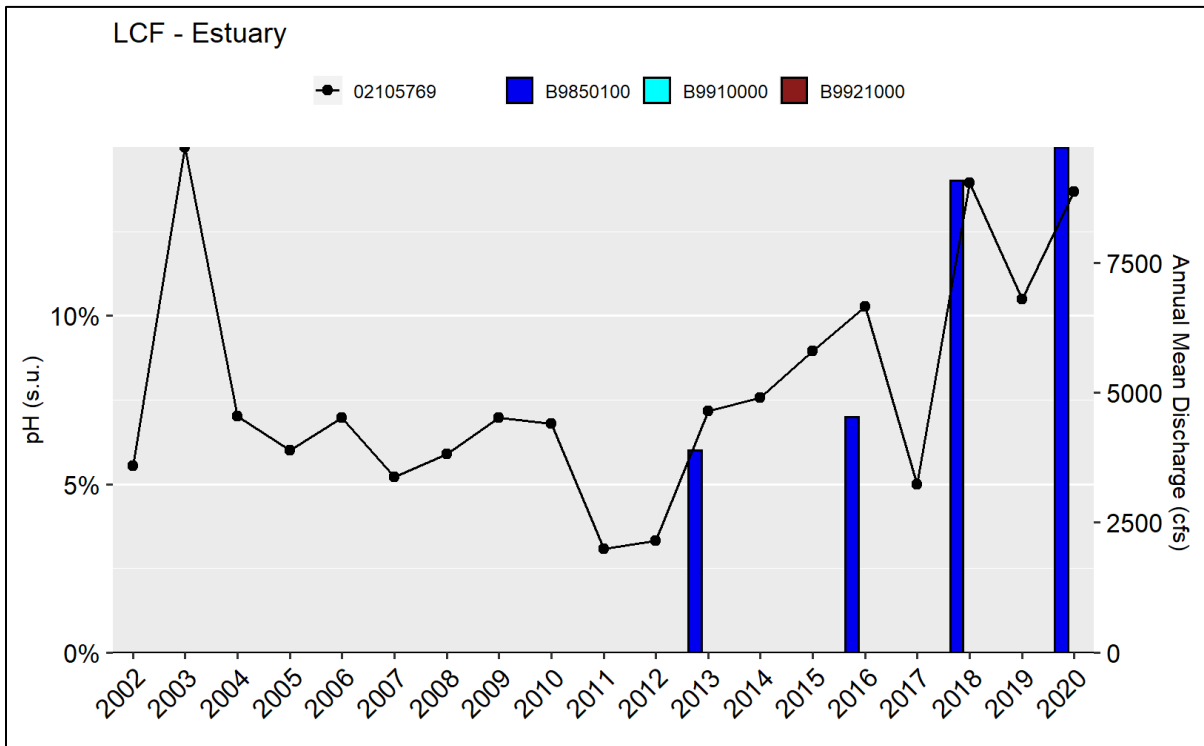


Figure 9-107: Lower Cape Fear Mainstem Estuary Stations Annual Mean Dissolved Oxygen

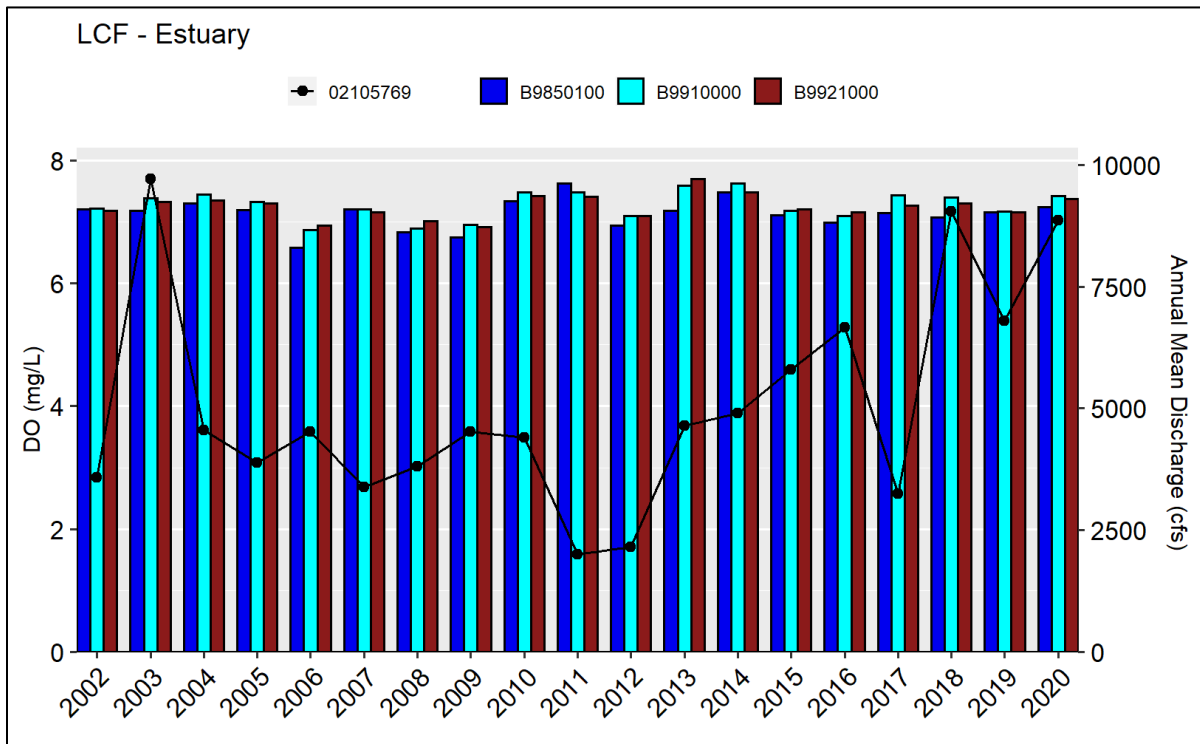


Figure 9-108: Lower Cape Fear Mainstem Estuary Stations that exceeded the 5 mg/L Dissolved Oxygen Water Quality Standard

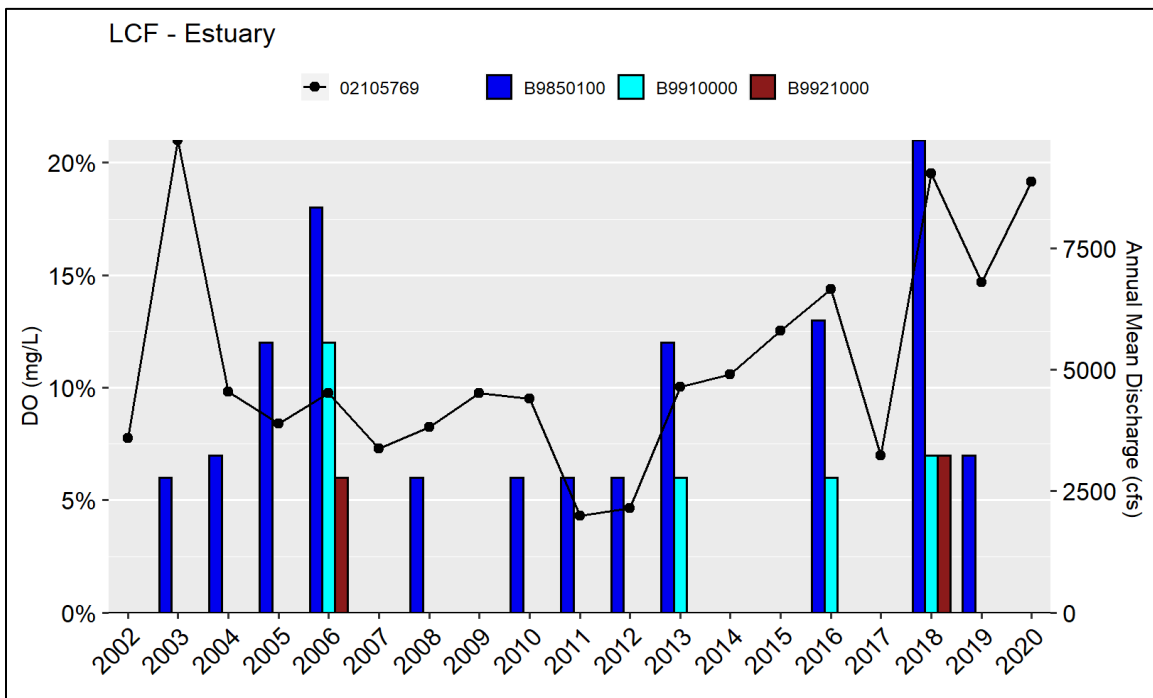


Figure 9-109: Lower Cape Fear Mainstem Estuary Stations Annual Mean FCB (400 colonies/100 ml Standard for FCB is shown in graph figure)

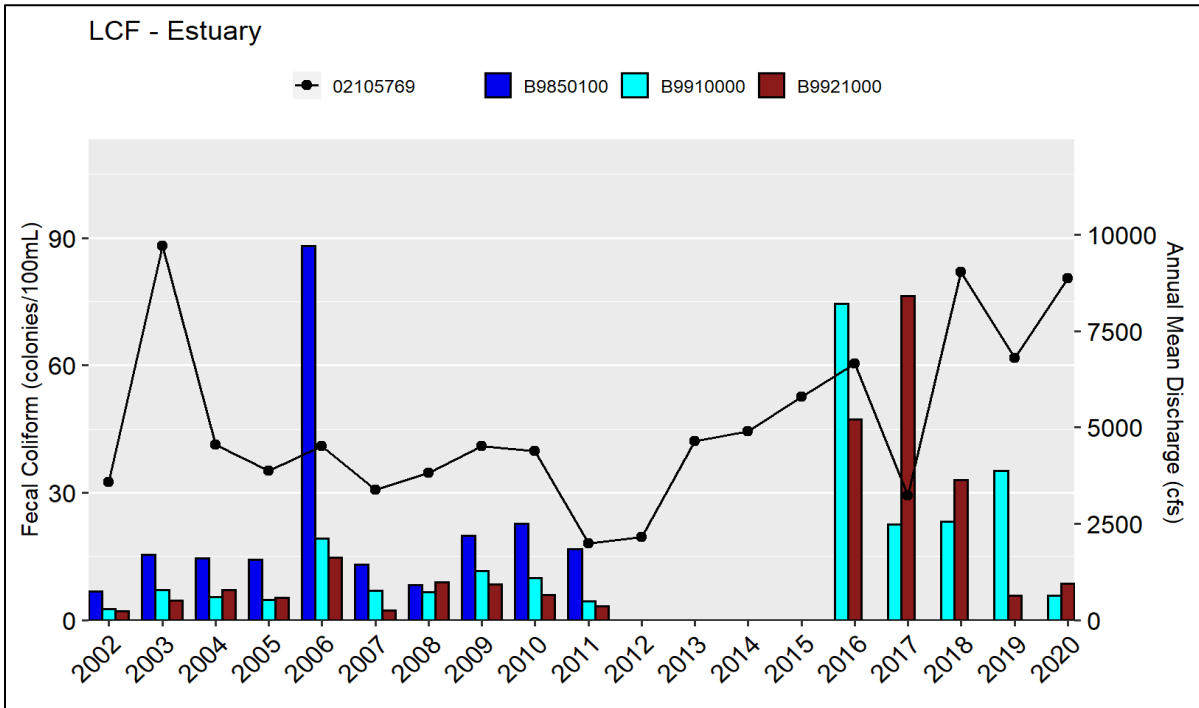


Figure 9-110: Lower Cape Fear Mainstem Estuary Stations FCB Annual Geomeans (Geomean standard is 200 colonies/100 mL)

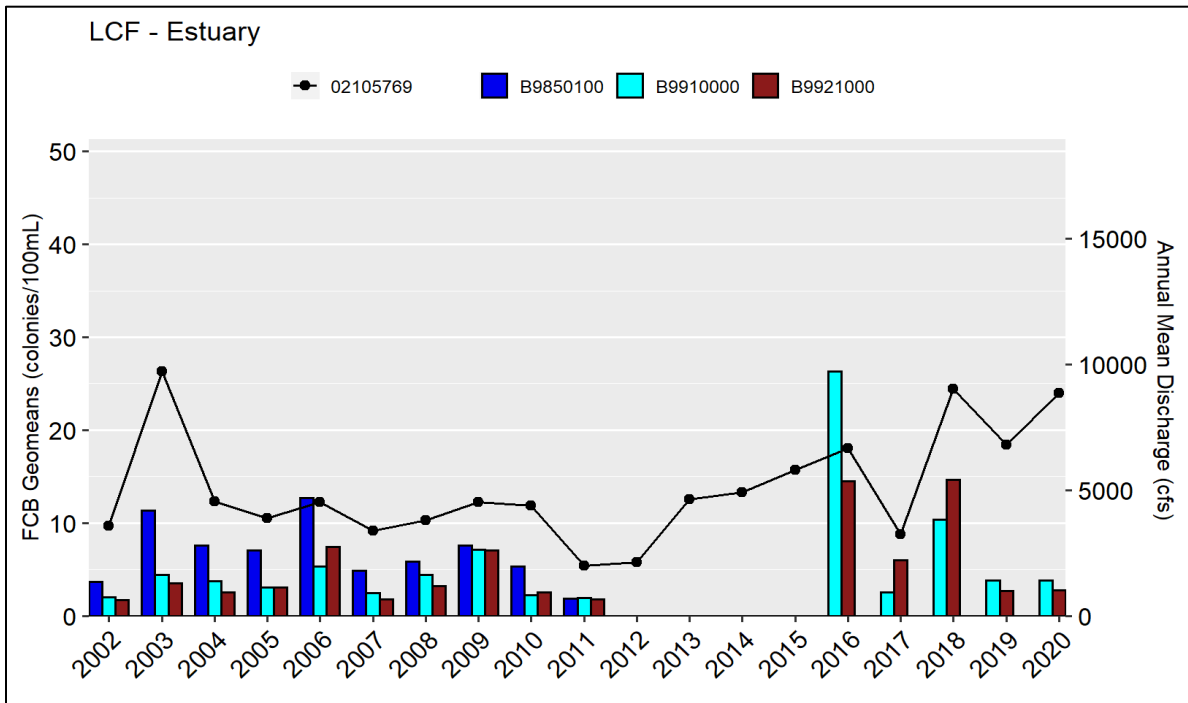


Figure 9-111: Lower Cape Fear Mainstem Annual Enterococcus Bacteria Geomean (Geomean Standard is 35 colonies/100 mL)

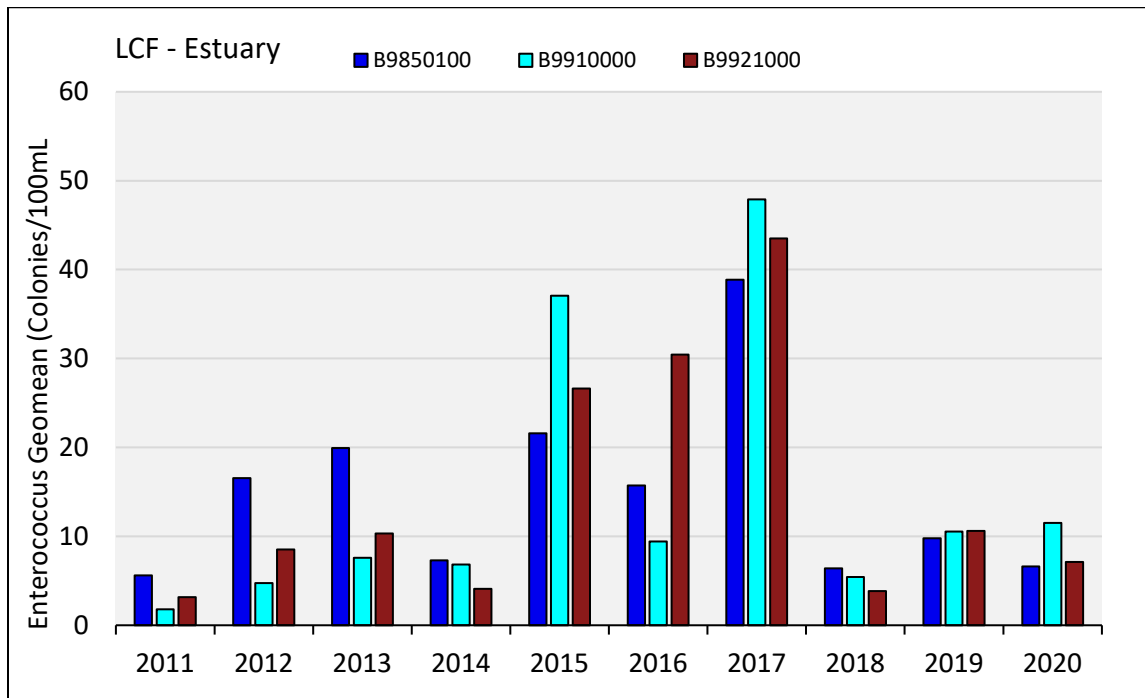


Figure 9-112: Lower Cape Fear River Stations Annual Mean TKN

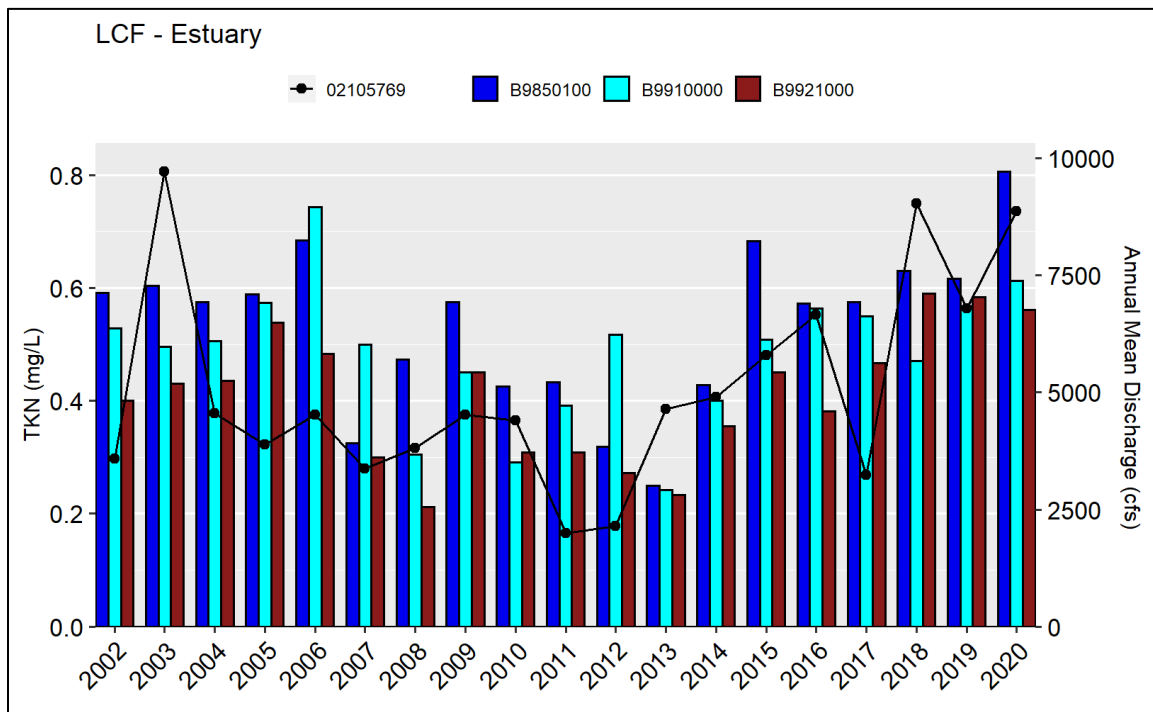


Figure 9-113: Lower Cape Fear Mainstem Estuary Stations Annual Mean Ammonia

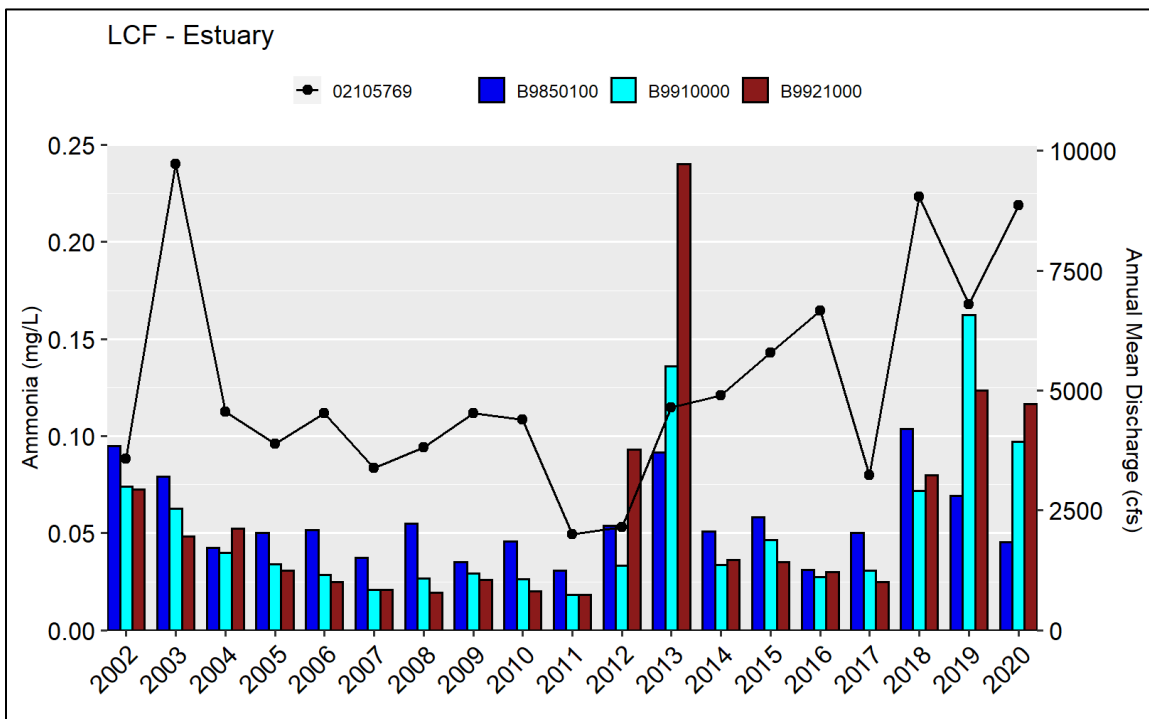


Figure 9-114: Lower Cape Fear Mainstem Estuary Stations Annual Mean for NOx

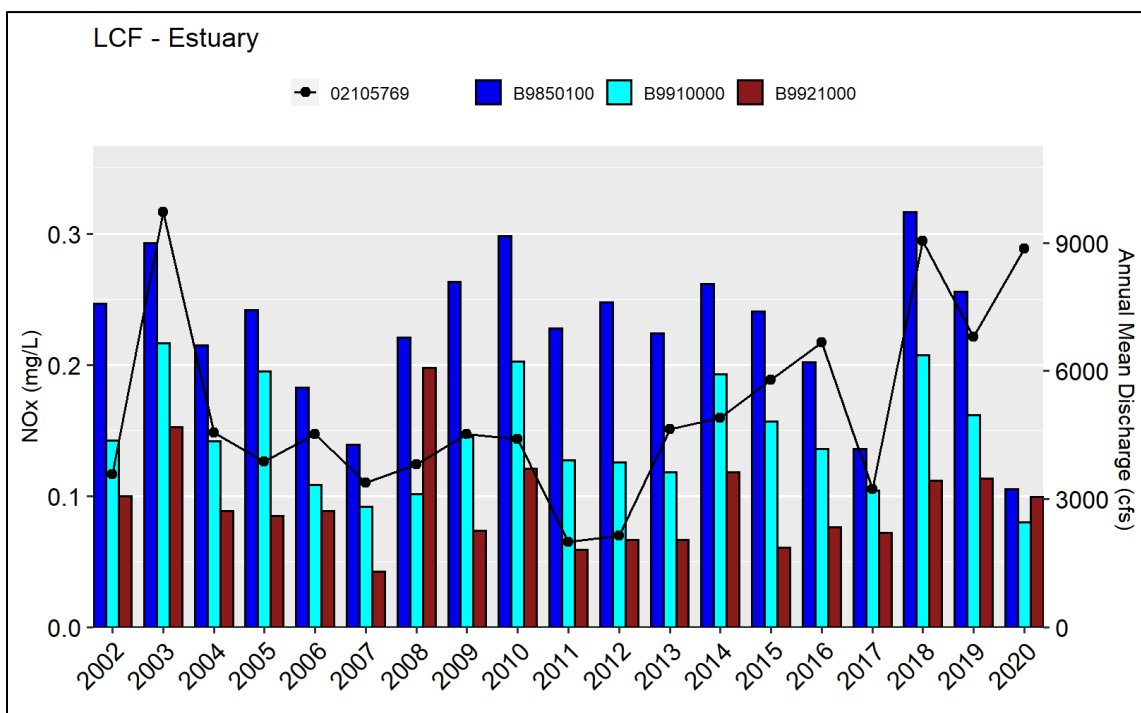


Figure 9-115: Lower Cape Fear Mainstem Estuary Stations Annual Mean for TN

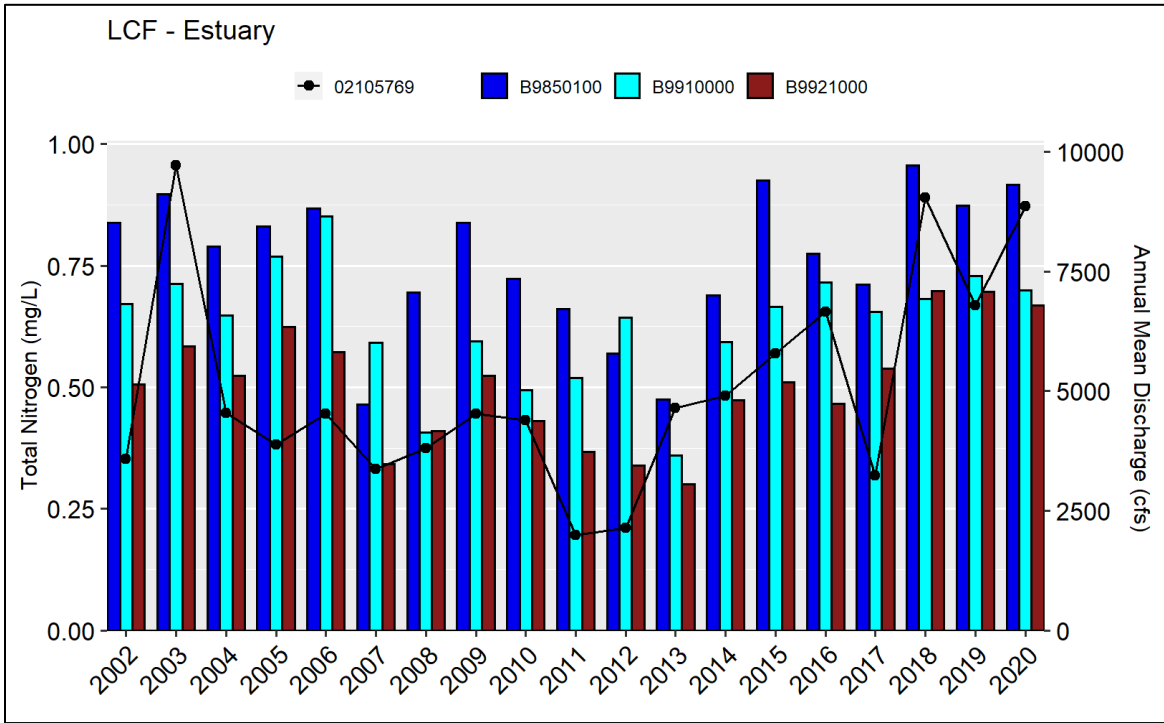


Figure 9-116: Lower Cape Fear Mainstem Estuary Stations Annual Mean for TP

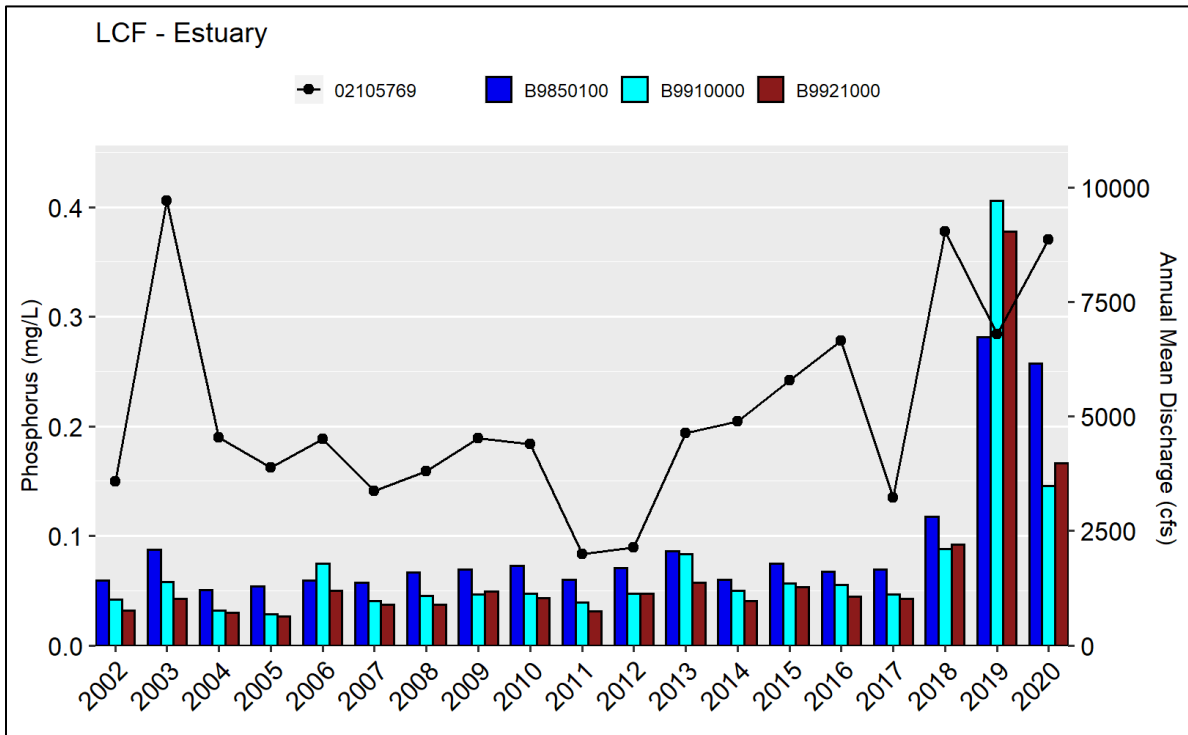


Figure 9-117: Cape Fear Estuary Mainstem TKN and NOx Annual Means

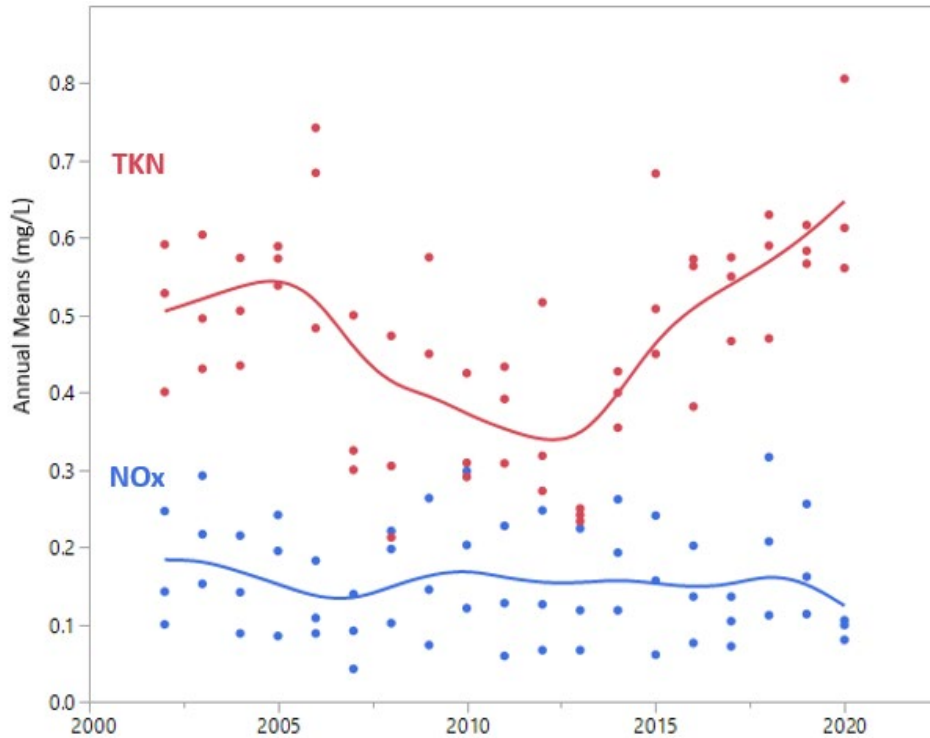


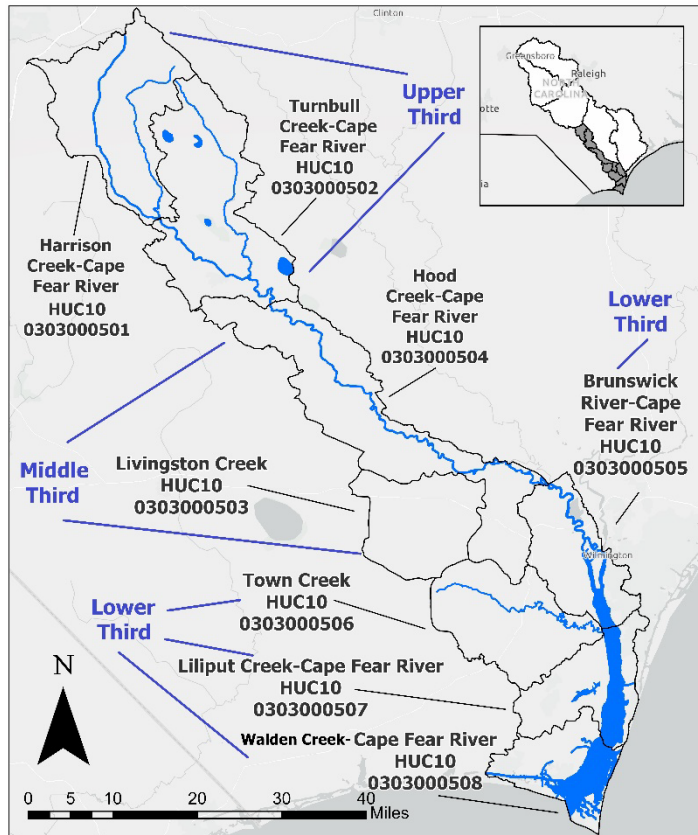
Table 9-20: Cape Fear Lower Estuary mainstem station screening level Mann-Kendall tests for significance.

Parameter	/TKN		Ammonia		NOx		Total Phosphorus		
	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	2000-2019	2010-2019	
<b>Town Creek</b>									
<b>1</b>	B9850100	not significant	significant increase	not significant	significant increase	not significant	not significant	significant increase	significant increase
<b>Carolina Beach WWTP (3 MGD)</b>									
<b>2</b>	B9910000	not significant	significant increase	not significant	not significant	not significant	not significant	significant increase	significant increase
<b>Archer Daniels Midland Company Southport Manufacturing Facility (3.51 MGD)</b>									
<b>3</b>	B9921000	not significant	significant increase	not significant	significant increase	not significant	not significant	significant increase	significant increase

Screening level Mann-Kendall tests were conducted by DWR Modeling and Assessment Branch. Stations had a minimum of six months of data ("good year") in the beginning and ending trend year and at least 70% of the years with the trend period have to be "good years." Trends were determined using the nonparametric seasonal and non-seasonal versions of the Mann-Kendall test at 95% confidence.

## 1.10 Lower Cape Fear River Summary

This section provides ambient water quality summary statistics for the most recent five years (2016-2020) for stations covered in the previous watershed scale HUC10 sections and a more detailed discussion of the upper (Section 9.10.1), middle (Section 9.10.2), and lower third (Section 9.10.3) of the Lower Cape Fear subbasin (see figure to right). The Lower Cape Fear River mainstem, tributary ambient stations, permitted facilities and non-discharge and residual solids fields are displayed in *Figure 9-118* to *Figure 9-122*. Where applicable five-year means and standard exceedance rates for turbidity, pH, DO, fecal coliform bacteria, and specific conductivity are shown in *Table 9-21*. Five-year nutrient means and TKN:NOx ratios are shown in *Table 9-22*. Five-year means and exceedances for the two lowest stations on the Black and Northeast Rivers are included in the tables and figures. In the Black River, the lower station, B9000000, is approximately six miles from the Cape Fear River confluence, above the Lion Thorofare, while the upper station, B9130000, is several miles upriver, closer to Colly Creek (*Figure 9-121*). In the Northeast Cape Fear River, the lower station, B9740000, is located 0.8 miles from the Cape Fear River confluence, and the upper station, B9670000, is 5.25 miles further upriver, above Highway 17 (*Figure 9-121*).



The five-year statistics indicate turbidity was relatively low in comparison with the upper Cape Fear River subbasins, ranging from 6.39 to 28.41 NTU, with most five-year station exceedances under 10% in the mainstem. The highest turbidity levels occurred in the upper two mainstem stations. Tributary turbidity ranged from 3.82 to 9.56 NTU, with the highest levels in Brown Creek (*Table 9-21*).

The five-year mean pH ranged from 6.5 to 7.9 s.u. and DO ranged from 6.33 to 8.07 mg/L in the mainstem. The most exceedances for DO and pH on the mainstem occurred in the upper estuary stations (also see Section 9.11). In the tributaries, pH ranged from 4.1 to 7.0 s.u. and DO ranged from 5.62 to 8.65 mg/L. The Brunswick River, also located in the upper estuary, had over 25% exceedance for DO and pH. Basinwide, these upper estuary stations had the most exceedances for DO. Two of the upper tributaries, Turnbull and Harrison creeks, that lack the swamp waters (Sw) supplemental classification, had 100% exceedance of the 6.0 pH standard due to acidic conditions (*Table 9-21*). For information on the DO and pH impaired section of the Cape Fear River Estuary, see details in section 9.11 below.

Figure 9-118: Lower CPF River Mainstem & Tributary Ambient Stations used in 2016-2020 Water Quality Analysis

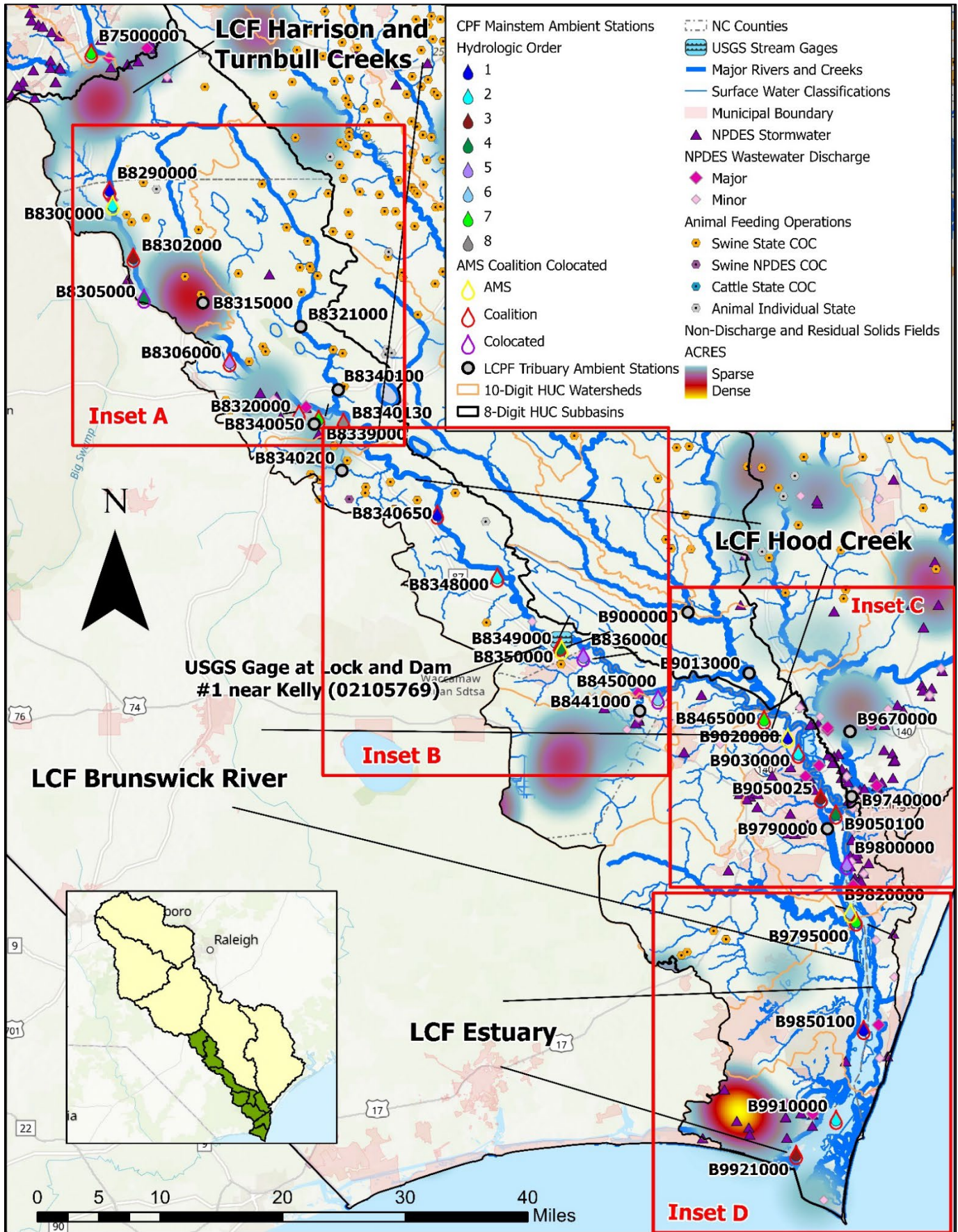


Figure 9-119: Lower CPF River Mainstem & Tributary Ambient Stations used in 2016-2020 Water Quality Analysis - Inset A

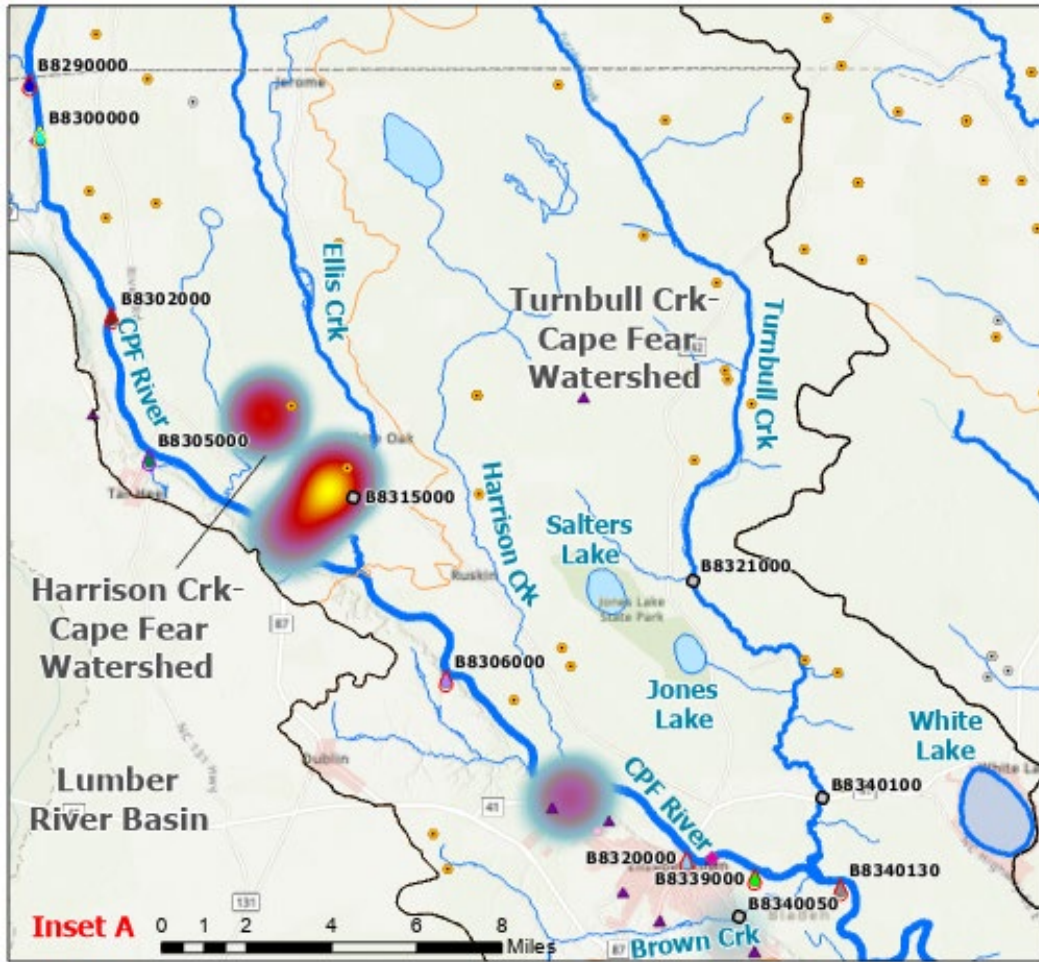


Figure 9-120: Lower CPF River Mainstem & Tributary Ambient Stations used in 2016-2020 Water Quality Analysis - Inset B

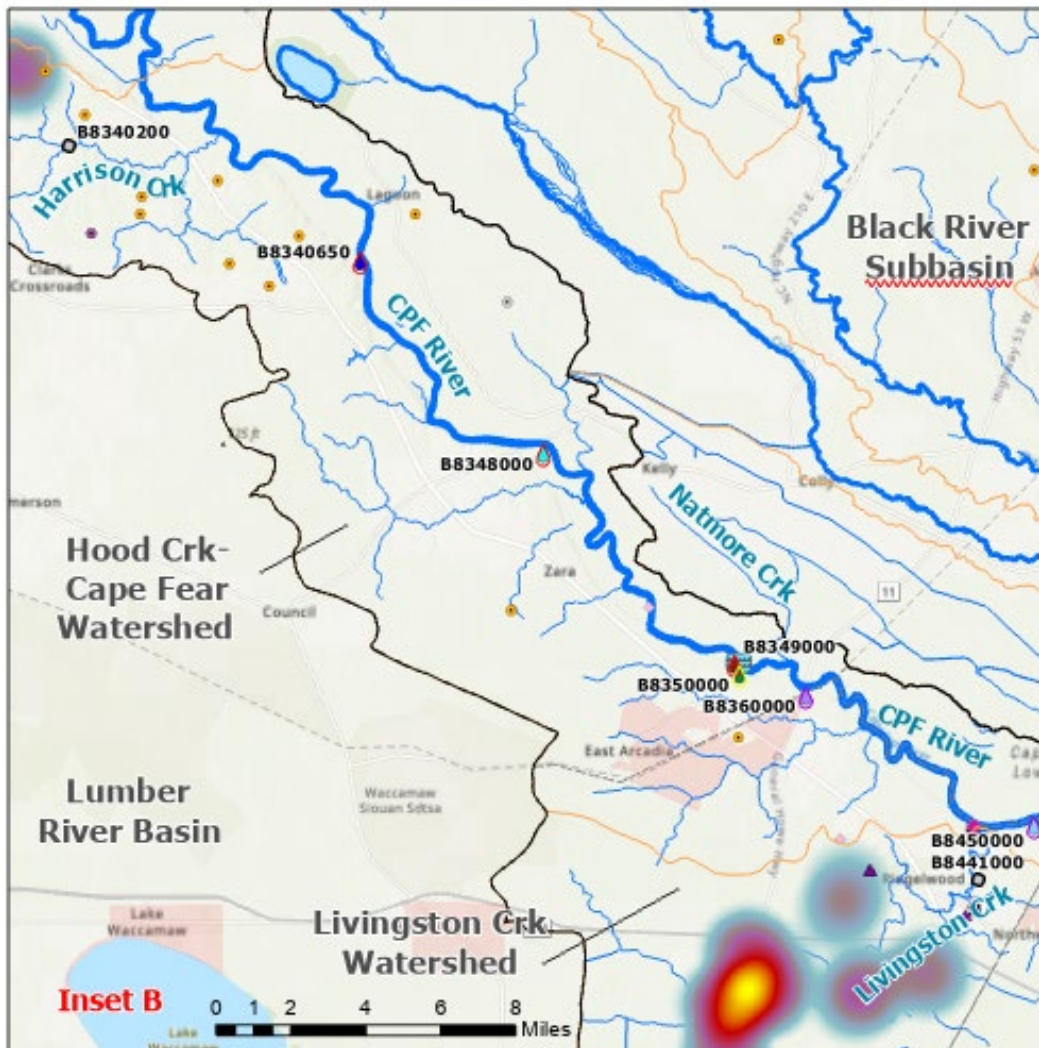


Figure 9-121: Lower CPF River Mainstem & Tributary Ambient Stations used in 2016-2020 Water Quality Analysis - Inset C

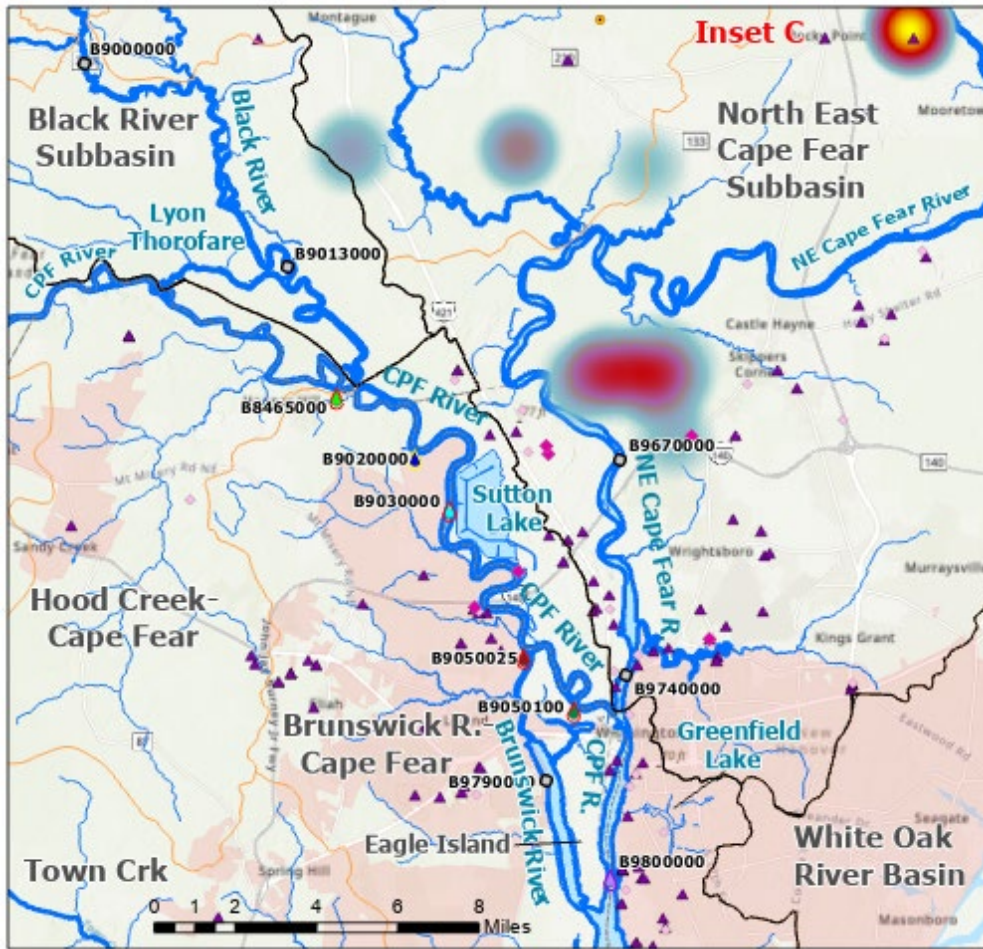


Figure 9-122: Lower CPF River Mainstem & Tributary Ambient Stations used in 2016-2020 Water Quality Analysis - Inset D

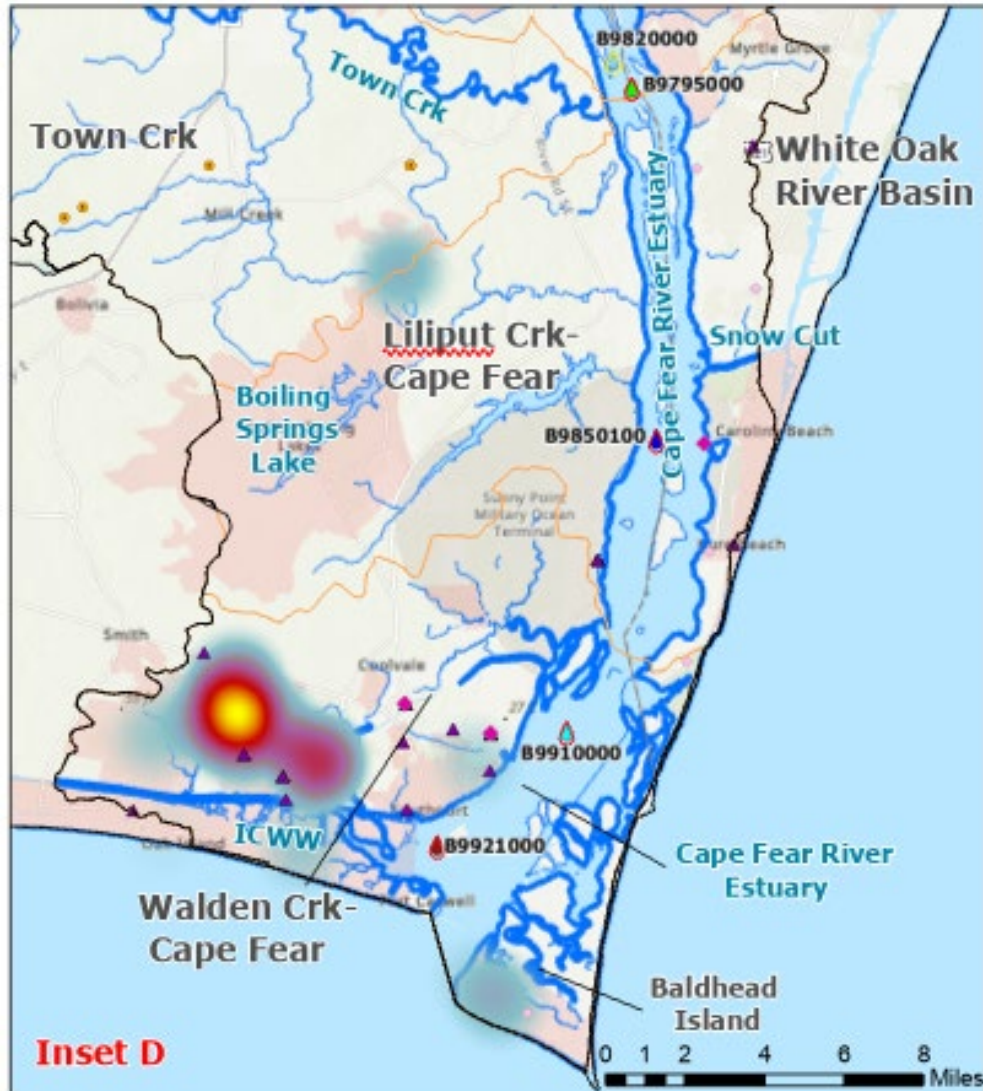


Table 9-21: Lower CPF River Mainstem & Tributaries 5-Year 2016-2020 Means and % Exceedance - Turbidity, pH, DO, FCB, Specific Conductivity

CPF Segment	Cape Fear Mainstem and Tributary Stations		Class	Turbidity NTU		pH s.u.		DO mg/L		FCB Colonies/100mL		Specific Cond. X μS/cm	
				X	% Exceed <sup>1</sup>	X	% Exceed <sup>2</sup>	X	% Exceed <sup>3</sup>	X	% Exceed <sup>4</sup>		
Harrison and Turnbull Creeks-Cape Fear	1	B8290000	C	20.86	7%	6.8	0%	7.61	0%	375	19%	106.31	
	Chemours												
	Lock & Dam #3												
	2	B8300000	C	28.41	15%	6.7	2%	8.07	0%			106.38	
	3	B8302000	C	17.53	7%	6.7	0%	7.58	0%	266	11%	108.11	
	Smithfield Tarheel Plant (3 MGD)												
	4	B8305000	C	16.68	4%	6.7	0%	7.53	0%	238	11%	112.44	
	Harrison Crk												
	5	B8306000	C	16.53	2%	6.7	0%	7.42	0%	224	11%	109.19	
	6	B8320000	C	16.21	4%	6.6	0%	7.31	0%	226	11%	108.80	
	7	B8339000	C	17.14	2%	6.6	0%	7.36	0%	188	9%	108.78	
	Elizabethtown WWTP (1.225 MGD)												
	Lock & Dam #2												
	Brown Crk												
	B8340050	C	9.56	2%	6.6	5%	8.65	0%	1,770	44%	118.93		
Turnbull Crk													
	B8321000	C	4.16	0%	4.1	100%	6.51	11%	179	12%	61.62		
Turnbull Crk													
	B8340100	C	3.42	0%	4.2	100%	7.18	0%	88	5%	52.95		
	B8340130	C	18.19	5%	6.6	0%	7.40	0%	160	9%	109.95		
Hood Creek-Cape Fear	Hammond Crk												
		B8340200	C	8.98	0%	6.8	0%	8.06	0%	3,712	39%	162.21	
	1	B8340650	C,WS-V	16.97	5%	6.6	2%	7.07	0%	93	5%	107.39	
	2	B8348000	C,WS-IV	14.46	3%	6.6	2%	7.11	0%	98	9%	106.75	
	3	B8349000	C, WS-IV, CA	16.04	4%	6.6	2%	7.04	0%	98	7%	106.15	
	Lock & Dam #1												
	4	B8350000	C, Sw, WS-IV	16.08	2%	6.5	0%	7.68		147	7%	104.19	
	Natmore Crk												
	5	B8360000	C, Sw, WS-IV	16.91	2%	6.5	0%	7.61		79	2%	108.72	
	Riegelwood Mill Facility (50 MGD)												
Livingston Crk*													
	B8441000	C, Sw	4.70	0%	6.4	0%	5.49		192	7%	137.22		
6	B8450000	C, Sw	15.44	3%	6.7	0%	7.70		411	6%	136.98		
Hood Crk													
	B8465000	C, Sw			6.6	0%	6.85		285	5%	140.48		
Brunswick River-Cape Fear River	Black River												
		B9000000	C, Sw			6.0	0%	6.64		183	12%	93.75	
	Black River												
		B9013000	C, Sw	4.79	0%	6.2	0%	5.88		61	0%	89.89	
	1	B9020000	C, Sw	10.48	0%	6.6	0%	7.53		83	2%	119.81	
	2	B9030000	C, Sw			6.5	0%	6.41		153	5%	201.32	
	Sutton Steam Electric Plant												
	NE Brunswick Regional WWTP (2.475 MGD)												
	3	B9050025	SC	12.32	4%	6.8	57%	6.34	40%	935			
	Brunswick River split at Eagle Island												
	4	B9050100	SC			6.8	43%	6.33	39%	442			
	NECPF River												
		B9670000	C, Sw			6.4	0%	5.62		174	7%	2,929.18	
NECPF River													
	B9740000	SC, Sw	8.85	0%	6.7	0%	6.73		70				
5	B9800000	SC	8.64	1%	6.9	27%	6.48	37%	64				
Brunswick Riv.													
	B9790000	SC			7.0	26%	6.81	28%					
Brunswick River remerges south of Eagle Island													
Wilmington Southside WWTP (12 MGD)													
6	B9820000	SC	9.21	5%	6.9	35%	7.41	24%	53				
7	B9795000	SC			7.2	13%	6.57	27%					
Lower Estuary	Town Creek												
	1	B9850100	SC			7.6	7%	7.12	9%				
	Carolina Beach WWTP (3 MGD)												
	2	B9910000	SC			7.8	0%	7.30	3%	30			
Archer Daniels Midland Company Southport													
3	B9921000	SC	6.39	2%	7.9	0%	7.25	1%	34				

<sup>1</sup>Turbidity standard is ≤50NTUs for freshwater (C) and ≤25NTUs for saltwater (SC). <sup>2</sup>pH standard is 6-9 for freshwater (C), ≥4.3 for Swamp Water (Sw), 6.8-8.5 for saltwater (SC). <sup>3</sup>DO standard is ≥4 for freshwater (C), no standard for Swamp Water (Sw), ≥5 for saltwater (SC). <sup>4</sup>Fecal coliform standard is ≤400 colonies/100mL for freshwater (C), no standard saltwater (SC).

\*Livingston Creek water quality data, station B8441000, was collected from 2011-2015

Fecal coliform bacteria (FCB) were collected throughout the subbasin, but standards only apply to freshwater. None of the assessed waterbodies are classified B for primary recreation so were not prioritized for 5-in-30 tests needed to label a waterbody impaired. FCB was highly variable, ranging from 53 to 935 colonies/100 mL along the mainstem and 88 to 3,712 colonies/100 mL in the tributaries. The uppermost freshwater mainstem station (B8290000) had the highest exceedance rate of 19%, and the uppermost estuary mainstem station had the highest mean levels at 935 colonies/100 mL. Tributary fecal coliform levels and exceedances were highest overall in Hood and Brown creeks (*Table 9-21*).

Specific conductivity five-year means were analyzed only for freshwater stations along the mainstem and the tributaries. Mainstem stations ranged from 104.2 to 201.3  $\mu\text{S}/\text{cm}$  with the highest levels occurring at the most downstream freshwater classified station, B9030000, which does receive some saltwater influence at times throughout the year. Specific conductivity ranged from 52.95 to 2,929.18  $\mu\text{S}/\text{cm}$  in the tributaries with the highest levels occurring at the upper Northeast Cape Fear station, which also receives some saltwater influence (*Table 9-21*).

The 2016 to 2020 nutrient concentrations along the Cape Fear River mainstem ranged from 0.51 to 0.94 mg/L for TKN, 0.09 to 0.82 mg/L for NO<sub>x</sub>, 0.61 to 1.67 mg/L for TN, 0.03 to 0.10 mg/L for ammonia (NH<sub>4</sub>), and 0.09 to 0.22 mg/L for TP (*Table 9-22*). The nutrient concentrations during the same period for the Cape Fear tributaries ranged from 0.62 to 1.13 mg/L for TKN, 0.06 to 0.52 mg/L for NO<sub>x</sub>, 0.84 to 1.26 mg/L for TN, 0.04 to 0.10 mg/L for ammonia, and 0.04 to 0.18 mg/L for TP (*Table 9-22*). DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) recommended <0.5 mg/L for TKN, <0.05 mg/L for ammonia, <0.3 mg/L for NO<sub>x</sub>, <0.8 mg/L for TN, and <0.05 mg/L for TP. The EPA nutrient criteria study for Coastal Plain streams recommended <0.72 mg/L for TN and 0.032 mg/L for TP (*Table 9-13*).

Five-year mean nutrient data indicates TKN, NO<sub>x</sub>, and TN generally decreased from upriver to downriver stations along the mainstem while ammonia and TP both increased (*Figure 9-123*). All the mainstem TKN mean five-year concentrations were over the <0.5 mg/L recommendation, with higher levels occurring above Lock & Dam #1 in the Harrison & Turnbull creeks and Hood Creek segments (*Figure 9-123*). The uppermost tributary, Harrison Creek, also had the most concentrated TKN levels at 1.13 mg/L (*Table 9-22*). Relatively higher NO<sub>x</sub> and TN concentrations also occurred in the upper two mainstem segments with only the lowest four saltwater stations meeting the <0.3 mg/L NO<sub>x</sub> recommendation. The lowest two saltwater stations met the <0.8 mg/L TN recommendation (*Table 9-22*). The tributaries were closer to or below the <0.3 mg/L NO<sub>x</sub> recommendation, with Brown Creek, located south of Elizabethtown, being the highest at 0.52 mg/L. All tributaries were over the TN <0.8 mg/L recommendation, with the upper tributaries, Brown and Harrison creeks, having the highest mean levels. However, the major large and lower tributaries, the Black, Northeast Cape Fear, and Brunswick rivers, had TN levels comparable to the mainstem stations above and below their confluences whereas the upper tributaries, Harrison and Brown creeks, had approximately 30% less TN than the mainstem stations above and below their confluences. The ratio of organic (TKN minus ammonia) to inorganic nitrogen in the mainstem, TKN:NO<sub>x</sub>, generally increased from upriver to downriver stations, although the overall concentrations of TN, TKN, and NO<sub>x</sub> declined (*Figure 9-124*). The TKN:NO<sub>x</sub> station ratios were highest in the Lower Estuary (*Figure 9-124*).

Ten of the upper mainstem stations met the <0.05 mg/L recommendation for ammonia. Ammonia levels were generally more concentrated in the lower half, below Lock & Dam #1 and Natmore Creek, with the highest levels at 0.10 mg/L occurring at station B8450000, below the Riegelwood Mill Facility and Livingston Creek (*Table 9-22* and *Figure 9-123*). The 2011 to 2016 data showed there were elevated levels of ammonia in the Livingston Creek watershed at station B8441000 (0.18 mg/L) and at station B8450000 (0.10 mg/L), suggesting the Livingston Creek watershed is likely still the main contributor in 2016 to 2020 of ammonia at station B8450000.

All the mainstem TP concentrations were also over the <0.05 mg/L recommendation with some as much as two to three, and even four times higher (B9050025 and B9800000). There is a notable rise along the mainstem at station B8360000, below Natmore Creek (*Table 9-22* and *Figure 9-123*). TP concentrations in the upper Northeast Cape Fear River at station B9670000 were the most concentrated (0.18 mg/L). Water quality data indicates some of the tributaries had relatively lower TP levels than mainstem stations near their confluences (Harrison and Turnbull creeks), while other tributaries were more comparable or higher than mainstem stations near their confluences, e.g., Brown and Hammond creeks, Black and Brunswick rivers (*Table 9-22*).

When environmental conditions are optimal, the elevated nutrients in the Cape Fear River system can result in algal bloom development. HABs have been identified in the Cape Fear River since 2009. NC DHHS routinely warns the public to avoid contact with large accumulations of algae and to prevent children and pets from swimming or ingesting water in areas of algal blooms. Chlorophyll a and algal bloom results for the mainstem Cape Fear River are discussed in detail below (section 9.10.4). Because of the ongoing nutrient enrichment issue leading to algal bloom development, a large portion of the Cape Fear River Basin was chosen for the development of instream nutrient criteria development as part of the EPA-approved Nutrient Criteria Development Plan (NCDP) (detail in section 2.14 of Chapter 2).

Table 9-22: Lower CPF River Mainstem & Tributaries 5-Year Means 2016-2020 - TKN, NOx, TN, Ammonia (NH4), TP and TKN:NOx Ratios

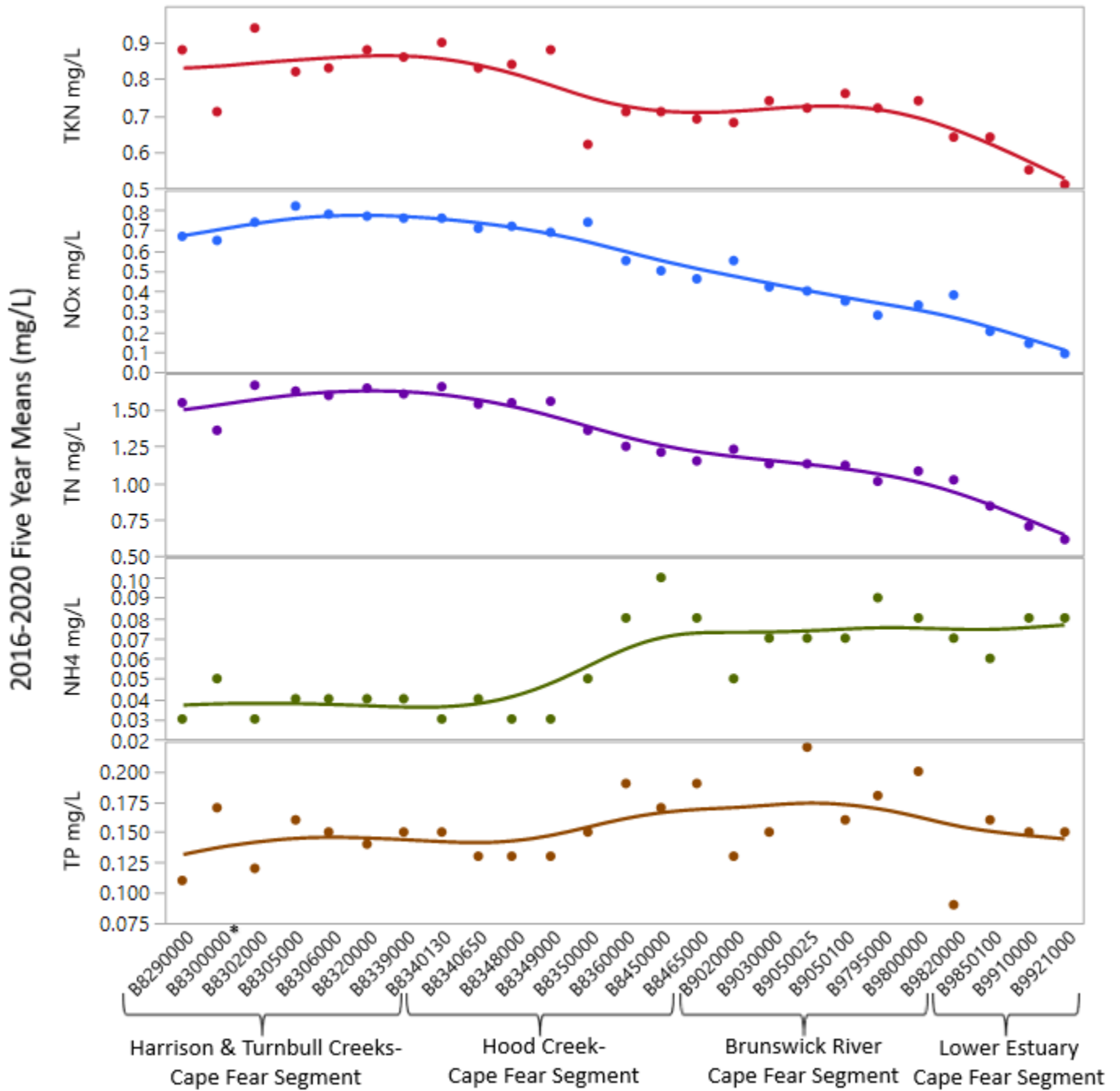
CPF Segment	Cape Fear Mainstem and Tributary Stations	Class	TKN <sup>1</sup> mg/L	NOx <sup>2</sup> mg/L	TN <sup>3</sup> mg/L	NH4 <sup>4</sup> mg/L	TP <sup>5</sup> mg/L	TKN:NOx Ratio	
Harrison and Turnbull Creeks-Cape Fear	1 B8290000	C	0.88	0.67	1.55	0.03	0.11	1.3:1	
	Chemours								
	Lock & Dam #3								
	2^ B8300000	C	0.71	0.65	1.36	0.05	0.17	1.1:1	
	3 B8302000	C	0.94	0.74	1.67	0.03	0.12	1.3:1	
	Smithfield Tarheel Plant (3 MGD)								
	4 B8305000	C	0.82	0.82	1.63	0.04	0.16	1.0:1	
	Harrison Crk B8315000	C	1.13	0.12	1.26	0.05	0.08	9.4:1	
	5 B8306000	C	0.83	0.78	1.60	0.04	0.15	1.1:1	
	6 B8320000	C	0.88	0.77	1.65	0.04	0.14	1.1:1	
	7 B8339000	C	0.86	0.76	1.61	0.04	0.15	1.1:1	
	Elizabethtown WWTP (1.225 MGD)								
	Lock & Dam #2								
Brown Crk B8340050	C	0.73	0.52	1.25	0.10	0.12	1.4:1		
Turnbull Crk B8340100	C	0.88	0.06	0.94	0.07	0.07	15.3:1		
8 B8340130	C	0.90	0.76	1.66	0.03	0.15	1.2:1		
Hood Creek-Cape Fear	Hammond Crk B8340200	C	0.74	0.37	1.11	0.08	0.17	2.0:1	
	1 B8340650	C, WS-V	0.83	0.71	1.54	0.04	0.13	1.2:1	
	2 B8348000	C, WS-IV	0.84	0.72	1.55	0.03	0.13	1.2:1	
	3 B8349000	C, WS-IV, CA	0.88	0.69	1.56	0.03	0.13	1.3:1	
	Lock & Dam #1								
	4 B8350000	C, Sw, WS-IV	0.62	0.74	1.36	0.05	0.15	0.8:1	
	Natmore Crk								
	5 B8360000	C, Sw, WS-IV	0.71	0.55	1.25	0.08	0.19	1.3:1	
	Riegelwood Mill Facility (50 MGD)								
	Livingston Crk* B8441000	C, Sw	0.62	0.22	0.84	0.18	0.04	2.9:1	
	6 B8450000	C, Sw	0.71	0.50	1.21	0.10	0.17	1.4:1	
Hood Crk									
7 B8465000	C, Sw	0.69	0.46	1.15	0.08	0.19	1.5:1		
Brunswick River-Cape Fear	Black River B9000000	C, Sw	0.80	0.31	1.10	0.05	0.14	2.6:1	
	Black River B9013000	C, Sw	0.76	0.35	1.11	0.04	0.10	2.2:1	
	1 B9020000	C, Sw	0.68	0.55	1.23	0.05	0.13	1.2:1	
	2 B9030000	C, Sw	0.74	0.42	1.13	0.07	0.15	1.8:1	
	Sutton Steam Electric Plant								
	NE Brunswick Regional WWTP (2.475 MGD)								
	3 B9050025	SC	0.72	0.40	1.13	0.07	0.22	1.8:1	
	Brunswick River split at Eagle Island								
	4 B9050100	SC	0.76	0.35	1.12	0.07	0.16	2.2:1	
	NECPF River B9670000	C, Sw	0.86	0.23	1.09	0.06	0.18	3.7:1	
	NECPF River B9740000	SC, Sw	0.74	0.37	1.11	0.07	0.11	2.0:1	
	5 B9800000	SC	0.74	0.33	1.08	0.08	0.20	2.2:1	
	Brunswick Riv. B9790000	SC	0.70	0.35	1.05	0.07	0.17	2.0:1	
	Brunswick River remerges south of Eagle Island								
Wilmington Southside WWTP (12 MGD)									
6 B9820000	SC	0.64	0.38	1.02	0.07	0.09	1.7:1		
7 B9795000	SC	0.72	0.28	1.01	0.09	0.18	2.6:1		
Lower Estuary	Town Creek								
	1 B9850100	SC	0.64	0.20	0.84	0.06	0.16	3.1:1	
	Carolina Beach WWTP (3 MGD)								
	2 B9910000	SC	0.55	0.14	0.70	0.08	0.15	4.0:1	
Archer Daniels Midland Company Southport									
3 B9921000	SC	0.51	0.09	0.61	0.08	0.15	5.4:1		

NC DWR's ESS-ISU special study findings for minimally impacted Coastal Plain streams recommends <sup>1</sup> <0.5 mg/L for TKN, <sup>2</sup> <0.3 mg/L for NOx, <sup>3</sup> <0.8 mg/L for TN, <sup>4</sup> <0.05 mg/L for ammonia (NH4), and <sup>5</sup> <0.05 mg/L for TP.

^Station B8300000 only has two years of nutrient data, 2019 and 2020.

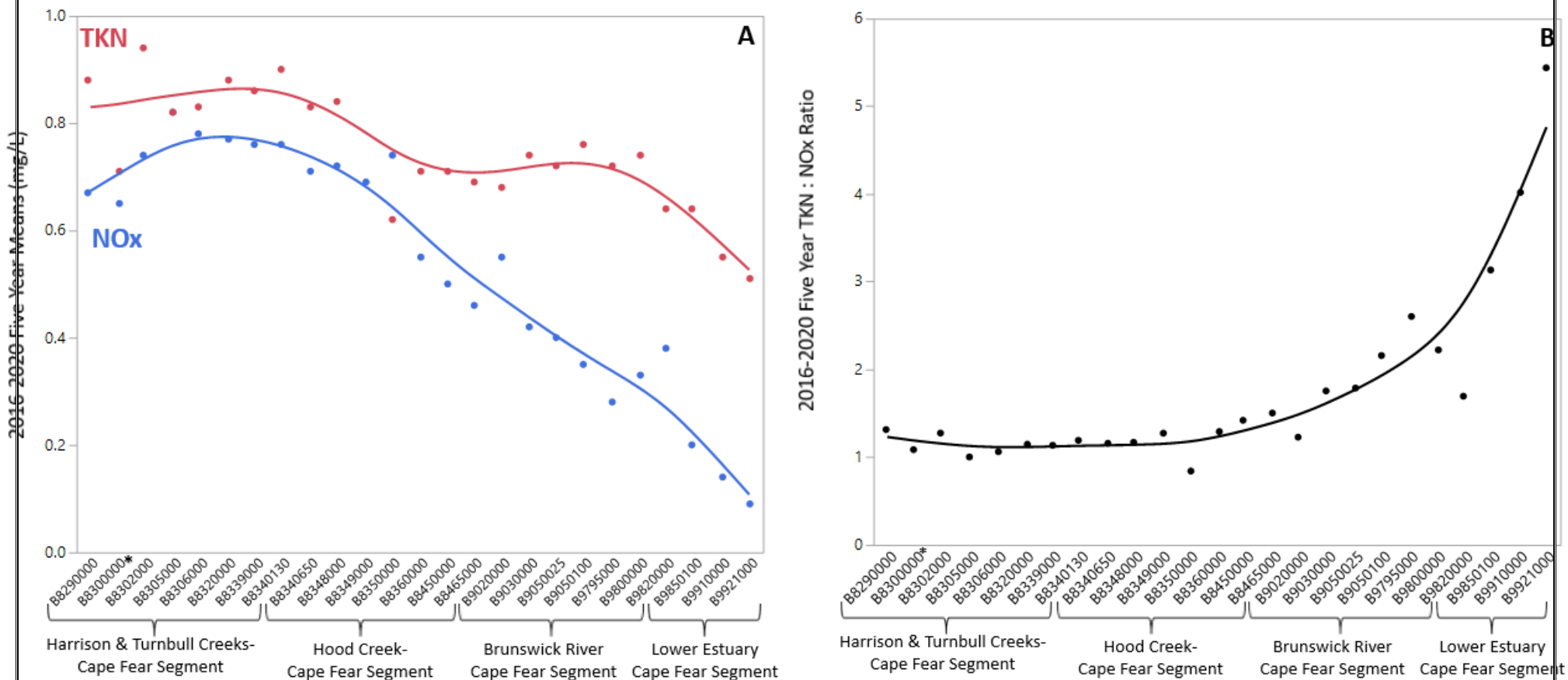
\*Livingston Creek water quality data, station B8441000, was collected from 2011-2015

Figure 9-123: Lower CPF River Mainstem 2016-2020 Five-Year Means TKN, NOx, TN, Ammonia (NH4), and TP



\*Station B8300000 has only two years of data, 2019 – 2020.

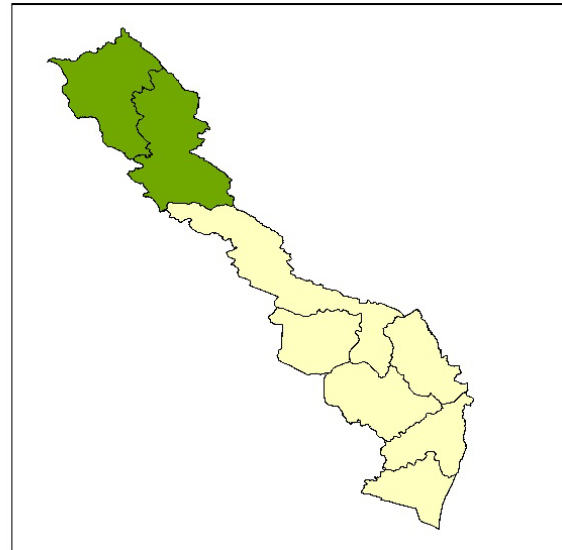
Figure 9-124: Cape Fear River Mainstem Station 2016-2020 Means for TKN and NOx (A) and TKN:NOx Ratio (B)



\*Station B8300000 has only two years of data, 2019 – 2020.

### 1.10.1 Harrison Creek-Cape Fear Watershed and Turnbull Creek-Cape Fear Watershed Summaries

The Harrison Creek-Cape Fear River and Turnbull Creek-Cape Fear River watersheds encompass 356 mi<sup>2</sup> in the upper third of the Lower Cape Fear subbasin. Monitored rivers and creeks are C-classified waters, and Jones, Salters, and White lakes are B classified for primary recreation. All **freshwater C** and B-classified surface water have the same water quality standards for turbidity, pH, DO, and fecal coliform (see diagram to right). Surface water quality in these two watersheds is influenced by point and nonpoint sources of pollution and natural landscape features. Point source examples include permitted industrial and municipal NPDES dischargers and permitted stormwater facilities. Nonpoint source examples include runoff from NPDES residual solids land application fields, permitted AFOs (primarily swine), non-permitted poultry operations (see Section 9.2), and land-use activities like agriculture and forestry operations. Agriculture is prevalent in this part of the subbasin with these two watersheds accounting for 55% of the permitted live weight and half the lagoons in the Lower Cape Fear River subbasin. There is a concentration of residual solids land application fields along Grays Creek and the lower end of Harrison Creek near the Cape Fear River confluence permitted by the Fayetteville Public Works Commission (WQ0000527) and Smithfield Fresh Meats Corps (WQ0014868). The Smithfield Fresh Meats Corps also owns the NPDES Smithfield Tarheel Plant wastewater facility (NC0078344) with a permitted 3 MGD as-built discharge to the Cape Fear River (see Section 9.9.1). Upstream flows into the Lower Cape Fear and the collective contribution of pollutant sources from the upper part of the basin has a direct effect on water quality conditions in this portion of the mainstem. Changes in land use and land cover over time and natural conditions of the landscape including wetland coverage also affect water quality.



**Harrison Creek and Turnbull Creek Cape Fear Mainstem and Tributary Stations**

Station #	Station ID	Location / Source	Classification	Cape Fear River Mainstem (35.1 FW Miles)	
				Distance (miles)	Flow (MGD)
1	B8290000	Chemours	18-(26.25)b		
		Lock & Dam #3			
2	B8300000		18-(26.25)c		
3	B8302000	Smithfield Tarheel Plant (3 MGD)	18-(26.25)c		
4	B8305000	Harrison Creek B8305000	18-(26.75)a		
5	B8306000		18-(26.75)a		
6	B8320000	Elizabethtown WWTP (1.225 MGD)	18-(26.75)a		
7	B8339000	Lock & Dam #2	18-(26.75)b		
		Turnbull Creek B8321000, B8340100			
		Brown Creek B8340050			
8	B8340130		18-(26.75)c		

Freshwater C standards are ≤50 NTU turbidity, 6-8 S.U. pH, ≥4 mg/L DO, <200 colonies/100 mL geometric mean, or <400 colonies/100 mL fecal coliform in 20% of the samples where five samples have been taken in 30 days (5-in-30).

The major issues of concern in this section of the subbasin include the 2017 discovery of PFAS, including GenX, a Contaminant of Emerging Concern (CEC) in the Cape Fear River--a water supply source, the declining water quality and eutrophication of the once crystal-clear White Lake, and nutrient enrichment that has led to HAB in the mainstem Cape Fear River (see sections 9.9.2.1 and 9.10.4).

### **Chemours and PFAS**

In 2017, GenX discovered in the Cape Fear River was traced to the Chemours Fayetteville Works facility, formerly owned by DuPont, which had been discharging directly to the Cape Fear River in the Harrison Creek watershed for over 30 years. PFAS from the facility entered the environment through four sources: an old outfall channel, four seeps, groundwater, and through air emissions from the facility. Since 2017, Chemours has been prohibited from discharging process wastewater to the river. Chemours was required to address PFAS sources and contamination from the facility through legal actions (the February 2019 [Consent Order](#) and August 2020 [Addendum to the Consent Order](#)). Contaminated groundwater, the largest reoccurring source of PFAS from the Chemours site due to the residual effect of decades of manufacturing, flowed into the Cape Fear River along the facility's riverbanks. The installation of an barrier wall and extraction and treatment system was completed on June 11, 2023 to intercept and treat groundwater before it enters the river. The Chemours remediation NPDES permit (NC0090042) requires:

- Treatment to remove more than 99% of the PFAS compounds collected from the groundwater extraction wells and four main seeps near the riverbanks.
- Technology limits requiring maximum treatment removal beyond 99%
- Comprehensive stream sampling to assess loadings of PFAS in the river as the wall is being installed and after completion.

### **PFOS (Perfluorooctane sulfonic acid) Fish Tissue Advisory**

A new NC Department of Health and Human Services [fish consumption advisory for PFOS](#) in the Cape Fear River Basin was issued July 13, 2023, for the middle and lower Cape Fear River from the Fayetteville Boat Ramp, near the I-95 overpass in the Upper Cape Fear River subbasin to the bluffs on the Cape Fear River near the I-140 overpass in the Brunswick River watershed. PFOS is a type of PFAS (per- and polyfluoroalkyl substances) that is considered a "legacy" PFAS due to its decades of widespread use. Fish tissue samples were collected from the Fayetteville boat ramp to the Atlantic Ocean during the summer of 2022. The analysis of 56 types of PFAS, found PFOS levels were most concerning in eight species of freshwater fish. PFOS levels were consistently elevated between sample locations and fish species was the only significant variable (NCDEQ 2023). This most recent fish tissue advisory will result in most of the Lower Cape Fear River being listed as impaired on the 2026 IR. For more details on the fish consumption advisory see section 9.6.1.

### **White Lake Eutrophication and Fish Kill**

White Lake is an important natural and economic resource to the community of White Lake in the Turnbull Creek watershed, however, the decline in water quality has threatened this unique aquatic ecosystem in recent years. During the timespan of this basin plan, White Lake has been the only lake in the basin to change from oligotrophic in 2008, to mesotrophic in 2013, then to eutrophic in 2018 (NC DWR 2009; NC DWR 2014; NC DWR 2018). The first known blue-green algal blooms have been observed at White Lake and are associated with a significant increase in nutrients--mostly organic nitrogen and TP, an increase in

pH levels, and increased biological productivity, as identified by higher chlorophyll *a* levels. To understand these drastic changes, DWR completed a [special study](#) from 2015 to 2017 that concluded shallow groundwater and nonpoint source nutrients are elevated and the volume of artesian spring input to the lake may be decreasing. Nearby groundwater and surface runoff have shown elevated nutrient concentrations (especially ammonium), potentially from failing/leaky local collection system infrastructure in the densely-developed area immediately surrounding the lake. In 2018, the Town of White Lake applied alum during an algal bloom that was soon followed by a mass fish kill of 40% to 50% of the total fish biomass in the lake. The timing of this unprecedented fish kill was attributed to a combination of the alum treatment and stress of the algal bloom. The town has been working to address White Lake's water quality issues through the establishment of the [White Lake Watch website](#) and the addition of a lake stewardship position in local government. To improve water quality in the lake, it is important for the town to repair its collection system leakage issue and for residents to develop a watershed action plan to reduce nutrients from all sources, including stormwater and lawn fertilizers.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

### **DO and pH**

Ambient, lake, and biological monitoring found that Jones and Salters Bay lakes and several of the tributaries--Harrison, Ellis, and Turnbull creeks--have very acidic conditions and low DO although none are classified as swamp waters (Sw). During the last five years (2016-2020) the Harrison Creek and Turnbull Creek stations yearly means had 100% exceedance below the pH standard of 6.0. The upper Turnbull Creek station (B8321000) also had an 11% exceedance of the 4.0 mg/L DO standard during the same period. Biology monitoring at these tributaries, plus Ellis Creek, noted low pH as well. These waterbodies are all located on the east side of the Cape Fear River where there is a dense concentration of Carolina bay wetlands and swamp forests that fringe Jones and Salters lakes and the creeks and streams. A natural conditions assessment for these waterbodies is recommended to verify the cause of the acidic conditions. Yearly mean pH levels along the mainstem decline from upstream to downstream as these naturally acidic tributaries and other nearby wetlands drain to the mainstem. Overall, pH levels were less acidic with fewer exceedances below the 6.0 standard in the mainstem and Brown Creek, a tributary that drains from the west side of the Cape Fear River. The mainstem had almost no pH exceedances in recent years, however, there were more before 2011, indicating a change in the watershed. Also, Mann-Kendall screening trend tests found a significant decrease in pH during the 2000 to 2019 timeframe at six mainstem stations, although from 2010 to 2019 there was no significant change at any station. DO levels have been a problem during some years in Turnbull Creek, with exceedances ranging from 8% to 30% below the 4mg/L standard, likely due to the presence of wetlands in the watershed. DO has not been concerning in the other tributaries or the mainstem in this section of the subbasin.

### **Fecal Coliform**

Brown Creek, which runs along the south side of Elizabethtown, the most urban community in this upper portion of the subbasin, has had significant issues with fecal coliform. Brown Creek station B8340050 had

a 1,770 colonies/100 mL mean and 44% exceedance of the 400 colonies/100 mL standard over the 2016 to 2020 period. However, Brown Creek, which is a class C waterbody, has not been listed as impaired because a 5-in-30 test is required for impairment, and class B waters are prioritized. The concentration of residual solids application fields upstream of this station is a potential source of fecal coliform. Other possible sources include the several AFOs in the watershed, urban stormwater runoff, or failing sewer pipes and septic tanks. Overall, fecal coliform levels in the mainstem and other tributaries in this section of the Lower Cape Fear are less concerning and are mostly meeting their designated uses. Water quality data suggests fecal coliform in the mainstem is highly influenced by upriver stormwater-driven sources from the Upper Cape Fear subbasin. Some years a small rise in fecal coliform at the mainstem station (B8340130), below Brown Creek, was also observed.

### **Turbidity**

Turbidity is very low in the tributaries and relatively low in the mainstem with yearly exceedances rarely over 10% of the samples above the 50 NTU standard. Turbidity levels in the mainstem were affected by discharge with higher levels occurring during wetter years, indicating stormwater sources drive turbidity. The relatively higher levels at the uppermost station (B8290000) for several years showed turbidity was influenced by the upper part of the basin. Mann-Kendall screening trend tests found this was the only station in the subbasin to have significantly increasing turbidity levels from 2010 to 2019. Higher levels and exceedances at the two stations directly below Chemours (B8300000 and B8302000) may have been related to activities at the facility. In 2012, a new outfall was installed, and ownership changed, and in 2020, mitigation-related construction for PFAS removal was implemented.

### **Nutrients**

Yearly water quality and flow data indicate nutrients in the Harrison Creek-Cape Fear and Turnbull Creek-Cape Fear watersheds have different drivers that caused TKN to increase while other nutrients decreased or remained more consistent. TKN levels appear driven by mostly nonpoint source stormwater while NO<sub>x</sub> and TP levels are affected more by point sources. TN was variable with nonpoint sources influencing wet years, driving the organic fraction up (TKN minus ammonia) and point sources influencing dry years, driving the NO<sub>x</sub> inorganic fraction higher. Ammonia was also variable but did not appear to correlate with flow. Specific conductivity, often associated with point source and pollutant contribution levels, was also negatively correlated with flow, indicating a point source influence. Graphical data indicates yearly mean NO<sub>x</sub> and TP water quality data were similar both in terms of their relation to flow and their spatial and temporal properties (i.e., which mainstem station and what year the mean concentrations became elevated). In some years, NO<sub>x</sub> and TP yearly means increased downstream of the Chemours facility at station B8302000 while in other years these means were more concentrated below the Smithfield Tarheel Plant at station B8305000. Nutrients were not collected at station B8300000, just below Chemours, most years.

A comparison to DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams ([Table 9-13](#)) found most mainstem station yearly means were over the <0.5 mg/L TKN, <0.3 mg/L NO<sub>x</sub>, <0.8 mg/L TN, and <0.05 mg/L TP recommendations while about half the yearly ammonia means were over the <0.05 mg/L ammonia recommendation. TP was particularly concerning as almost all yearly mean concentrations were at least twice the recommendation and more than half were three times as high or greater. Also

concerning was TKN, which Mann-Kendall screening tests showed six of the seven analyzed mainstem stations significantly increased during one or both periods tested, 2000 to 2019 and 2010 to 2019 (*Table 9-16*). All other nutrient mainstem stations significantly decreased during these periods or had no significant change (*Table 9-16*). In recent years, the three tributaries had comparable or even higher mean concentrations of TKN than the mainstem. Mann-Kendall screening tests and/or graphical patterns also indicate TKN levels are increasing in the Harrison, Turnbull, and Brown creek tributaries, with concentrations most elevated in Harrison Creek.

### **Biology Assessments**

In this upper section of the Lower Cape Fear subbasin, biology assessments for the 2022 IR were completed at six stations on four creeks: Harrison, Ellis, Brown, and Turnbull. The most recent 2003 benthos assessments rated Good-Fair at Harrison, Ellis, and Turnbull creeks. Brown Creek benthos assessments rated Moderate in 2003 and 2008 and Natural in 2013 and 2018. Fish community assessments in 2008 on Harrison and Brown creeks were Not Rated.

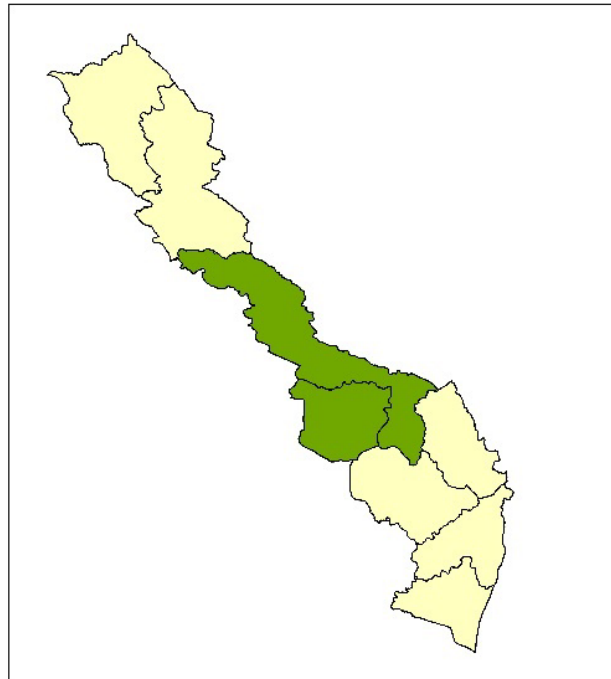
### **Actions and Recommendations**

*Basin planning has several recommendations specific to this section of the Lower Cape Fear subbasin:*

- The Town of White Lake should repair its collection system leakage issue and work with residents to develop a watershed action plan to reduce nutrients from all sources, including stormwater and lawn fertilizers.
- Continue monitoring Brown Creek and, as resources allow, perform a special watershed study to identify the sources of fecal coliform bacteria. Monitoring should include a 5-in-30 assessment to properly evaluate Brown Creek for the Integrated Report.
- A natural conditions assessment should be completed for Jones and Salters lakes and Harrison, Ellis, and Turnbull creeks.
- Currently only one biology station in the Turnbull Creek-Cape Fear River watershed is monitored. When resources allow, DWR should evaluate re-establishing existing stations or adding new stations in both Turnbull Creek-Cape Fear River and Harrison Creek-Cape Fear River watersheds to assess water quality conditions.
- Watershed evaluations should be conducted to determine the source of rising TKN levels.
- NC DEQ will continue to ensure Chemours complies with NPDES permits and state and federal water quality standards as they are developed.
- NC DEQ will continue to work with the Secretaries' Science Advisory Board to understand how to manage emerging compounds to protect public health and the environment.

### 1.10.2 Hood Creek-Cape Fear and Livingston Watershed Summary

The Hood Creek-Cape Fear River and Livingston Creek-Cape Fear River watersheds encompass 316 mi<sup>2</sup> in the middle third of the Lower Cape Fear subbasin. Water quality standards vary in this section of the subbasin for pH and DO. The Swamp Water classified (**Freshwater C, Sw**) stations, below Lock & Dam #1, have a lower pH standard ( $\geq 4.3$ ) and no DO standard, while the upper three stations (**Freshwater C**) have a higher pH (6 to 8) standard and do have a DO standard ( $\geq 4$  mg/L DO) (see diagram to right). Surface water quality in these two watersheds is influenced by many factors. Potential pollutant sources include permitted point source facilities, NPDES discharge and stormwater facilities, nonpoint source runoff from NPDES residual solids land application fields, permitted AFOs (primarily swine), non-permitted poultry operations (see Section 9.2), septic tanks, and land-use activities like agriculture and forestry operations. Changes in land use and land cover over time and natural features of the landscape, like wetland coverage, also affect water quality. Near the Riegelwood Mill Facility and Livingston Creek, there is a large bend in the Cape Fear River where the floodplain widens, and more wetlands have formed. Aerial photography indicates many areas of forested wetland have been cleared in recent years along this section of the river. Livingston Creek is the largest tributary along the Hood Creek-Cape Fear River mainstem section (see diagram above). Water flowing into the Hood Creek-Cape Fear River mainstem from the upper parts of the basin, including the Harrison Creek-Cape Fear and Turnbull Creek-Cape Fear watersheds, directly affects water quality conditions. Identifying sources of pollutants from tributaries along this section of the mainstem is challenging due to limited or lack of data. Hammond Creek (B8340200) was the only tributary with a full set of monitoring data and Livingston Creek was monitored just from 2004 to 2015.



#### Hood Creek-Cape Fear Mainstem Stations

Hood Creek-Cape Fear Mainstem Stations		
Hammond Creek B8340200		
Cape Fear River Mainstem - 50.1 FW Miles	1	B8340650 18-(49)
	2	B8348000 18-(53.5)
	3	B8349000 18-(58.5)
	Lock & Dam #1	
	4	B8350000 18-(59)
	Natmore Creek No station	
	5	B8360000 18-(59)
Riegelwood Mill Facility (50 MGD)		
Livingston Creek B8441000		
6	B8450000 18-(63)a	
Hood Creek No station		
7	B8465000 18-(63)b	

Freshwater C and **Freshwater C, Sw** standards are  $\leq 50$  NTU turbidity,  $< 200$  colonies/100 mL geometric mean, or  $< 400$  colonies/100 mL fecal coliform in 20% of the samples where five samples have been taken in 30 days (5-in-30). **Freshwater C** standards are 6-8 S.U. pH,  $\geq 4$  mg/L DO. **Freshwater C, Sw** standards are  $\geq 4.3$  pH, none for DO.

The Riegelwood Mill Facility (NC0003298), with a permitted as-built flow of 50 MGD, is the second largest NPDES discharger in the basin and accounts for over 60% of the permitted as-built discharge in the Lower Cape Fear River subbasin. There are also six minor NPDES dischargers in this section of the subbasin. AFOs, scattered throughout the Hood Creek-Cape Fear River watershed, make up a third of the permitted live weight and a quarter of the lagoons in the subbasin. The Livingston Creek watershed has no permitted AFOs; however, there is a concentration of residual solids land application fields permitted by the Cape Fear Public Utility Authority (WQ0001271), which account for over 20% of the residual land application and non-discharge wastewater fields in the subbasin. Nine NPDES and 68 state stormwater facilities are found primarily in the lower part of the Hammond Creek-Cape Fear River watershed and within the Livingston Creek watershed.

As noted in Section 9.7, the method typically used to identify an impaired waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

### **PFOS (Perfluorooctane Sulfonic Acid) Fish Tissue Advisory**

The 2023 NCDHHS [fish consumption advisory for PFOS](#) in the Cape Fear River Basin, described in the previous Harrison Creek-Cape Fear River and Turnbull Creek-Cape Fear River summary section, applies to the entire Hood Creek-Cape Fear River segment of the Cape Fear River proper and will be added to the 2026 IR as impaired for fish consumption.

### **Turbidity**

Turbidity levels were not high along the mainstem or tributaries, with all yearly means below the 50 NTU standard and most yearly exceedances less than 10%. Water quality data indicates turbidity is strongly correlated with discharge suggesting nonpoint stormwater sources. Elevated levels in the upper mainstem stations show the influence from upriver sources during some years. Mainstem station data indicate water became more turbid when it flowed over Lock & Dam #1 some years and that the Riegelwood Mill Facility and/or Livingston Creek also contributed to turbidity other years. Stormwater facilities, forestry operations, and other land-use activities in this section of the river may also have contributed to turbidity.

### **DO and pH**

Yearly means for pH and DO usually met water quality standards with few exceedances most years along the mainstem and the tributaries. Neither DO nor pH had a strong correlation with discharge, but data did indicate the upper stations were impacted by upriver sources. The increased monitoring of the coalition stations during warm seasons, particularly the LCFPR, which monitored Hammond Creek and the lower three mainstem stations multiple times during the warm season months before 2012, likely affected the yearly means and caused some variability in the mainstem stations. There also may have been slight instrumentation differences between the MCFBA, LCFRP, and DWR AMS programs. Exceedances of the standard were typically under 10% for both parameters and only occurred at the upper three mainstem and Hammond Creek stations which have stricter standards for pH (6-8) and DO ( $\geq 4$  mg/L) than the lower four mainstem and Livingston Creek stations which have the swamp water (Sw) supplemental classification (Sw standard is pH  $\geq 4.3$  and no DO standard).

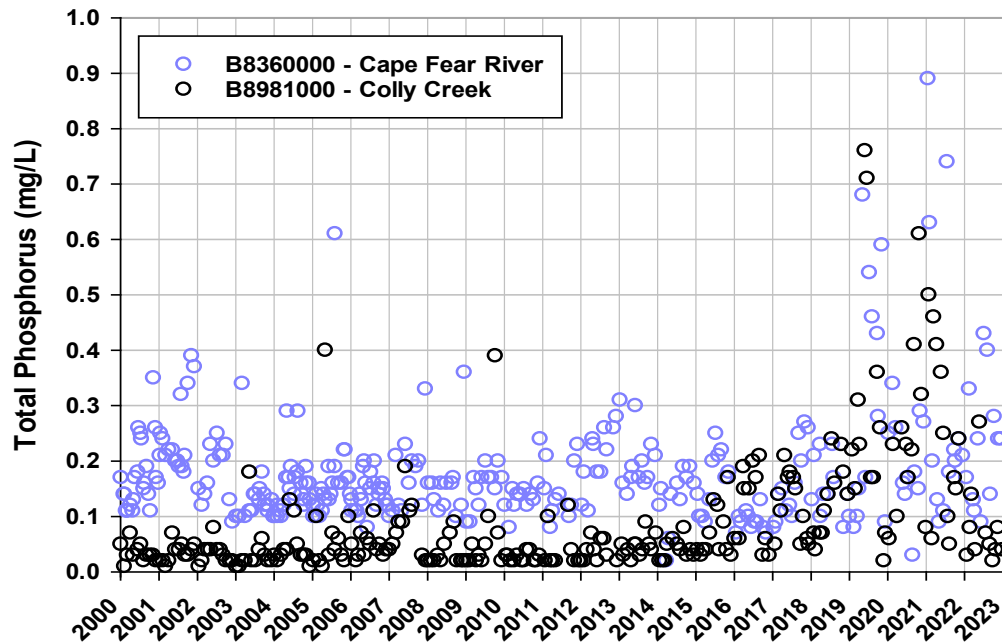
## Fecal Coliform

Mainstem fecal coliform results varied from year to year, but the annual geomeans suggest that overall fecal coliform correlates with discharge indicating nonpoint sources. The Hammond Creek tributary had extremely high levels of fecal coliform from 2010 to 2018 with several years well over the 400 colonies/100 mL standard and exceedance rates ranging from 40% to 80%. The 2016 and 2017 yearly means were particularly elevated due to extreme outliers as high as 60,000 colonies/100 mL. Fecal coliform levels were lower during the last two monitored years. The watershed for station B8340200, on Hammond Creek, is small, only 17.5 mi<sup>2</sup> and there are eight AFOs permitted for 4.49 million pounds live weight. Aerial photography indicates one of the AFOs (AWS090210) has cattle close to the creek and there have been several problems with high freeboards at its three lagoons. Screening level Mann-Kendall trend tests for the Hammond Creek station found fecal coliform bacteria significantly increased from 2000 to 2019 but had no significant change from 2010 to 2019. Water quality data indicated there were no concerning issues with fecal coliform in the mainstem directly below Hammond Creek. The data also showed most yearly mean fecal coliform levels in both the mainstem and Livingston Creek met the fecal coliform standard and usually the exceedance rates were less than 10%. However, fecal coliform levels did spike at the lowest two or three mainstem stations in 2015 and 2016. The lack of monitoring data in Natmore Creek and limited data in Livingston Creek makes identifying the source challenging. Mann-Kendall screening tests for fecal coliform in the mainstem stations found a significant decrease or no change for the 2000 to 2019 and 2010 to 2020 timeframes.

## Nutrients

Yearly water quality and flow data indicate nutrients in the mainstem have different drivers that have caused TKN to increase while other nutrients decreased or remained more consistent, similar to the upriver Harrison and Turnbull Creek-Cape Fear River segment. Along the mainstem, NO<sub>x</sub>, TP and to a lesser degree TN were negatively correlated with flow, indicating point source influence while TKN and ammonia were more variable and did not appear to be affected by flow. Fluctuations in nutrients along the mainstem suggest the Riegelwood Mill facility, Natmore Creek, Livingston Creek, and upriver sources have contributed to nutrient levels. TKN concentrations changed over time with levels typically being more concentrated at the lower three stations (below Natmore Creek) before 2010 and more concentrated at the upper stations since 2010. NO<sub>x</sub> and sometimes TN were more concentrated at the upper three stations, which suggests an upriver source. TP concentrations were comparable along the mainstem stations except in 2019 and 2020 when levels spiked at the stations below Natmore Creek, which originates in the Black River subbasin. TP levels also spiked in 2019 and 2020 at the Colly Creek station B9891000, located in the same general vicinity of the Black River subbasin (*Figure 9-125*). More recent 2022 and 2023 water quality data show TP levels have continued to be elevated, although lower in 2023 (*Figure 9-125*).

Figure 9-125: Cape Fear River Mainstem B8360000 & Colly Creek Station B8981000 TP mg/L 2000 - 2023



Ammonia concentrations had a notable uptick at the lower two stations below the Riegelwood Mill facility and Livingston Creek and sometimes below Natmore Creek at the lower three stations. Specific conductivity, which was negatively correlated with the flow, also spiked every year below the Riegelwood Mill Facility, indicating a point source influence. Ammonia levels were extremely high at the Livingston Creek station (B8441000) particularly during drier years, indicating a potential point source. The five-year mean ambient concentration, 0.18 mg/L, collected from 2011 to 2015, was higher than any other station in the Lower Cape Fear and yearly maximum levels have ranged from 0.15 mg/L to 2.95 mg/L. A RAMs station in the Livingston Creek headwaters, monitored from 2015 to 2016, and another AMS station on Livingston Creek near the Cape Fear River, monitored until 2005, also had concentrated ammonia levels. The uptick in ammonia along the mainstem is likely coming from a point source in the Livingston Creek watershed, possibly a stormwater facility or minor NPDES wastewater discharge facility.

A comparison to DWR’s WSS-ISB special study findings for minimally impacted Coastal Plain streams (*Table 9-13*) found most mainstem station yearly means were over the <0.5 mg/L TKN, <0.3 mg/L NO<sub>x</sub>, and <0.8 mg/L TN recommendations, about half the yearly means were over the <0.05 mg/L ammonia recommendation, and most yearly means were at least twice the <0.05 mg/L TP recommendation. The 2019 and 2020 TP spikes at the lower three mainstem stations were three to six times above the recommendation. Many of the tributary yearly means were also over the recommended nutrient concentrations. TP was two to four times over the recommendation every year in Hood Creek and ammonia was four to ten times over the recommendation for half the monitoring years in Livingston Creek. TKN is of particular concern as screening level Mann-Kendall trend tests showed there was a significant increase at all seven mainstem stations during one or both periods tested, 2000 to 2019 and 2010 to 2019. All other nutrients significantly decreased or did not change during the same periods. Screening level trend tests at

the Hood Creek station found a significant increase in TKN and ammonia from 2010 to 2019 and a significant increase in NOx from 2000 to 2019. Trend tests were not conducted in Livingston Creek due to limited data. The ratio of organic (TKN minus ammonia) to inorganic (NOx) nitrogen varies along the mainstem but overall has increased as the organic nitrogen fraction has increased, and the inorganic nitrogen fraction decreased or remained unchanged. The two monitored tributaries Harrison and Livingston creeks also had a higher ratio of organic to inorganic nitrogen than the mainstem.

### **Biology Assessments**

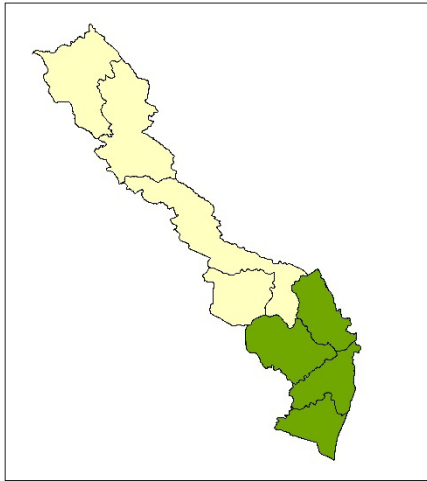
Two benthos and two fish community biology station assessments were done on Hood Creek for use on the 2022 IR. The benthos stations were rated either Moderate or Natural between 2003 and 2018, and the fish stations, assessed only in 2008, were unrated. Just one benthos station was assessed on Livingston Creek in 2003 for the 2022 IR and rated Good-Fair.

### **Actions and Recommendations**

Basin Planning has the following recommendations specific to this middle section of the Lower Cape Fear subbasin:

- Nutrient data along the mainstem indicate Livingston and Natmore creeks may be a source of nutrients, but monitoring data is lacking. When resources allow, DWR should evaluate re-establishing the AMS B8441000 monitoring station on Livingston Creek and establishing a new monitoring station on Natmore Creek.
- Continue monitoring Hammond Creek and when resources allow do a watershed assessment to identify the fecal coliform sources. Monitoring should include a 5-in-30 assessment to properly evaluate Hammond Creek for the Integrated Report. Implementation of BMPs to address fecal coliform issues is recommended.
- There is only one biology station in the Hood Creek-Cape Fear River watershed with current monitoring data. The re-establishment of existing stations or the addition of new stations in both the Hood Creek-Cape Fear and Livingston Creek-Cape Fear watersheds is recommended.
- Basin planning will work with the Wilmington Regional Office to investigate the recent spike in TP found in the mainstem Cape Fear River. A change in the Natmore and Colly Creek watersheds in the Black River subbasin appear to be the source to the mainstem Cape Fear River.

### 1.10.3 Brunswick River-Cape Fear, Town Creek, Lilliput Creek-Cape Fear, and Walden Creek-Cape Fear Watersheds Summary



The lowest third of the Lower Cape Fear River subbasin is composed of four watersheds: Brunswick River-Cape Fear River, Town Creek-Cape Fear River, Lilliput-Cape-Fear River, and Walden Creek-Cape Fear River. These four watersheds encompass 389 mi<sup>2</sup> and include some of the most densely developed (Brunswick River-Cape Fear River) and rapidly growing (Walden-Creek-Cape Fear River) watersheds in the basin. The Cape Fear River mainstem flows from the upper parts of the subbasin through the Brunswick River-Cape Fear River watershed where it merges with the Black and Northeast Cape Fear rivers. It then passes through the Lilliput Creek-Cape Fear River watershed where the Town Creek confluence is

located and lastly flows through the Walden Creek-Cape Fear River watershed to the Atlantic Ocean. The mainstem transitions from **freshwater swamp C, Sw** classified river to **saltwater (SC)** classified estuary within the Brunswick River watershed. Water quality standards also change at this **freshwater swamp - saltwater** transition point (see diagram). Some tidal creek tributaries in the Walden-Creek Cape Fear River watershed are also estuarine. The Intercoastal Waterway (ICWW) separates Oak Island from the mainland near Southport to the west of the Cape Fear River's mouth. Baldhead Island, with its myriad of coastal wetlands, is located to the east of the river's mouth. Surface water quality in these four lower watersheds

Brunswick River-Cape Fear Mainstem Stations		
— Black River <b>B9000000</b> & <b>B9013000</b>		
<b>1</b>	<b>B9020000</b>	18-(63)b
<b>2</b>	<b>B9030000</b>	18-(63)b Adjacent to Sutton Lake Berm
— Sutton Steam Electric Plant		
— Northeast Brunswick Regional WWTP (2.475 MGD)		
<b>3</b>	<b>B9050025</b>	18-(71)a2a
— Brunswick River split at Eagle Island <b>B9790000</b>		
<b>4</b>	<b>B9050100</b>	18-(71)a2a
— Northeast Cape Fear River <b>B9670000</b> & <b>B9740000</b>		
<b>5</b>	<b>B9800000</b>	18-(71)a3
— Brunswick River reemerges south of Eagle Island		
— Wilmington Southside WWTP (12 MGD)		
<b>6</b>	<b>B9820000</b>	18-(71)a4
<b>7</b>	<b>B9795000</b>	18-(71)a5
Lower Estuary Cape Fear Mainstem Stations		
— Town Creek		
<b>1</b>	<b>B9850100</b>	18-(71)b
— Carolina Beach WWTP (3 MGD)		
<b>2</b>	<b>B9910000</b>	18-(87.5)a
— Archer Daniels Midland Company Southport Manufacturing Facility (3.51 MGD)		
<b>3</b>	<b>B9921000</b>	18-88-3.5 Adjacent to Intercoastal Waterway
<p><b>Freshwater C, Sw</b> classified standards are ≤50 NTU turbidity, ≥4.3 pH, none for DO, &lt;200 colonies/100 mL geometric mean, or &lt;400 colonies/100 mL fecal coliform in 20% of the samples where five samples have been taken in 30 days (5-in-30). <b>Saltwater SC</b> standards are 6.8-8.5 pH and <b>SC, Sw</b> are ≥4.3 pH. <b>Saltwater SC</b> and <b>SC, Sw</b> standards are ≤25 NTU turbidity, none for DO, &lt;35 enterococci/100 mL geometric mean of (5-in-30).</p>		

is influenced by many factors, including pollutants, natural landscape features, tides, dredging, sea-level rise, and extreme weather events likely associated with climate change.

Ambient monitoring in this section of the subbasin included 10 stations in the mainstem and the Brunswick River station (B9790000). Four other major tributary stations, the two lowest stations in the Black and the Northeast Cape Fear rivers, are included in this discussion. The upper two mainstems, both Black River and the upper Northeast Cape Fear stations, are freshwater (C) and swamp water (Sw) classified. The lower eight mainstem and the Brunswick River stations are saltwater (SC) classified. The lower Northeast Cape Fear station is SC and Sw classified.

### **Climate Change and Coastal Areas**

Coastal areas are extremely vulnerable to climate change. The [North Carolina Climate Science Report](#) key findings on climate change found it is virtually certain sea level rise and storm surge flooding will continue; it is very likely temperatures and extreme precipitation frequency and intensity will increase; and likely droughts and wildfire will increase in frequency and intensity (see Chapter 1 for more detail). Five hurricanes have affected North Carolina during the timespan of this plan: Hurricane Isabel (September 18, 2003); Irene (August 27, 2011); Sandy (October 28, 2012); Matthew (September 28, 2016); and Florence (September 14, 2018). Intense rains from Hurricane Florence caused peak flood stages in the Cape Fear River of two to three feet higher than Hurricane Matthew less than two years prior. Sea level rise and storm surges from severe weather events drive saltwater further up the Cape Fear River and its network of tidal creek tributaries (Breisinger 2021). Extreme drought conditions also increase saltwater intrusion by pushing tides higher in the river system when freshwater volume and discharge decrease. There is usually not much saltwater above the northern edge of Wilmington; however, during the 2007 drought, salinity levels increased as far up the Cape Fear River as the confluence with the Black River, just a few miles downstream from Lock and Dam #1 (Holman 2022). Saltwater intrusion can also raise groundwater and cause the corrosion of essential infrastructure like underground sewer pipes (Holman 2022).

The deepening of the Cape Fear River channel for shipping has also dramatically increased the effects of tides and storm surges along the riverbanks. Tides cause saltwater to slosh up and down further in a deepened channel causing an amplification of the tidal range at the top of the estuary (Holman 2022). The effects of sea-level rise, in combination with dredging, are evident in the lower part of the Cape Fear River where forested wetlands have been rapidly transitioning to tidal marshes full of dead or dying trees, often called “ghost forests” due to their gray skeleton-like appearance (see Chapter 1 for more information).

Hurricane Florence’s intense rains and flooding affected two man-made lakes: Sutton Lake (Section 9.9.6.1), located adjacent to a large inside bend of Cape Fear River in the Brunswick River watershed, and Boiling Spring Lake (Section 9.9.7.1) in the Lilliput Creek watershed. Boiling Spring Lake was an important economic and recreational resource for the City of Boiling Spring Lakes; however, in 2018, Hurricane Florence caused the lake’s dam to fail, draining the lake. The town received a federal grant in 2022 from the Defense Community Infrastructure Program to repair the dam. Lake Sutton was a cooling reservoir for the former coal-fired Duke Energy Progress-owned Sutton Steam Electric Plant. There were two on-site coal ash basins when Hurricane Florence hit, one built in 1971 and the other in 1984. Flooding caused the older coal ash basin to overflow into Sutton Lake, which was designed to be a buffer between the ash

basins and the Cape Fear River. However, the Sutton Lake dam was also breached during Florence at several points along the southern side, potentially sending polluted floodwaters into the Cape Fear River. Reports of gray sludge seen washing into the Cape Fear River reached DEQ (Biesecker and Sudermand 2018). DWR later conducted supplemental metals monitoring to quantify and characterize potential impacts from Florence when conditions were deemed safe for fieldwork. The [Survey of Surface Water Quality Associated with Hurricane Florence, September 2018 Report](#) (DWR 2019) found no significant pollution in the Cape Fear River post-Florence. Duke Energy completed the excavation and capping of the coal basins in 2021 to protect Sutton Lake and the Cape Fear River from future contamination during extreme storm events.

Climate change resiliency planning is imperative for vulnerable coastal areas. Evaluation and fortification of all facilities and infrastructure that store pollutants are necessary to protect aquatic habitats and drinking water supplies. See Chapter 1 for more information on sea level rise, wetlands, and climate risk and resiliency in the Cape Fear River Basin.

### **Impairments**

This lowest third of the Lower Cape Fear River subbasin contains the majority of the impaired waterbodies. Both point and nonpoint pollutants are influencing factors in this part of the subbasin. Point sources include seven major and 11 minor industrial and municipal NPDES dischargers and a multitude of stormwater facilities--58 NPDES and over 1,400 state--that are densely concentrated near Wilmington and the watersheds of the Brunswick River, Lilliput Creek-Cape Fear River, and Walden Creek-Cape Fear River. Nonpoint source urban stormwater runoff is frequent in this rapidly growing and densely populated part of the subbasin. Brunswick County, where much of this section of the subbasin is located, is the fastest-growing county in the state and seventh fastest-growing in the country, according to the U.S. Census Bureau in 2022. AFOs are less common, although there are several swine operations in the Town Creek watershed, which is still a more rural area. There is also a concentration of non-discharge high-rate infiltration fields owned by the Southeast Brunswick Sanitary District WWTP (WQ0013200) and reclaimed water fields owned by the Town of Oak Island (WQ0005790) in the Walden Creek-Cape Fear River watershed. Other potential sources of pollution may arise from forestry operations, golf course communities, failing septic tanks, or failing stormwater infrastructure. Changes in land use and land cover over time, natural landscape characteristics, like wetland coverage or forested buffers, and ocean tides can affect water quality conditions. The water quality standards for freshwater swamp waters are different than saltwater where fish are more sensitive to the depletion of oxygen. High concentrations of bacteria, or other pollutants in saltwater, can be harmful to filter-feeding shellfish and hazardous to human health if consumed.

Impairments are primarily within the upper and parts of the lower estuary, including the mainstem from above the Brunswick and Cape Fear River split (north of Eagle Island) at the mouth of Toomers Creek to Snows Cut (above Carolina Beach) and the ICWW and various tidal tributaries near Southport. The upper estuary impairments are for DO, pH, total copper, and hexavalent chromium and arsenic fish tissue advisories. The lower estuary impairments are for shellfish growing areas, and total copper, arsenic, and nickel ([Table 9-2](#)). There are also freshwater impairments for benthos, chlorophyll *a*, and hexavalent chromium and arsenic fish tissue. As noted in Section 9.7, the method typically used to identify an impaired

waterbody for the IR is based on 10% exceedance rate of a standard and 90% percent confidence for a set of data generally collected over five years and not based on individual yearly statistics as represented in the graphs in this chapter (see Chapter 2 for more information on the IR).

### **Fish Consumption Advisories**

[Fish consumption advisories](#) have been issued by NCDHHS in the Lower Cape Fear subbasin due to elevated fish tissue concentrations of hexavalent chromium, arsenic, and PFOS.

The placement of the Kerr-McGee Chemical Corporation site in Navassa, in the Brunswick River watershed, on the US EPA's Superfund National Priorities List (NPL) in 2010 prompted the EPA and DEQ to collect and analyze fish and shellfish tissue in 2011 for polycyclic aromatic hydrocarbons (PAHs), a contaminant of concern and known by-product of the creosote-based wood treatment facility ([Kerr-McGee Chemical Corp-Navassa Superfund website](#)). Semivolatile organic compounds, polychlorinated biphenyl (PCB) congeners, and metals were also analyzed in 2011, and additional samples were collected and analyzed for metals in 2013. PAHs, PCBs, arsenic, hexavalent chromium, mercury, and copper were all detected at concentrations above Division of Public Health levels of concern, indicating the potential for cancer and non-cancer health effects. New and more stringent fish tissue advisories were issued in 2017 for arsenic and hexavalent chromium for three species because the existing statewide advisory for mercury already covered the advised consumption rates for other species (NC DHHS 2018). The new advisories also caused 2020 impairments to sections of the Cape Fear and Brunswick rivers and Sturgeons Creek (*Table 9-11*).

The Duke University Superfund Research Center and the School of Health Sciences at Oakland University, with support from several partners, conducted a follow-up study in the Lower Cape Fear from 2016 to 2022. The follow-up study investigated who fishes for subsistence, held focus groups to develop messaging for safer consumption practices, organized a fish forum to discuss challenges and opportunities to create a more effective fish consumption advisory process in North Carolina, and collected and analyzed fish and shellfish tissue samples from new locations in the Lower Cape Fear and Northeast Cape Fear subbasins (Shapiro-Garza et al. 2022). This study led to the issuance of 2021 hexavalent chromium and arsenic fish tissue advisories to additional sections of the Cape Fear and Brunswick rivers and a section of the Northeast Cape Fear River and its Burnt Mill Creek tributary (*Table 9-11*). These new fish tissue advisories will be on the 2024 303(d) impaired waters list. This study also found those eating fish for subsistence tended to be low-income and/or food-insecure individuals and families. Focus group results led to the development of a public outreach campaign, "[Stop, Check, Enjoy!](#)", to improve messaging to subsistence and recreational fishers. The [Fish Forum](#) concluded that resource constraints limit all phases of developing fish tissue advisories, and that North Carolina needs to invest more in establishing and communicating fish consumption advisories (Shapiro-Garza et al. 2022). The new fish tissue advisory for PFOS in the Cape Fear River Basin, described in the previous Harrison Creek-Cape Fear River and Turnbull Creek Cape Fear River summary section, applies to approximately 10 miles the Brunswick Creek-Cape Fear River segment above the bluffs near the I-140 overpass and will be on the 2026 IR as impaired. Fish tissue analysis for marine species collected in the estuary is underway.

## Shellfish Growing Areas and Bacteria Monitoring

In 2022, the Lower Cape Fear contained all or a portion of seven Shellfish Growing Areas (SGAs), one entirely “Approved” and open (B3), four entirely “Prohibited” and closed (A3, B1, B5, and B10), and two partially open (B2, B4) with “Conditionally Approved” closed, “Approved” open, and “Prohibited” closed harvest area sections (Section 9.5). For water quality assessment purposes, shellfish growing areas that are conditionally approved (open or closed), restricted, or prohibited are considered impaired and not meeting their designated use. In the Lower Cape Fear estuary, over 2,400 acres are impaired for shellfish harvesting. Sanitary Surveys Reports developed by DEQ’s Division of Marine Fisheries (DMF) Shellfish Sanitation Section found potential nonpoint pollution sources of bacteria causing the impairments to be stormwater, marinas, subdivisions, golf courses, on-site wastewater, subdivisions, and domestic animals and wildlife. Nearby point source facilities were also deemed potential sources of pollution for shellfish and were evaluated in the reports (Table 9-23). The two Wilmington WWTPs located further away and owned by the Cape Fear Public Utility Authority were also evaluated due to their size. DWR used a [Kernel Density](#) tool for spatial analysis to determine the high concentration of potential nonpoint pollution sources in SGAs. The most concentrated pollution sources drained to prohibited and closed harvest areas in SGA A3, B1, and B4. Price Creek, which drains to B4, was the most notable, other more concentrated pollution areas draining to B1 and A3, included Cottage Creek to the west of Southport, Dutchman’s Creek with headwaters in Coolvale, and Beaverdam Creek which passes through the St. James development.

Table 9-23: Lower Cape Fear permitted facilities evaluated as pollution sources in Shellfish Sanitary Reports

SGA <sup>*^+</sup>	Permit	Facility Name	Description of Pollutant Application
B1*	WQ0013200	Southeast Brunswick Sanitary District	Sprays treated effluent on golf courses at the St. James Plantation
B1*	WQ005790	Oak Island Fish Factory Road Wastewater Reclamation Facility	Discharges reclaimed water to an infiltration pond and spray fields
B1*	WQ0031857	Oak Island Satellite Wastewater Reclamation Facility	Irrigates reclaimed water to golf courses
B1*	NC0027065	Archer Daniels Midland Plant	Redirects domestic waste to the Town of Southport and point source discharge to Cape Fear River
B2,B3^	WQ0000193	Baldhead Island Non-Discharge Treatment plant	Discharges to two infiltration ponds and the Baldhead Island golf course
B4+	NC0065480	Beau River Plantation Package	Point Source Discharge to Cape Fear River
B4+	NC0057703	Cape package WWTP	Point Source Discharge to Cape Fear River
B4+	NC0023256	Carolina Beach WWTP	Point Source Discharge to Cape Fear River
B4+	NC0025763	Kure Beach WWTP	Point Source Discharge to Cape Fear River
B4+	NC0023973	Wilmington Southside WWTP	Point Source Discharge to Cape Fear River
B4+	NC0023965	Wilmington Northside Plant WWTP	Point Source Discharge to Cape Fear River

\*DMF 2020-a, ^DMF,2020-b, +DMF 2020-c

## Fecal Coliform

Fecal coliform data was collected during some or all years at every station from this section of the subbasin and the Black River and Northeast Cape Fear River stations. The fecal coliform standard of  $\leq 400$  colonies/100 or  $\leq 200$  colonies geomean for 5-in-30 tests is only applicable to freshwater. The saltwater standard is a geometric mean of 35 colonies/100 mL enterococcus bacteria for 5-in-30 tests. Enterococcus bacteria was also collected at five of the mainstem saltwater stations. The 5-in-30 tests were not prioritized for any of the waterbodies in this section of the Lower Cape Fear River subbasin or the Black and Northeast Cape Fear rivers as none were classified for primary recreation. Fecal coliform yearly means and geomeans at the freshwater stations (and lower saltwater stations) were below the standard with few exceedances most years except in 2015 and 2016 when levels spiked. Enterococcus bacteria also spiked during several monitoring years, 2012, 2013, and 2015 to 2017, at most saltwater stations. Mann-Kendall screening tests conducted on fecal coliform bacteria in the mainstem river and estuarine stations found some of the upper stations significantly increased during the 2000 to 2019 period while some of the lower stations significantly decreased. Fewer stations had significant results from 2010 to 2019, a few upper stations increased and the two lowest decreased. Upriver sources in this subbasin and the many AFOs in the Black and Northeast Cape Fear subbasins are likely contributing to bacteria levels as many of the nearby sources were identified and evaluated by the DMF Sanitary Surveys Reports (*Table 9-23*).

## Turbidity

Turbidity was collected at half the mainstem stations and the lower Black River and Northeast Cape Fear River stations. Overall turbidity was low in this part of the subbasin and in the Black and Northeast Cape Fear tributaries with all yearly means below the 50 NTU freshwater and 25 NTU saltwater standards. Graphical patterns and yearly exceedance rates suggested turbidity levels were sometimes affected by point sources, including the Riegelwood Mill Facility, located upriver, the Sutton Steam Electric Plant, and Northeast Brunswick Regional WWTP located in this section of the subbasin.

## DO and pH

There have been persistent issues with low DO in the upper Cape Fear estuary causing over 5,000 saltwater acres to be impaired for exceedance of the 5.0 mg/L standard on the 2022 IR. Estuarine DO impairments include about 14.5 river miles of the Cape Fear River from Cartwheel Branch (located above Eagle Island) to 1.9 miles south of Motts Creek and all of the Brunswick River. Low pH occurred in the same upper estuary areas but only the Brunswick River was also impaired for exceedance of the 6.8 standard on the 2022 IR. DWR's Basin Planning Branch determined the same 14.5-mile upper estuary section, impaired for DO, should also have been impaired for pH for exceedance of the 6.8 saltwater standard and will be corrected on the 2024IR. The extensive swamp riverine wetland coverage in this part of the subbasin, where the Black and Cape Fear rivers merge, and along the lower Northeast Cape Fear River, have likely contributed to the low DO and pH levels in the upper estuary. Other sources of pollutants affecting these parameters may include permitted (e.g., WWTPs or AFOs) or deemed permitted (poultry operations) facilities, but further investigation is needed for verification. None of the swamp (Sw) classified waters above the estuary, with less strict pH standards and no DO standards, were impaired for these parameters. The increased tidal flushing in the lower section of the estuary raised both the DO and pH levels, causing

these areas not to be impaired. Section 9.11 provides a detailed assessment of the low DO and pH issues in the Cape Fear River estuary.

### **Chlorophyll *a* and Nutrients**

Wilmington's Greenfield Lake is highly eutrophic and has been impaired for chlorophyll *a* since 2014 (Section 9.9.6.1). The lake has been plagued with algal blooms, anoxic conditions, and fish kills for many years. Episodic blooms have been reported nearly every year since 2013 and potentially harmful algal blooms (HABs) have been identified, although the toxin microcystin was only found in 2021. Historic studies found waterfowl contributed to nutrient loading and lake sediment also contributed phosphorus to the water column. Restoration efforts in 2005 to improve DO included introducing grass carp, installing solar-powered circulators and herbicide treatments, which increased the occurrence of phytoplankton and chlorophyll *a*. A more recent study found Jumping Run and Squash branches are contributing to nutrient loading. Water quality data indicate pollution sources vary, with Jumping Run Branch being stormwater driven and Squash Branch being point source driven. Mitigation measures using constructed wetlands and floating macrophyte islands are planned through the [City of Wilmington's Greenfield Lake 9-Element Restoration Plan](#).

Yearly water quality and flow data indicate nutrients in this lowest third of the subbasin have different drivers. Along the mainstem, TKN was generally positively correlated with the flow, indicating nonpoint source influence, while NO<sub>x</sub> was generally negatively correlated with the flow, indicating point source influence. TKN varied from station to station while NO<sub>x</sub> and TP mostly declined from upstream to downstream suggesting influence from upriver. TN also generally declined from upstream to downstream, particularly during low-flow years when upriver point sources contributed more to TN. TN was also more negatively correlated with the flow at the upstream stations and more positively correlated with the flow at the downstream stations. This was consistent with the increasing ratio of organic (TKN minus ammonia) to inorganic (NO<sub>x</sub>) nitrogen from upstream to downstream stations. Neither ammonia nor TP had a notable correlation with the flow. Notably, TP spiked in 2019 and 2020 throughout the mainstem and estuary. Water quality data indicate the source is Natmore Creek, which drains from the Black River subbasin. The Colly Creek station (B8981000) in the Black River subbasin, located in the same vicinity as where Natmore Creek originates, and the upper Black River tributary station (B9013000) also have TP levels that spiked in 2019 and 2020. Natmore and Colly creeks are in a highly agricultural area with no permitted facilities. LCFRP coalition data for 2021 and 2022 also indicate TP levels have remained high.

Nutrient yearly mean concentrations from 2002 to 2020 in this lowest section of the subbasin were compared to DWR's WSS-ISB special study findings for minimally impacted Coastal Plain streams ([Table 9-13](#)). Along the mainstem stations, about three-quarters of the yearly means were over both the <0.5 mg/L TKN and <0.05 mg/L ammonia recommendations, 63% of the yearly means were over the <0.3 mg/L NO<sub>x</sub> recommendation, 71% of the yearly means were over the <0.8 mg/L TN recommendation, and 89% were over the <0.05 mg/L TP recommendation. In comparison to the recommendation, TP concentrations were highest with two-thirds of the yearly means being twice the <0.05 mg/L recommendation and some as much as four times the recommendation. Many of the tributary yearly means for the Brunswick, Black, and Northeast Cape Fear river stations were also over the recommended nutrient concentrations, particularly for TKN and TP.

Mann-Kendell screening trend tests conducted on the mainstem and tributary stations for nutrient data collected from 2010 to 2019 found results were variable. NOx significantly decreased at the Brunswick River station, the upper Northeast Cape Fear River station, and three of the upper mainstem stations. Ammonia was inconsistent with the most upper mainstem station significantly decreasing, while four other mainstem stations and the upper Black and upper Northeast Cape Fear rivers' stations were significantly increasing. TKN was concerning as all but the uppermost mainstem station and all five tributary stations were significantly increasing. Mann-Kendall screening tests for TP from 2010 to 2019 also show that five of the lower mainstem stations and the upper Black and Northeast Cape Fear stations significantly increased. It is important to note that many stations in the Cape Fear River Basin as well as other river basins across the state are experiencing statistically significant increases in instream TKN concentrations. This has been reported across the US as well. The driver for this is not well understood at this point. It likely has to do with our changing landscapes and climate impacts. One suggestion is the change in soil pH due to reducing the impacts from acid rain resulting in more organic nitrogen being released from the many years of fertilizer and waste applications as well as from natural sources in forests and wetlands (Deiningner et al., 2020).

## Metals

There are some old impairments based on the total metal standards for copper, arsenic, and nickel in this lowest section of the Cape Fear River. The copper impairments include approximately 6.5 river miles equivalent to 5,568 SW Acres of the mainstem in the upper estuary between Wilmington and Snows Cut and a 715-acre section of the lower estuary (AU# 18-88-35) near Southport. The lower estuarine section near Southport is also impaired for arsenic and nickel. Metals can enter surface waters through industrial and wastewater point source dischargers and atmospheric deposition. For aquatic organisms, metals in surface waters can have chronic, sublethal long-term health and reproductive effects and at high concentrations can have an acute lethal effect. These waters need to be reassessed using the new dissolved metals standard that are more applicable to aquatic health assessments than total metals.

## Biology Assessments

Benthic macroinvertebrate assessments used on the 2022 IR were completed at three stations in this lowest section of the lower Cape Fear River. In the Brunswick River-Cape Fear River watershed, Barnards Creek was rated Moderate for benthos in both 2003 and 2013, and Sturgeon Creek, monitored in 2008 only for benthos, was not rated. In the Town Creek-Cape Fear River watershed, Town Creek was rated Natural for benthos in 2003.

## Actions and Recommendations

Basin Planning has several recommendations specific to this section of the Lower Cape Fear River subbasin:

- There are very few biology stations in this lowest section of the subbasin and none with current monitoring data. The re-establishment of older existing stations or the addition of new stations is recommended when resources allow.
- Watershed evaluations should be conducted to determine the source of rising TKN levels.
- There are no ambient stations in the Town Creek watershed and the only mainstem estuarine stations in the Lilliput Creek-Cape Fear River and Walden Creek-Cape Fear River watersheds.

Adding additional ambient monitoring stations to these watersheds will help identify pollutant sources and help inform BMP recommendations.

- DWR supports the recommendations of the [City of Wilmington's Greenfield Lake 9-Element Restoration Plan](#), including monitoring, education, BMP installation, and assessment of the efficacy of individual BMPs outlined in the restoration plan to address the chlorophyll *a* and algal bloom issues at Greenfield Lake. Examples of nonpoint source management measures recommended in the plan include the use of riparian buffers, constructed wetlands, and floating macrophyte islands.
- An inventory and assessment of all coastal facilities and infrastructure that store, treat, or transport waste is needed to identify the risk factor for storm-related breaches or leaks. High-risk facilities and infrastructure should be prioritized for fortification and improvement to keep waste from being released into the environment during future intense storm events.
- Basin planning supports the implementation of the North Carolina Coastal Habitat Protection Plan (CHPP). The CHPP is a guidance document that addresses habitat and water quality efforts needed to protect, enhance, and restore fish habitat along North Carolina's coasts. There are four major goals: improve the effectiveness of existing rules and programs; identify and delineate strategic coastal habitats; enhance and protect habitats from adverse physical impacts; and enhance and protect water quality. Each goal has multiple recommendations to achieve the overarching goal of long-term improvement of coastal fisheries through habitat protection and enhancement efforts. See Chapter 4, Section 4.6, for a list of individual recommendations.
- This section of the Lower Cape Fear River has several old total metals impairments for copper, arsenic, and nickel. It is recommended that DWR and the coalition monitoring programs identify areas within the subbasin to do dissolve metal monitoring.
- 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.

#### 1.10.4 Cape Fear Mainstem Chlorophyll *a*/Algal Bloom Summary

Chlorophyll *a* is an algal pigment that is used as a proxy for algal biomass and an indicator of how biologically productive an aquatic ecosystem is at a specific point in time. The location of algal blooms in a large river system like the Cape Fear River are highly dependent on many environmental factors such as stream clarity, nitrogen, and phosphorus (nutrients) availability, stream flow and climate impacts like temperature, light intensity, precipitation, wind and storm events. DWR has found that once climate conditions are optimal (e.g., temperature and sunlight) stream flow, stream clarity and thermal stratification are likely large controlling factors over the ability of most algal species to bloom in the rivers and streams throughout the basin. One of the unique features of the Cape Fear River system includes the locks and dams on the mainstem Cape Fear River. These structures create large segments of impounded river acting more like slow moving lakes rather than swift moving river. The slow movement in the backwaters behind the dams are perfect for the development of algal blooms when conditions are conducive. As the river slows, water clarity increases as suspended sediment settles out of the water column. At the same time, vertical mixing in the slow-moving waters is sufficiently weak to permit daytime thermal stratification of the upper few feet of the water column. The combination of clearer water and a shallow, well-lit upper layer provides enough light to support algal growth (Hall, 2021).

The mainstem Cape Fear River has a long history of algal blooms. First reported in the 2000 basin plan, it was recognized that algal productivity influences dissolved oxygen (DO) dynamics in the Cape Fear River. Algal blooms were reported in the Cape Fear River during a severe drought in 2002. The data used for the 2005 basin plan (9/1/1998-8/31/2003) showed that algal blooms were forming in the surface waters during the critical summer growing period. The 2005 Cape Fear River Basin Plan reported elevated chlorophyll *a* concentrations in the mainstem Cape Fear River from the confluence with the Haw and Deep rivers downstream to NC 42 (24% of samples exceeding the standard), from Grays Creek to LD#3 (27% exceedance) and from LD#3 to NC 41 (57% exceedance). This caused several large segments of the Cape Fear River being added to the 2006 303(d) impaired waters list. The lower segment was classified as not rated due to an insufficient number of samples collected to assign a use support rating.

The 2005 water quality assessment identified chlorophyll *a* issues along the entire Cape Fear River mainstem in the Upper Cape Fear River Subbasin (03030004) and a large section of Cape Fear River in the Lower Cape Fear River Subbasin (03030005). Algal productivity was shown to influence the dissolved oxygen dynamics in the river. As a result of these findings, a nutrient-related NPDES permitting strategy was put in place to prevent the continued decline of instream water quality conditions. See Chapter 3 for Cape Fear River basinwide permitting history in section 3.2.4.

Algal growth continued to be a concern especially in 2009 when a systemwide blue-green algal/cyanobacteria bloom started in June and persisted well into November. The Cape Fear River system was responding to a persistent drought, low stream flow rates, increased instream clarity, and nutrient enrichment, resulting in blooms that covered parts of the river from above Buckhorn Dam downstream to below Riegelwood. At one point the bloom covered a 75-mile stretch of the river. Long-term drought conditions persisted along with algal blooms throughout much of the river through 2012 (*Figure 9-126*). The 2009-2012 algal blooms consisted of many species, including many dominated by the HAB blue-green/cyanobacteria *Microcystis aeruginosa*, which can form surface blooms that can be potentially toxic as well as cause taste and odors problems for drinking water treatment facilities. NC DEQ and DHHS put out press releases cautioning the public to avoid contact with large accumulations of algae in the Cape Fear River and to take precautions to prevent children and pets from swimming or ingesting water in those areas. Microcystin toxin was detected in several samples throughout the 4-year bloom period (DHHS and Isaacs et al., 2014).

Based on WSS data available for 2012 to 2019, there were 63 episodic blooms reported to DWR in the Cape Fear River Basin. Forty of the 63 reported blooms, or 63.5%, were identified as potentially harmful blue-green algal blooms and 23, or 36.5%, were non-HAB dominated blooms (*Table 9-24*).

Figure 9-126 Algal Bloom Photographs from 2009 -2012.



Cape Fear River behind LD#1 at canoe launch (9/24/09 WSS)



Cape Fear River downstream of LD#1 (10/23/2009)



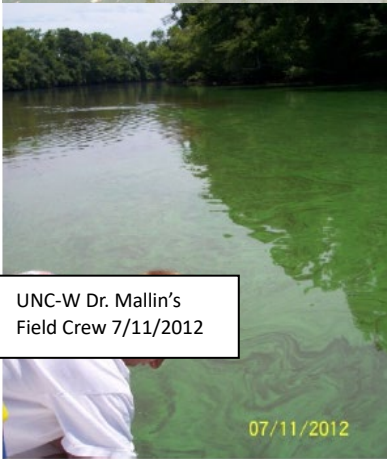
Cape Fear River at NC11 (6/27/2011 WiRO)



Cape Fear River above LD#3 (7/20/2011 WSS)



Deep River at Moncure (8/2/11 WSS)



UNC-W Dr. Mallin's Field Crew 7/11/2012



8/6/2011 WSS

Table 9-24 Cape Fear River Basin Episodic Bloom Summary for 2012-2019.

Year	Number of Blooms/Year	Cyanobacteria/ Blue-Green Blooms	Non-HABs
2012	14	4	10
2013	2	0	2
2014	6	5	1
2015	6	4	2
2016	8	7	1
2017	7	4	3
2018	14	11	3
2019	6	5	1
<b>Total Bloom Count</b>	63	40	23

Chapter 2 has an extensive assessment of the mainstem Cape Fear River’s chlorophyll *a* and algal blooms with a review and summary of the special research studies that have occurred in the basin to help understand what is contributing and controlling the biological productivity in this complex riverine system (see Chapter 2 Sections 2.5.8 and 2.7).

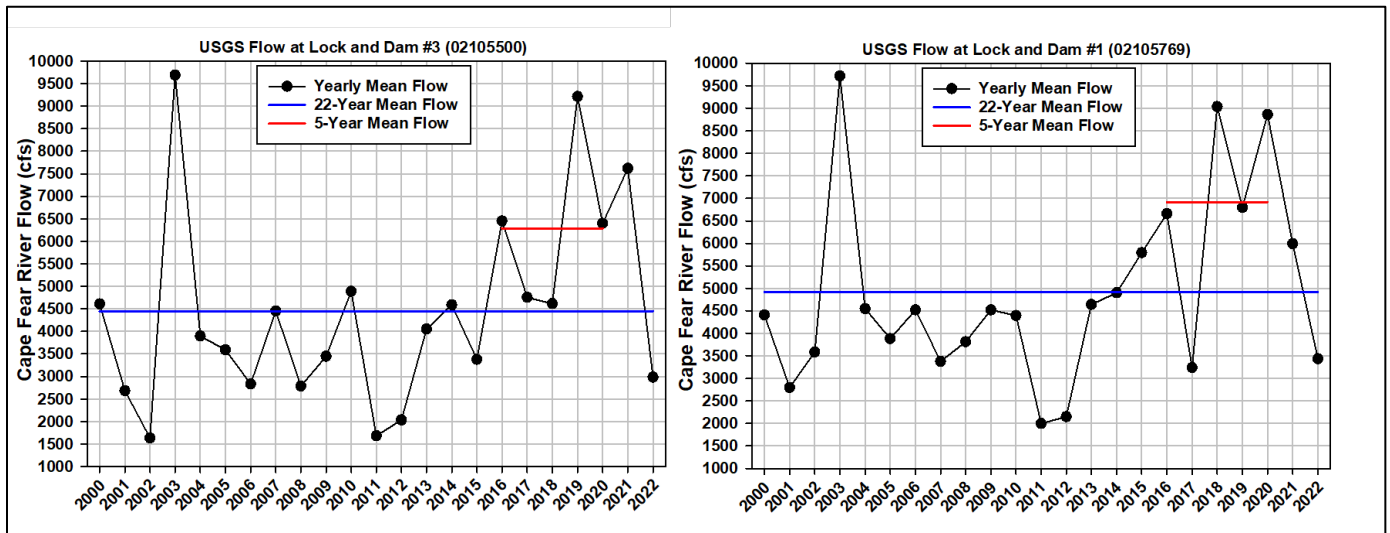
For the 2022 IR assessment, the mainstem Cape Fear River was assessed for chlorophyll *a* concentrations at eight ambient stations and one lake station behind Buckhorn Dam (*Table 9-25*). (See Figure 2-40 in Chapter 2 for a map of all 12 ambient chlorophyll *a* stations in the basin.) Seven of the ambient stations are located in the Lower Cape Fear River Subbasin (03030005) and are monitored by the Middle or Lower Cape Fear River monitoring coalition programs using the depth-integrated sampling technique, which is twice the Secchi depth. Several special studies have shown that the river discharge rate is a significant controlling factor in the development of bloom formation in the mainstem Cape Fear River. During the 2022 IR assessment period, Cape Fear River flow was at or above the 22-year mean flow at the USGS gage stations at LD#3 and LD#1 all years except for 2017 at LD#1 (*Figure 9-127*). There were several large weather events, i.e., hurricanes and tropical storms, that impacted this region and the yearly mean discharge rates. (See Section 9.10.3 under Climate Change and Coastal Areas for a list of storms.) During the 2022 IR period, mean chlorophyll *a* concentrations at the seven Lower Cape Fear River stations were between 3.9 and 7.0 µg/L with the maximum recorded reading between 13.2 and 37.0 µg/L (*Table 9-25*). The higher flows during the 2022 IR period likely contributed to the lower chlorophyll *a* concentrations during this period (*Figure 9-127*).

Table 9-25 2016-20202 (2022 IR) Mainstem Cape Fear River Chlorophyll a Summary Date with Mean TN and TP Concentrations. Depth Integrated Monitoring Technique Used at these Stations.

Subbasin	Station	Location	AU#	Stream Class	Monitoring Program	Chlorophyll a			TN	TP	
						n	Mean	Median	Max	Mean	Mean
Upper Cape Fear River 03030004	B6160000	At NC 42 near Corinth	18-(4.5)	WS-IV; CA	MCFBA	69	16.5	10.7	91.6*	1.44	0.10
	Lakes Station CPFBDL2	Upstream of Buckhorn Dam	18-(5.5)a	WS-IV; CA	DWR-ALMS	4	14.3	16	20	1.25	0.11
Lower Cape Fear River 03030005	B8290000	Upstream of LD#3	18-(26.25)b	WS-IV	MCFBA	68	4.8	3.9	21.4	1.55	0.11
	B8305000	At Tar Heel	18-(26.75)a	C	MCFBA	56	3.9	2.9	13.2	1.63	0.16
	B8339000	Upstream of LD#2	18-(26.75)b	C	MCFBA	65	3.9	2.8	18.3	1.61	0.15
	B8349000	Upstream of LC#1	18-(58.5)	WS-IV; CA	MCFBA	69	4.1	3.1	26.5	1.56	0.13
	B8360000	At NC11 near East Arcadia	18-(59)	WS-IV; Sw	LCFRP	56	4.5	3.0	37.0	1.25	0.19
	B9800000	At CM 61 at Wilmington	18-(71)a3	SC	LCFRP	56	4.2	3.0	23.0	1.08	0.20
	B9921000	At CM18 near Southport	18-88-3.5	SC	LCFRP	56	7.0	6.0	26.0	0.61	0.15

\*Six percent of samples exceeded the 40 µg/L standard

Figure 9-127 Cape Fear River Yearly Mean Flow at USGS Gage Station 02105500 (Lock and Dam #3) and 02105769 (Lock and Dam #1).



The Blue Line is the 22-Year Mean Flow and Red Line is the 2022 IR Period (2016-2020) Mean Flow for Comparison.

As discussed above, there are several factors that impact the overall chlorophyll *a* concentrations. Understanding the changes in the mainstem Cape Fear River algal bloom development and nutrient impacts using chlorophyll *a* concentrations as a surrogate is challenging due to many reasons including the changes in sampling techniques and use support assessment methods and the extreme climate variability over the last several decades.

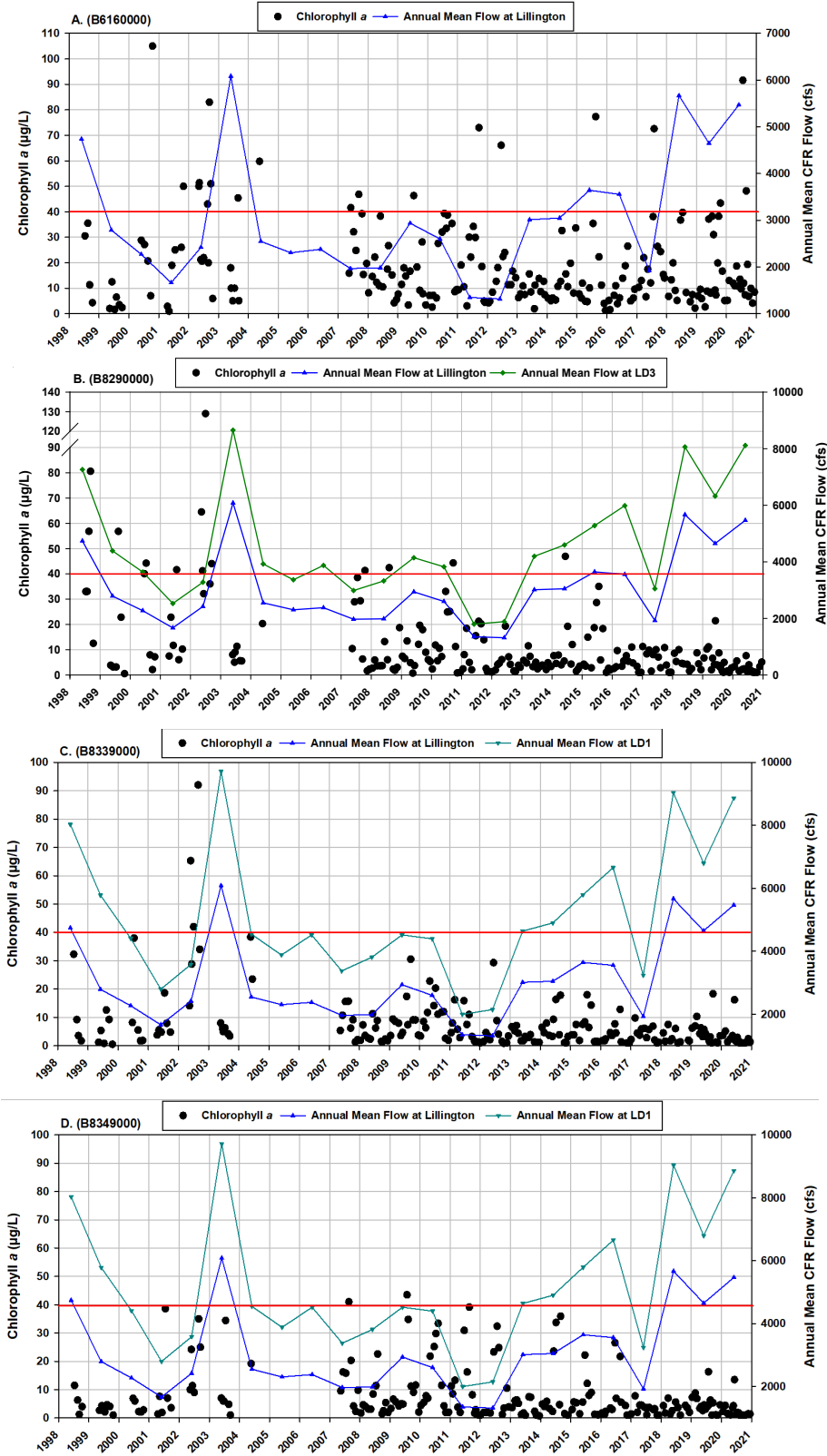
Long-term water quality changes and data interpretation challenges include:

- Chlorophyll *a* samples collected using a surface grab sampling technique prior to November 2004.
- Since November 2004, Cape Fear River chlorophyll *a* samples are collected from a boat using a depth integrated sampling technique--twice the Secchi depth, resulting in the likely dilution of the chlorophyll *a* concentrations.
- In November 2004, the monitoring coalitions changed from monthly summer critical-period monitoring to year-round monthly monitoring, a change in monitoring frequency.
- Between June 2004-April 2007, monitoring coalition laboratory chlorophyll *a* methodology issues caused exclusion of data.
- The 2014 IR/303(d) use support methodology changed from >10% excursion of a standard to inclusion of a 90% statistical confidence. This increased the actual number of excursions needed to rate a stream segment as impaired to 15-30%, depending on the number of samples taken during the 5-year assessment period. Statistical confidence was not needed in 2014 to delist a waterbody. Statistical confidence to delist a waterbody was added to methodology in 2018. The 2014IR data window was 2008-2012.
- A 2010 Cape Fear River algal special study identified “severe” and “extreme” blooms that did not exceed the existing 40 µg/L chlorophyll *a* standard below Buckhorn Dam.
- Most episodic blooms did not exceed the chlorophyll *a* standards, even when bloom conditions warranted DEQ and DHHS to release public advisories to limit contact with the river due to HAB blooms or presence of microcystin toxin.
- Changing environmental factors that influence algal bloom intensity, extent, and duration.
- There are very few access points or river crossings on the mainstem Cape Fear River upstream of Wilmington. This likely results in algal blooms going unreported. Most of the mainstem Cape Fear River algal bloom reports come from the ambient monitors and the USACE lockmasters at the three Cape Fear River locks and dams.

Four stations located in the backwaters of Buckhorn and the lock dams on the mainstem Cape Fear River are presented here for comparing concentrations over time (*Table 9-25* and *Figure 9-128*).

- A. **B6160000**, Upstream Cape Fear River station, located upstream of the Buckhorn Dam at NC 42 near Corinth.
- B. **B8290000**, Middle Cape Fear River station, located upstream of LD#3 at the Dupont water intake.
- C. **B8339000**, Middle Cape Fear River station, located upstream of LD#2 near Elizabethtown.
- D. **B8349000**, Lower freshwater portion of the Cape Fear River station, located upstream of LD1 near East Arcadia

Figure 9-128: 1998-2020 Chlorophyll a Concentrations at Four Cape Fear River Mainstem Stations with Yearly Mean USGS Flow. (Red Line Represents the 40 µg/L Chlorophyll a Standard).



A.) Station B6160000 at NC 42 and USGS Gage at Lillington # 02102500,

B.) Station B8290000 at Dupont water intake and USGS Gages at Lillington #02102500 and William O. Huske Lock #02105500,

C.) Station B8339000 at Lock and Dam #2 and USGS Gages at Lillington #02102500 and Lock#1 #02105769,

D.) Station B8349000 at Lock and Dam#1 and USGS Gages at Lillington #02102500 and Lock#1 #02105769.

The chlorophyll *a* concentrations tend to be higher in the upstream portion of the Cape Fear River mainstem no matter what sampling technique was used (*Figure 9-128*). The upper portion of the river is likely influenced by releases from Jordan Lake Dam. This includes contributing nutrients and algal populations that feed possible blooms downstream. Algal species found behind Buckhorn Dam are often similar to those identified in Jordan Lake (DWR-AAP communication). Chlorophyll *a* concentrations were generally higher at all four stations during low-flow conditions and prior to the switch to depth integrated sampling by the monitoring coalitions in November 2004. Very few excursions of the standard occurred even during the periods of extreme algal blooms in 2009-2012.

A 2016 DWR assessment looked at how chlorophyll *a* concentrations corresponded to river flows at two mainstem Cape Fear River locations behind LD#1 (B8349000; USGS gage 02105769) and LD#3 (B8290000; USGS gage 02105500). These are two locations where blooms formed during the 2009-2012 chronic bloom events and are located close to a USGS flow gage. Chlorophyll *a* data used for the assessment was collected by the MCFBA and was collected between 1998 and 2014. (See discussion above on how chlorophyll *a* monitoring and sampling have changed over the years.) The flow statistics for this assessment were based on USGS flow gage records for 1/1/1983 to 8/7/2016.

Elevated chlorophyll *a* concentrations generally occurred during lower-flow conditions at these two stations on the Cape Fear River (*Table 9-26* and *Figure 9-129*). At LD#3, in the middle portion of the Cape Fear River above Tar Heel, NC, corresponding chlorophyll *a* and flow data show that algal productivity causing a chlorophyll *a* concentration of 20 µg/L or greater can develop at flows approximately <2,300 cfs, which occurred about 51% of the time (*Table 9-26*). Chlorophyll *a* concentrations of 30 µg/L or greater occurred at flows <1,900 cfs with the majority of the elevated chlorophyll *a* concentrations occurring historically at stream flows <1,450 cfs, occurring about 34% of the time (*Table 9-26* and *Figure 9-129*).

At LD#1 near Riegelwood NC, river flow <1,650 cfs, which occurred 35% of the time, can cause chlorophyll *a* concentrations of 20 µg/L or more and river flow <1,250 cfs, which occurred 21% of the time, can cause chlorophyll *a* concentrations of 30 µg/L or more (*Table 9-26* and *Figure 9-129*).

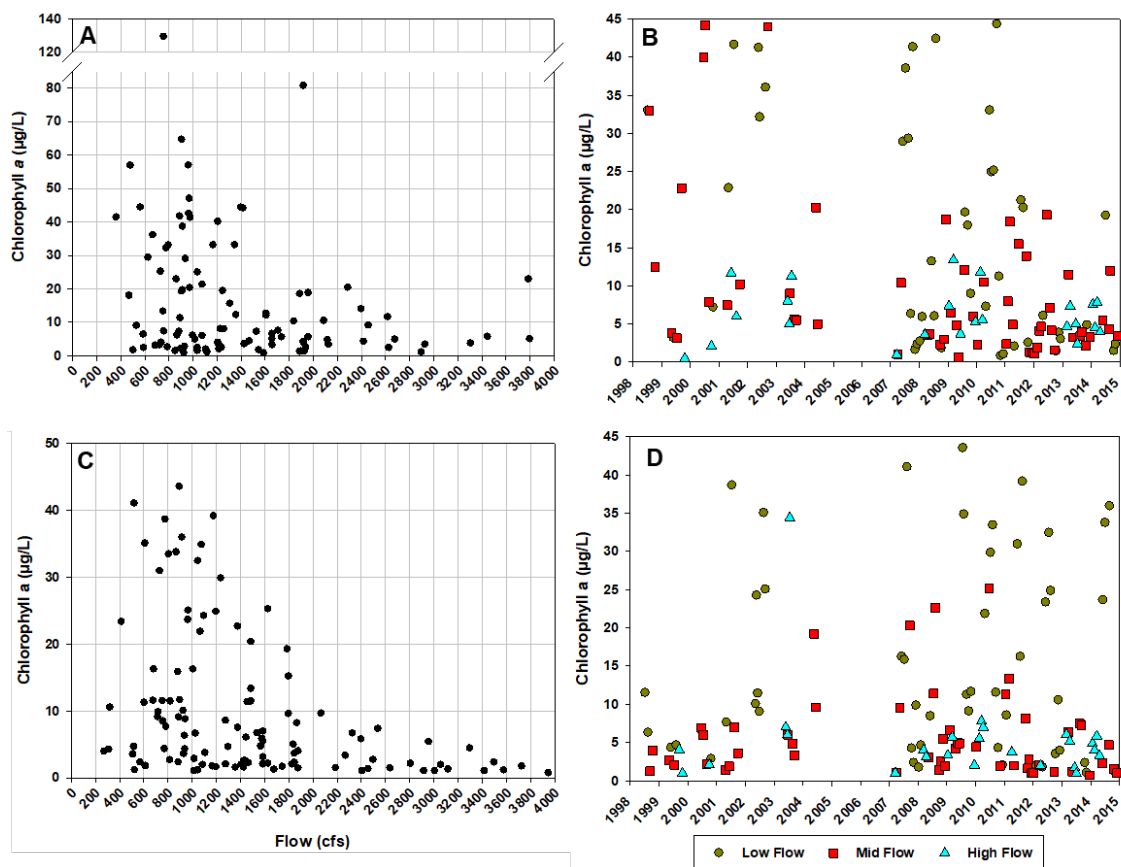
*Table 9-26: Historical Cape Fear River Streamflow's Which Limit Algal Productivity Behind Lock and Dam Number 1 and 3 (LD#1 & LD#3) and the Percent of Time Below that Flow.*

Chlorophyll <i>a</i> Concentration	B8290000/ LD#3 Flow (02105500)	Percent of Time Below Flow at LD#3*	B8349000/ LD#1 Flow (02105769)	Percent of Time Below Flow at LD#1*
>10 µg/L	<2,625 cfs	~ 66 %	<1,800 cfs	~ 38 %
>20 µg/L	<2,300 cfs	~ 51 %	<1,650 cfs	~ 35 %
>30 µg/L	<1,450 cfs	~ 34 %	<1,250 cfs	~ 21 %

\*Flow statistic based on the flow record of 1/1/1983-8/7/2016.

Chlorophyll *a* data summaries for data collected between 1998 and 2014; No available data for the period of July 2004-February 2007.

Figure 9-129: Corresponding Chlorophyll *a* and Streamflow Data at the Middle Cape Fear River Station B8290000 (A and B) (LD3) and Lower Cape Fear River Station B8349000 (C and D) (LD#1).



Note: Flow statistics were done using DWR-WRISAR database. Stream flow was separated into three categories:

- 1.) Low-flows, the bottom 25<sup>th</sup> percentile flows;
- 2.) Mid-flows based on flows between the 25<sup>th</sup> and 75<sup>th</sup> percentile; and
- 3.) High-flows based on greater than the 75<sup>th</sup> percentile of river flow between 1/1/1983 (post Jordan Lake impoundment) through 8/7/2016 (time of assessment).

Chlorophyll *a* sampling technique changed throughout this assessment period with samples prior to November 2004 collected using as surface grab method and post November 2004 using depth integrated technique.

Research and modeling has shown that the Cape Fear River is nutrient replete with instream nutrients well in excess of phytoplankton growth requirements, and the river becomes thermally stratified during sustained periods of low flow resulting in algal bloom formation in the upper portion of the water column (Hall 2021; Hall and Rosman 2022; Whalen and Dubbs 2005).

It has been recognized that “harmful toxigenic blooms of cyanobacteria, *Microcystis sp.* have become common during summertime along the Cape Fear River from Fayetteville to LD#1” (Hall 2021). Hall and Rosman (2022) reported “the highest chlorophyll *a* values occurred on low flow days when the water column was thermally stratified and indicated that low flow thermally stratified conditions are conducive for net phytoplankton growth”. They also reported that the highest chlorophyll-*a* concentrations were

observed on a day with strong thermal stratification and was preceded by about a week of stable flow around 1,500 cfs. They concluded that thermal stratification was found to “suppress vertical mixing and isolates the surface layers from the bottom layer. With limited vertical mixing, phytoplankton remain close to the surface and experience higher average irradiance conditions that can stimulate blooms of the light limited Cape Fear River phytoplankton community” (Hall and Rosman 2022). This work supports the efforts by TNC and USACE [Sustainable Rivers Program](#) (SRP) on the Cape Fear River to use pulse releases from Jordan Lake Dam to improve water quality and fish passage efforts downstream throughout the year as hydrologic conditions allow.

Many of the research findings described here and in Chapter 2, support the need to re-evaluate how algal blooms and routine chlorophyll *a* monitoring should be conducted in this system. Depth-integrated sampling during bloom events does not allow for a clear understanding of the instream conditions as the algal blooms appear to be highly influenced by the stratified conditions that set up during low-flow river conditions.

DWR has received suggestions to modify the chlorophyll *a* sampling protocols as part of the 303(d) public review, noting that the depth-integrated method in the mainstem Cape Fear River is not likely an appropriate method given the type of algal species that bloom and the light limitations. One of the many questions to consider moving forward would also be, is chlorophyll *a* the most effective means to measure the impact of nutrient in flowing streams and/or is the current 40 µg/L standard appropriate for determining the overall health of flowing streams? *It is recommended that DWR work with researchers to review current standard operating procedures (SOPs) for monitoring Cape Fear River algal blooms and monthly routine monitoring.*

Over the last 20+ years, the instream water quality condition of the Cape Fear River has been investigated in the hopes of furthering our understanding of this complex and important ecosystem. There are many factors that impact the ability of algae to grow and bloom. DWR will continue to work with researchers and stakeholders to understand this system and *will work with the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) to develop instream criteria* that makes it possible to accurately assess the health and protect this critically important resource as our state continues to grow along with the need for more clean water to drink and support growing communities and industries in this basin.

## **Actions and Recommendations**

*Basin Planning has several recommendations specific to the Cape Fear River:*

- Based on best available science, modify the chlorophyll *a* sampling techniques to capture actual instream conditions.
- Add monitoring where needed to improve understanding of water quality conditions (parameters, frequency, spatial extent, large streams, small streams, bloom events, etc.).
- Based on best available science, develop instream nutrient criteria (nitrogen and phosphorus) as directed by EPA.
- Modify the chlorophyll-*a* criteria to better protect flowing riverine systems.
- Develop nutrient management strategies as needed to reduce loading from all sources.

- Encourage WWTP optimization to improve nutrient removal processes at existing treatment works.
- Support additional research and modeling on conditions influencing algal productivity and nutrient source identification.
- Support the TNC/USACE Cape Fear River Sustainable Rivers Program (SRP) initiative.
- Support local initiatives to improve water quality (BMPs, Watershed Action Plans, stream restoration efforts, water and wastewater regionalization efforts, stronger stormwater programs, stronger sediment and erosion control programs, stronger local ordinances, etc.).

### 1.11 Cape Fear Estuary Low DO and pH Summary

As noted throughout the basin plan, water quality standards are based on the classification of the waterbody and the designated uses they are devised to protect. The classifications throughout the lower segment of the Cape Fear River estuary change from freshwater class C, WS-IV, swamp water (Sw) at the base of LD#1 near Kelly, NC and transitions to saltwater, class SC with some shellfishing waters (SA) along the approximate 60-mile estuarine path to the Atlantic Ocean near Bald Head Island. This area also includes Primary Nursery Areas (PNAs) where initial post-larval fish development takes place ([15A NCAC 03I .0101](#)) and critical habitat exists for the federally listed endangered Atlantic (*Acipenser oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum*). To see a map of PNAs in the Cape Fear River Estuary see the DMF [PNA map link](#).

The Lower Cape Fear River subbasin has all of the saltwater (SW) acre impairments, 743.7 acres exceeding the pH 6.8 s.u. standard. There was an error identified during the development of the basin plan that found an additional 4,282.8 SW acres should have been on the 2022 IR due to pH levels <6.8 s.u. in the Lower Cape Fear River estuary--between AU # 18-(71)a1, from Cartwheel Branch upstream of Toomers Creek to AU# 18-(71)a5, 1.9 miles downstream of Mott Creek--for a total of 5,025.6 SW acres ([Table 9-2](#) and [Table 9-27](#)). The standard applied was <4.3 s.u. instead of <6.8 s.u. These sections of the Cape Fear River estuary will be added as a correction on the 2024 IR as long as the instream value remains low. This low pH coincides with the same area of low DO and the SC to swamp waters declassification area.

The acidic conditions along the lower Cape Fear River are likely affected by the presence of wetlands, particularly, the stations near Wilmington that receive drainage from the most expansive areas of swamp forest in the basin near where the Cape Fear and Black rivers merge and the lower part of the Northeast Cape Fear River. Further investigation is needed to verify whether any other non-natural anthropomorphic pollutants may be affecting pH levels.

The DO in Class C freshwaters should not be less than a daily average of 5 mg/L or a minimum instantaneous value of not less than 4 mg/L. Swamp waters, backwaters, and lake bottoms may have lower DO if caused by natural conditions (15A NCAC 02B .0211). DO levels in saltwater should not be less than 5.0 mg/L. Swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions (15A NCAC 02B .0220). As of 2022, DWR only assesses the DO standard at the surface of the water column. DO generally declines with depth

if a system is stratified, not well mixed, or in estuarine systems with the salt wedge at the bottom flowing in from the ocean. In the areas impaired for low DO, the entire water column is experiencing low DO. The DO concentrations generally decline with depth and are likely much lower at the bottom of the water column, making it difficult for many aquatic species to find refuge during long periods of low DO. The Cape Fear River [AU# 18-(71)] was added to the NC Impaired Waters list in 1998 and the Brunswick River (AU# 18-77) was listed in 2006.

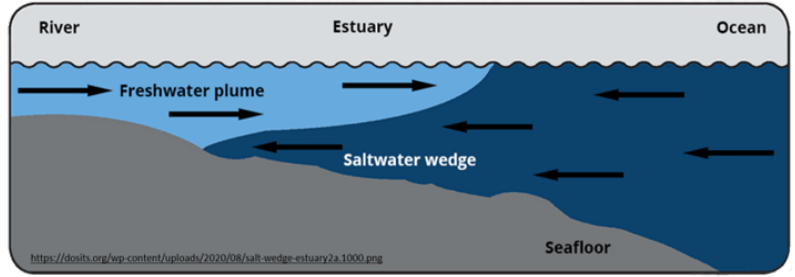


Table 9-27: Lower Cape Fear River Estuarine Stations with Percentage of Samples Not Meeting Water Quality Standards for pH and Dissolved Oxygen (DO) for 2022 IR Period (2016-2020)

Cape Fear River Estuary	Assessment Unit #	Stream Class	Area Miles (mi) or Acres (A)	Station #	~ # of samples	Mean DO (mg/L)	Minimum DO (mg/L)	% DO < 4 mg/L* or < 5mg/L	Median pH	Minimum pH	% pH <4.3 ^ or <6.8
Cape Fear River Nr Acme	18-(63)a	C; Sw	3.8 mi	B8450000	100	7.70	4.3	0*	6.7	5.5	0^
Black River Flows into Cape Fear River											
Cape Fear River Nr Sutton Lake	18-(63)b	C; Sw	18.5 mi	B9030000	71	6.41	0.2	9.6*	6.6	5.6	0^
Brunswick River	18-77a & 18-77b	SC	743.7 A	B9790000	57	6.81	3.2	28.1	7.0	5.3	26.3
Cape Fear River At Navassa (upstream of split)	18-(71)a1	SC	*10.6 A	B9050000	35	7.12	3.2	28.6	6.6	5.2	60.6
Cape Fear River At Navassa (upstream of split)	18-(71)a2a	SC	*290 A	B9050025	70	6.34	3.1	40.0	6.7	5.4	57.1
Cape Fear River At Horseshoe bend nr Wilmington	18-(71)a2b	SC	*149.8 A	B9050100	70	6.33	2.9	38.6	6.8	5.2	42.9
Northeast Cape Fear River Flows into Cape Fear River Estuary											
Cape Fear River Below NCFR/above confluence with Brunswick R.	18-(71)a3	SC	*1,274.9 A	B9800000	104	6.49	2.7	36.5	7.0	5.6	26.9
Brunswick River Flows into Cape Fear River Estuary											
Cape Fear River Below confluence of Brunswick R.	18-(71)a4	SC	*372.9 A	<b>B9820000</b>	34	7.40	4.0	24.2	6.9	6.2	45.5
Cape Fear River Just below B9820000	18-(71)a5	SC	*2,183.7 A	B9795000	71	6.57	3.0	26.8	7.3	5.6	12.7
Cape Fear River Above Snows Cut	18-(71)a6	SC	1,394 A	NA	--	--	--	--	--	--	--
Cape Fear River Nr Carolina Beach	18-(71)b	SC	7,855.1 A	B9850100	71	7.12	3.3	8.5	7.7	6.4	7
Cape Fear River Nr The Basin	18-(87.5)a	SA;HQW	769 A	B9910000	74	7.30	4.0	2.7	7.9	6.9	0

Cape Fear River Estuary	Assessment Unit #	Stream Class	Area Miles (mi) or Acres (A)	Station #	~ # of samples	Mean DO (mg/L)	Minimum DO (mg/L)	% DO < 4 mg/L* or < 5mg/L	Median pH	Minimum pH	% pH <4.3 ^ or <6.8
Cape Fear River Nr Southport	18-88-3.5	SC	715 A	B992100	74	7.25	4.7	1.4	8.0	6.8	0

\* Area may be added to 2024IR for low pH standard violations. Depends on data collected between 2018-2022.

Note:

Saltwater SC DO standard is not less than 5 mg/L and the pH standard is not less than 6.8 s.u.

Freshwater \*DO standard not less than 4mg/L in class C waters.

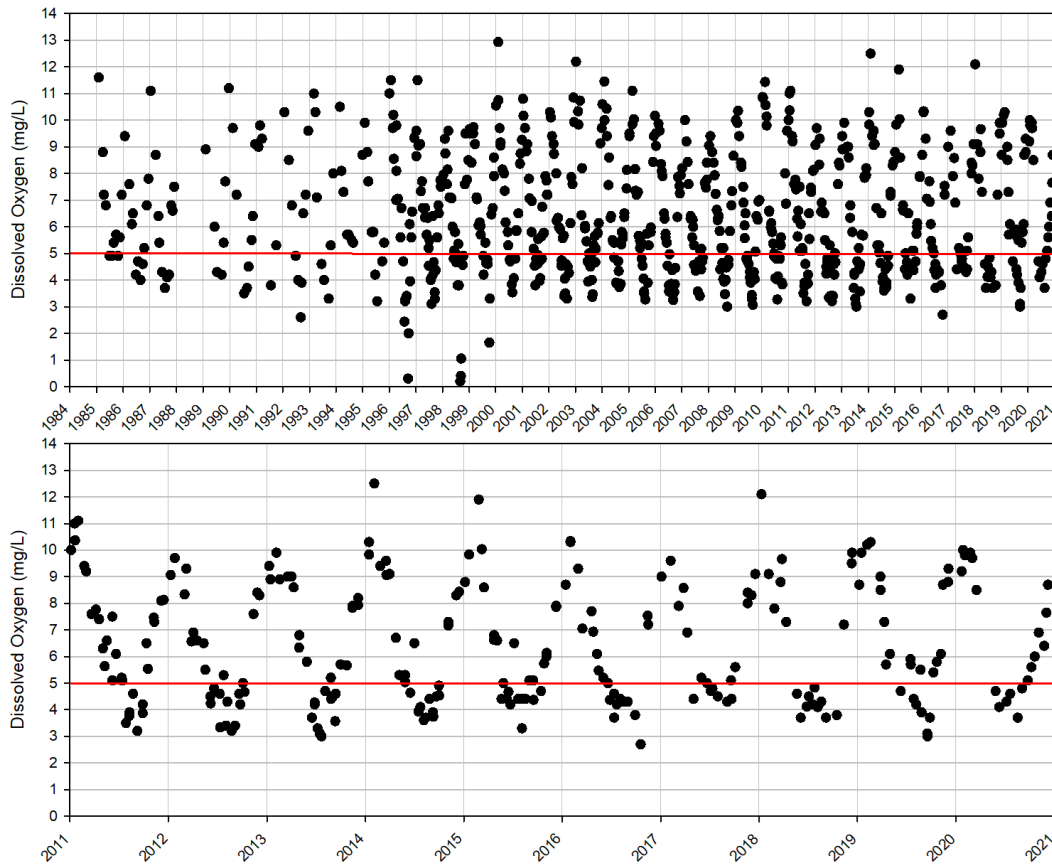
Freshwater ^pH standard not less than 4.3 s.u. in class Sw waters.

Green highlights the Brunswick River from the Cape Fear River mainstem. Saltwater standards apply.

In 2022, there were 5,025.6 SW acres impaired for DO, all in the Lower Cape Fear River subbasin ([Table 9-2](#) and [Table 9-27](#)). The same lower Cape Fear River and Brunswick River saltwater stations located near Wilmington with acidity (low pH) issues also had low DO during the 2016 to 2020 timeframe ([Table 9-27](#)). The impairment extends from AU# 18-(71)a1, from Cartwheel Branch (upstream of Toomers Creek and above Eagle Island) to AU# 18-(71)a5, 1.9 miles downstream of Mott Creek and includes all of the Brunswick River (AU# 18-77a and 18-77b). These stations were below the 5 mg/L DO saltwater standard between 25 and 39% of the time ([Table 9-27](#)).

A substantial drop in the surface DO levels begins between Cape Fear River mainstem station B8450000 near Acme (C; Sw) and station B9030000 adjacent to Sutton Lake (C; Sw). The 2022 IR mean and minimum readings were 7.70 and 4.3 mg/L at B8450000 and 6.41 and 0.2 mg/L at B9030000 respectively. The DO dropped below 4 mg/L 9.6% of the time (2016-2020) at B9030000 ([Table 9-27](#)). Note, in the previous sections that summarize water quality in the Cape Fear River mainstem and tributaries, B8450000 was the sixth station in the Hood Creek-Cape Fear segment and B9030000 was the second station in the Brunswick River-Cape Fear segment (see [Table 9-21](#) or [Table 9-22](#)). The Black River drains to the Cape Fear River Estuary between these two monitoring stations and appears to influence the conditions in the mainstem Cape Fear River. About 5.5 miles downstream, the stream classification of the Cape Fear River Estuary transitions to SC, where the water quality standard changes from 4 to 5 mg/L. The number of times the ambient surface water reading falls below the standard increases substantially resulting in the low DO impairment ([Table 9-27](#)). The impairment extends about 14.5 river miles from Cartwheel Branch to 1.0 mile downstream of Mott Creek and includes all of the Brunswick River. The highest percent exceedance of the DO standard was 40% in station B9050025 (third station in the Brunswick River segment, [Table 9-21](#) or [Table 9-22](#)). The lowest recorded surface DO reading of 2.7 mg/L occurred on 10/19/2016 further downstream at station B9800000, the fifth station in the Brunswick River segment, which is below the confluence with Northeast Creek ([Table 9-21](#); [Table 9-22](#); [Table 9-27](#)). [Figure 9-130](#) shows the historical DO concentrations at B9800000. The range in DO concentrations has remained fairly consistent over the 35 years of data presented. There were a few years with very low DO concentrations (1996, 1998, and 1999). There is a summer/fall seasonal low DO pattern that can be easily distinguished in the shorter period in [Figure 9-130](#). Warmer water holds less DO, so this trend is seen in most warm water ecosystems like the Cape Fear River Estuary. The concern is how low the DO gets throughout the water column and the potential effect on the aquatic organisms and the critical habitat.

Figure 9-130: Cape Fear River Estuarine Ambient Surface Water DO Readings for Station B9800000 between 1985-2020 and 2011-2020. Red Line Represents the Saltwater DO Standard



In order to understand seasonal or monthly impacts on DO concentrations, DWR examined the monthly mean DO concentrations at several stations along the mainstem Cape Fear River Estuary as well as the lowest stations in the Black and Northeast Cape Fear rivers to understand their influence on the overall low DO issue in the estuary. The average DO concentration for each month's average concentration, based on the surface water quality monitoring data from 2002 to 2020, was used for this assessment. As described above, there is a substantial drop in the surface DO levels between Cape Fear River mainstem station B8450000 (dark gray line) and station B9030000 (black line) between the months of May and December (*Figure 9-131-a; Table 9-27*). The Black River (green line, B9013000) and Hood Creek drain to the mainstem Cape Fear River between these two stations and likely contribute to lowering the instream DO concentrations. All of these streams are classified as C, swamp (Sw) waters and are known to have naturally low DO concentrations. The long-term monthly means did not fall below 4 mg/L at B9030000 in the Cape Fear River but were below 5 mg/L between June and October (black line, *Figure 9-131-a*). The long-term monthly DO means in the Black River were below 5 mg/L between May and October and below 4 mg/L from June through September (green line in *Figure 9-131-a*).

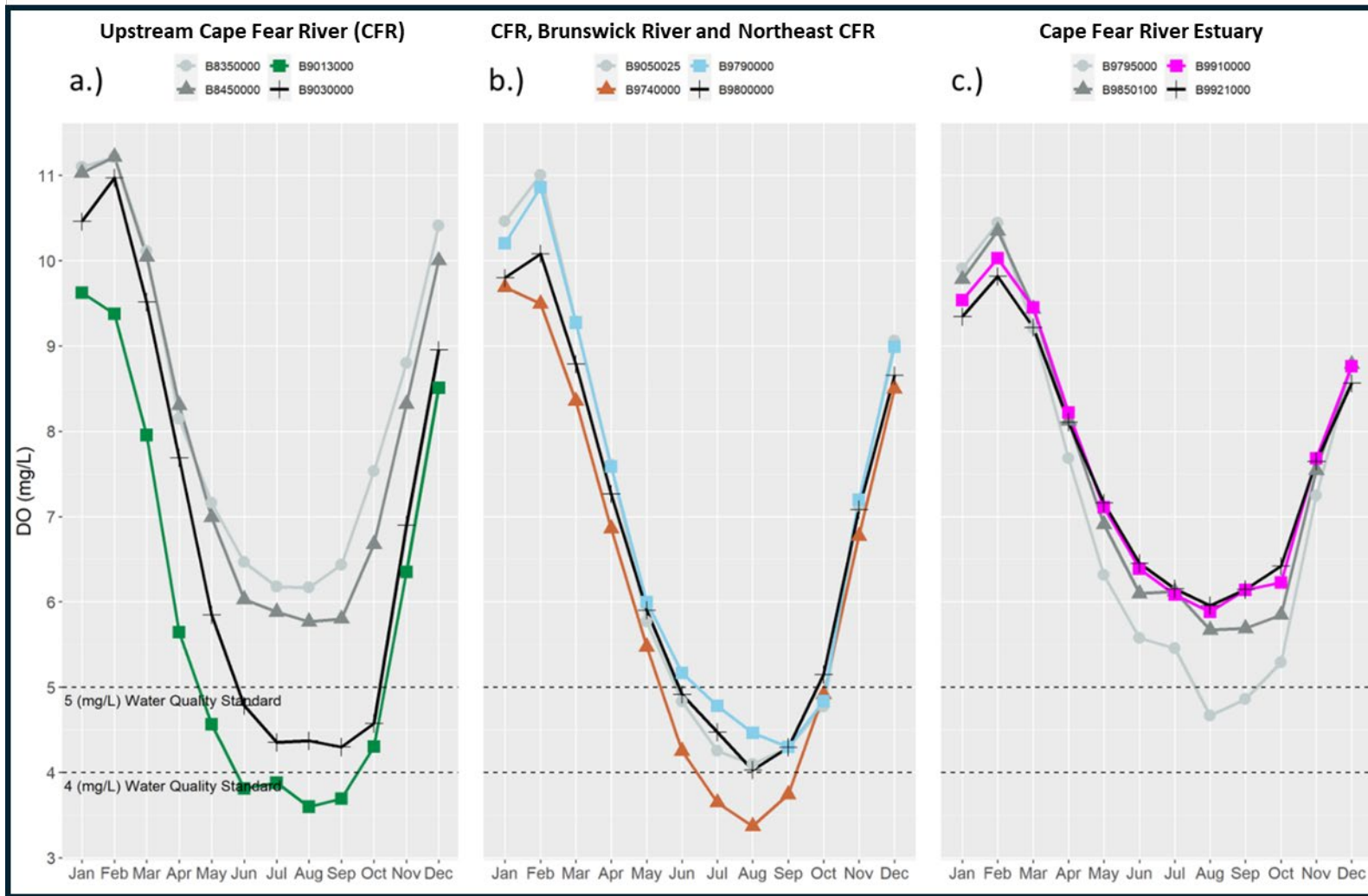
The rest of the Cape Fear River estuarine stations for this assessment are classified as SC except for the Northeast Cape Fear River, which is SC and swamp (Sw). The Cape Fear River station B9050025 (light gray)

is just upstream of the split around Eagle Island with the Brunswick River flowing to the right and the mainstem Cape Fear River flowing to the left where it is joined by the Northeast Cape Fear River about 2.8 miles downstream in downtown Wilmington. Station B9800000 (black) is on the Cape Fear River side of Eagle Island about 3.3 miles downstream of the confluence of the Northeast Cape Fear River. Station B9790000 (blue) is about midway down the Brunswick River. The Northeast Cape Fear River station B9740000 (orange) is located 0.8 miles upstream of the confluence with the Cape Fear River near the Hwy 74 bridge in Wilmington. The long-term monthly means fall below 5 mg/L between June and October for station B9050025 (gray line), between June and September for station 9800000 (black line), between July and October for B9790000 (blue line) and June-October for B9740000 (orange line) (*Figure 9-131-b*). The drop in the DO concentrations during the warmer months of the year is very similar at all these stations with the Northeast Cape Fear River having a slightly lower overall summer mean (*Figure 9-131-b*). The two mainstem river stations (B9050025 and B9800000) and the Brunswick River station (B9790000) fell below the 5 mg/L standard between 28 and 40% of the time for the 2022 IR period (*Table 9-2*).

The lower portion of the estuary is represented in *Figure 9-131-c*, where there is a gradual improving instream DO condition moving seaward (*Table 9-27*). Station B9795000, just north of Town Creek and the seventh station in the Brunswick River segment, is the last station in the DO impairment area (*Table 9-21*; *Table 9-22*). While 27% of the samples recorded were below 5 mg/L during the 2022 IR period, the overall seasonal/monthly excursions of the standard appear to occur mainly in August and September (light gray line; *Figure 9-131-c*). The remaining stations show improving DO conditions as seen in the monthly means and by the percent exceedances declining with each successive downstream station (*Table 9-27*). The lower end of the Cape Fear River Estuary has a much larger tidal exchange and is more likely to be less stratified due to mixing with the Atlantic Ocean currents and wind-driven mixing.

The low summertime dissolved oxygen concentrations (<5 mg/L), similar to the low pH levels are likely impacted by the expansive forested swamp lands draining to the Cape Fear River estuary. The dissolved oxygen concentrations like other instream constituents are also impacted by all the upstream point and nonpoint sources of pollutants that drain to the Cape Fear River Estuary. The estimated number of permits is extensive at the Cape Fear River estuarine station B9820000, located at channel marker 56 near Barnards Creek, south of Wilmington, NC (*Table 9-28*). The drainage area at station B9820000 is estimated to be about 8,865 mi<sup>2</sup> with the whole basin being 9,164 mi<sup>2</sup>.

Figure 9-131: Long-Term Mean Monthly DO Levels in the Cape Fear River Estuary. Estuary split into Three Sections: Upper, Middle, and Lower



Stations are examined from upstream to downstream based on data collected between 2002 and 2020 at surface water quality monitoring stations. Three Segments: a.) Upper represented by stations B8350000, B8450000, B9013000 & B9030000, b.) Middle represented by stations B9050025, B9740000, B97900000, & B9800000, and c.) Lower represented by stations B97950000, B9850100, B9910000 & B99210000. Also see [Figure 9-118](#) map of stations.

Table 9-28: Number of Watershed Permits and Land Use Type at Cape Fear River Estuarine Station B9820000 (Located at Channel Marker 56 Near Barnards Creek).

Possible Source Type at Station B9820000	Permits	Other
NPDES Wastewater	46 Major; 412 Minor	Total of 417.85 MGD Permitted As-Built Flow
NPDES Stormwater	672	1,261 Outfalls
NPDES Non-Discharge	1,813 fields	21,280 Permitted Acres
Animal Feed Operations	1,173	2,270 Lagoons
Poultry Inventory <sup>1</sup>	Deemed permitted only	76 million head, 2,464 operations <sup>3</sup>
Poultry Production Contracts <sup>2</sup>	Deemed permitted only	332.2 million head, 687 operations <sup>3</sup>
MS4 Stormwater Communities	34	
2019 NLCD Land Cover Type	Percentage of Watershed at Station B9820000	
Agriculture	21 %	
Developed/Impervious Surface	14 % Developed/3.7 % Impervious	
Forest	38 %	
Wetland	18 %	

<sup>1</sup>USDA Inventory numbers represent a point in time (End of December 2022) when the census data was collected.

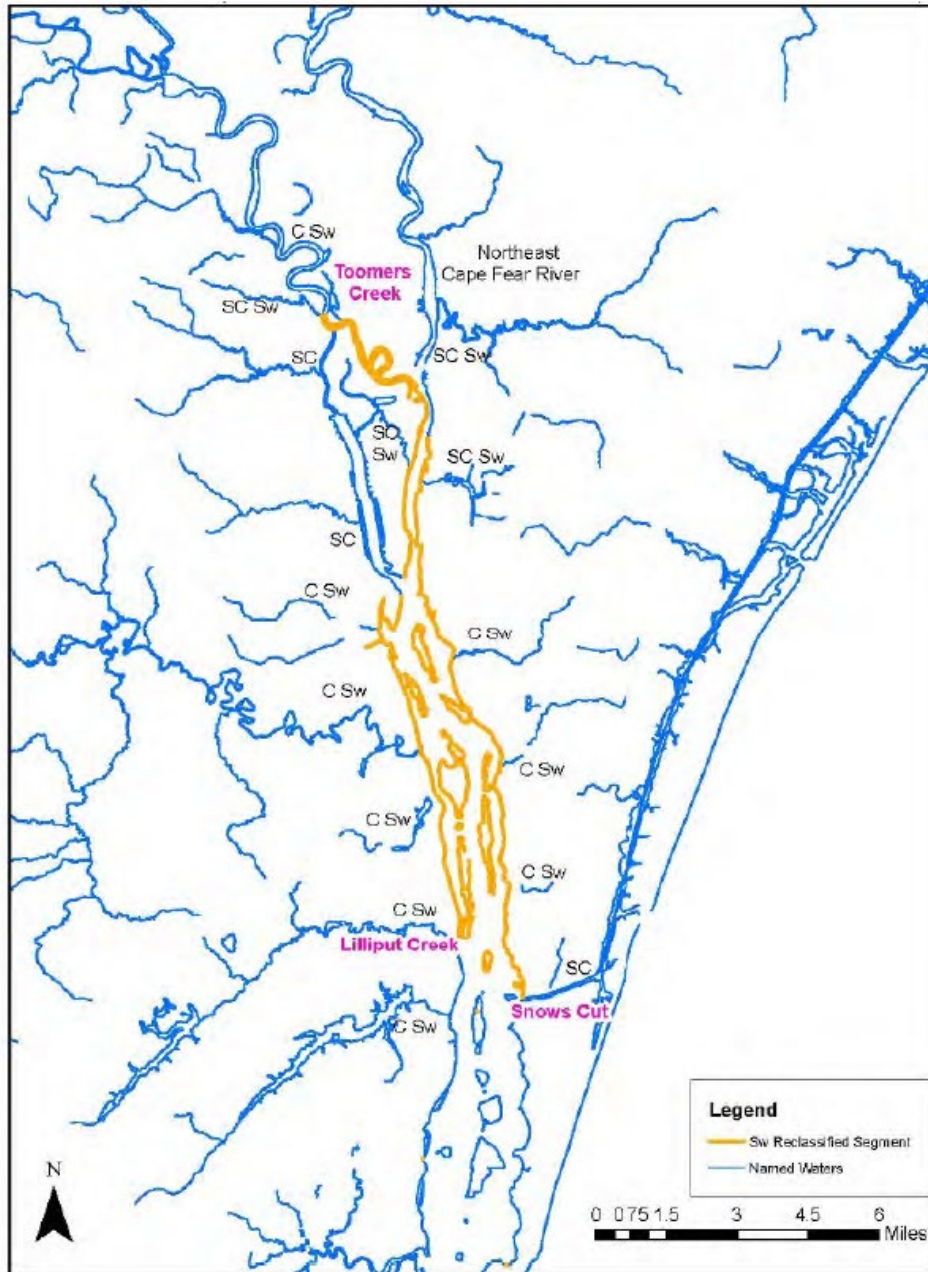
<sup>2</sup>USDA Production Contract numbers are “totals for the portion of agriculture production raised and delivered under production contract” (USDA, 2022). Production Contract numbers and Inventory are not additive. They each represent different data items.

<sup>3</sup>Poultry headcount and operations estimation for inventory and poultry production is based on 14 counties that had >50% land area within the Cape Fear River Subbasin. See Chapter 1 for more information.

### Cape Fear River Swamp Water Reclassification/Declassification

On May 13, 2021, the EMC removed the Swamp Waters (Sw) classification to an approximate 15.5-mile section of the Cape Fear River [AU# 18-(71)a1- 18-(71)a6] from the upstream mouth of Toomers Creek to a line across the river between Lilliput Creek and Snows Cut (*Figure 9-132*). The official action on May 13, 2021, removed the swamp waters (Sw) supplemental classification that was originally approved by the EMC in 2016, leaving this section classified as saltwater SC only (May 2021 [EMC Agenda](#); [15A NCAC 02B .0311](#)).

Figure 9-132: Map of Lower Cape Fear River Reclassification Area in Orange.



Due to the persistent low DO and pH impairments discussed above, a reclassification of the above segment of the Cape Fear River to include a supplemental Swamp Waters (Sw) classification was undertaken. A summary of the actions that followed include:

- 2014 - Lower Cape Fear River Program submitted a request for a supplemental Sw reclassification.
- 2016 - EMC adopted supplemental Sw classification amendments to 02B .0311 (and .0227 management plan to be discussed separately below).

- 2017 - Sw classification became effective in the NC Administrative Code.
- 2018 (July) - EPA disapproved the Sw amendments to 02B .0311 (detail below).

All state water quality standards, including classifications that are adopted by the state, must ultimately receive EPA approval to be used for Clean Water Act purposes. EPA disapproved the Sw reclassification on July 24, 2018, after determining that DEQ did not provide sufficient documentation that the above Cape Fear River segment met the state’s existing [definition of swamp waters](#), including velocities and other characteristics associated with the swamp classification (DEQ 2020, [Report of Proceedings, Appendix-EPA letter](#)).

EPA also noted that there were several tidal saltwater species, including the federally endangered shortnose sturgeon and Atlantic sturgeon<sup>1</sup>, and that this area is officially designated Primary Nursery Area (PNA) by the NC Marine Fisheries Commission. EPA stated that DEQ did not “provide alternative dissolved oxygen or pH values that could demonstrate the protection of the organisms living in the river, including endangered sturgeon.”

In July 2019, Southern Environmental Law Center (SEL) submitted a rulemaking petition requesting the EMC remove the supplemental Sw classification. The EMC granted the petition for rulemaking and approved the removal of the Sw classification on May 13, 2021 (May 2021 [EMC Agenda](#); [15A NCAC 02B .0311](#)).

Included with the 2021 removal of the supplemental Sw classification, part of the [15A NCAC 02B .0227](#) management plan that was disapproved by EPA was also removed. What remains in the management plan are requirements for new and expanding dischargers to provide treatment for oxygen-consuming wastes. For more details, see the permitting strategy in Chapter 3, section 3.2.4.

As with any waterbody on the 303(d) impaired waters list, a TMDL or management strategy is required. DWR continues to explore potential paths to address the low DO and pH issue in the estuary. Currently, DWR is working with the EPA to finalize a model for the middle portion of the Cape Fear River Basin that will include source assessment and support nutrient criteria development. Researchers at UNC-Wilmington have shown that inputs of dissolved nitrogen (nitrate, ammonium, and urea) significantly stimulate algal growth, which in turn significantly stimulates BOD (Mallin et al., 2004). They have also reported that nutrients are directly correlated to BOD in the blackwater streams and rivers of the Cape Fear River Basin (Mallin et al., 2004). As the NCDP process looks to protect the designated uses in the middle Cape Fear, understanding the impacts nutrients have on the downstream condition will be important to consider when developing the most appropriate instream criteria.

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<sup>1</sup> The 2016 Coastal Habitat Protection Plan (CHPP) states that the Cape Fear River and Albemarle Sound are the only estuaries in North Carolina that presently show evidence of spawning for the Atlantic sturgeon. According to the Atlantic States Marine Fisheries Commission (2009), “... *dissolved oxygen is a very important habitat parameter for juvenile Atlantic sturgeon. A large proportion of Atlantic sturgeon nursery habitat has been degraded as a result of persistent low levels of dissolved oxygen.*”

## 1.12 Cape Fear River Estuarine Tidal Flow and Nutrient Processing

The Cape Fear River Estuary is unique in NC because it is the only major NC estuary with direct access to the Atlantic Ocean. This feature allows for the daily exchange of water, limiting the buildup of nutrients, algae, and other pollutants. The construction of Snow's Cut in 1930, as part of the ICWW, and the Carolina Beach Inlet in 1952 added an additional connection of the estuary to the ocean and has a major impact on salinity and the exchange rate in the estuary (McAdory 2000). The Cape Fear River from the mouth to the port at Wilmington has been modified to maintain shipping lanes, since the 1800's. The present depth is 42 feet with plans to deepen to 47 feet to accommodate larger vessels (NC Ports 2023). Additionally, the lowermost 2.5 miles of the Northeast Cape Fear River was dredged to a depth of 32 feet. The next 48 miles of the Northeast Cape Fear River were dredged to a depth of six feet in 1896 and the next eight miles were dredged to a depth of three feet (Giese et al. 1985).

There is a strong tidal influence that can reach about 65 miles upstream from the mouth of the Cape Fear River near Southport to Lock and Dam #1 (Giese et al. 1985). Tidal influence also extends 48 miles upstream in the Northeast Cape Fear River from its confluence with the Cape Fear River at Wilmington. In the Black River, a tidal influence has been recorded at Davis Landing, 38 miles upstream from the river's confluence with the Cape Fear River (Giese et al. 1985). The extent of the tidal influence is highly dependent on the freshwater river discharge rate. The lower segment of the estuary experiences tidal oscillations resulting in upstream flow during incoming tides that can push contaminants upstream for a tidal cycle.

Mallin et al. (1997) captured the diversity of the estuary at three sampling stations. The uppermost sampling station near Navassa, upstream of Eagle Island and the Brunswick River diffluence, was described as fresh to oligohaline, nutrient levels were high and average chlorophyll biomass was low, and water samples exceeded the state turbidity standard. The researchers suggested that light may be the limiting factor to phytoplankton production at the site. The second sampling station, south of Eagle Island, was found by the researchers to be mesohaline and bottom samples indicated the presence of an occasional salt wedge. Nitrogen was limiting to the phytoplankton community in summer and phosphorus was occasionally limiting in early spring. There was no nutrient limitation during months with heavy precipitation. Light appeared to be limiting in fall and winter when waters were rich in nutrients and turbid. Average monthly turbidity exceeded the state standard. The turbidity was typically associated with dredging operations and high river flow. The third and most downstream sampling station, between Snow's Cut and Southport, was polyhaline, with less turbid waters than upstream stations and nitrogen limited in summer and fall, and phosphorus limited in winter and spring. All the stations exceeded both the DO and turbidity state standards at some point during their study.

Mallin et al. (1997) found rainfall and river flow in the upper Cape Fear Basin to be a potentially important physical forcing mechanism in the estuary. Light attenuation, the change in intensity through the water column, is high in the upper estuary in part due to the inflow of water high in tannic acid from the Black and Northeast Cape Fear rivers. They found that there was a tendency to shift from light limitation to nutrient limitation with increasing distance between the upper and lower estuary.

Biological uptake plays an important role in the concentration of nitrogen constituents throughout the riverine/estuarine system. Inorganic forms of nitrogen (NO<sub>x</sub> and NH<sub>3</sub>) are generally utilized and converted

to organic forms as normal processes in biologically active systems. Mallin et al. (1997) found that greater than 50% of the total nitrogen was in the inorganic forms. Inorganic and organic nitrogen enter the upper estuary primarily through runoff and groundwater (Hines et al. 2012). Mallin et al. (1997) suggested that strong currents likely inhibited chlorophyll-*a* increases in the estuary. Ensign et al. (2004) stated that there was limited time for algal bloom formation and between 5 and 9% of nitrogen is incorporated into primary productivity and subsequently recycled.

Graham (2009) reported that the upper and middle reaches of the estuary showed a net removal of nitrate through the dominance of anaerobic ammonium oxidation (ANAMMOX) and denitrification, and the lower estuary displayed a net recycling of nitrate through dominance of dissimilatory nitrate reduction to ammonium (DNRA). Removal was defined as a loss from the system as N<sub>2</sub> while recycling was defined as conversion into NO<sub>3</sub><sup>-</sup> or NH<sub>4</sub><sup>+</sup>. The ANAMMOX and denitrification rates were generally highest upstream at lower salinities, whereas the DNRA rates were highest at elevated salinities. Rates of ANAMMOX and denitrification tended to be highest upstream where sulfide concentrations were lowest, and DNRA was highest downstream where sulfide concentrations were elevated.

A number of models have been developed for the Cape Fear River Estuary to simulate natural processes to better understand the impacts of channel deepening (McAdory 2000); the relationship of channel deepening to tidal changes and storm surge (Familkhalili and Talke 2016); flushing rates (Ensign et al. 2004); compound flooding from tropical cyclones (Gori et al. 2020); discharge plumes at the estuary-ocean confluence (Xia et al. 2007); nutrient pathways (Hines et al. 2012); and hydrology-water quality relationships (Bowen et al. 2009).

*Modeling of the estuary found that the flushing time could vary from one day to 22 days, depending on inflow* (Ensign et al. 2004). The flushing rate is seasonally dependent, with short durations occurring during the high-flow winter months and long durations occurring during the summer months. During the Atlantic hurricane season, June 1 through November 30, high-flow events within the basin can reduce residence time significantly. *Modeling of the estuary suggests that deepening of the channel has increased the mean tidal range and storm surge at Wilmington* (Familkhalili and Talke 2016). The researchers suggest that channel deepening reduces the amount of drag, which has a greater influence than changes to the channel margin.

Bowen et al. (2009), using the three-dimensional water quality model Environmental Fluid Dynamics Code (EFDC), found that over a three-year period approximately 10% of the organic matter loading and 50% of the ammonia loading to the estuary came from the 20 wastewater point sources that discharged directly to the estuary. *The dominant sources of oxygen demanding wastes to the estuary originated in the rivers, creeks, and wetlands.* They also investigated the impact of deepening the navigation channel on predicted dissolved oxygen concentrations in the estuary. Their model indicated a decrease in DO concentrations by approximately 0.1 to 0.2 mg/L. An increase from 32% to 34% in DO concentrations in the summertime in the impaired region that would be below 5.0 mg/L was reported.

Hines et al. (2012) created a network model to represent the microbial N cycle in the estuary. They listed 43 pathway parameters under aerobic and anaerobic conditions in both the water column and the sediment. Their modeling implied that large quantities of organic nitrogen move through the oligohaline

portion of the estuary without entering the microbial N cycle. Their results suggest that  $\text{NH}_4^+$  contributes more to nitrogen removal activity than organic nitrogen and that  $\text{NH}_4^+$  plays the most central role in the N cycle of the oligohaline portion of the estuary due to the coupling of nitrification to denitrification.

### 1.13 Lower Cape Fear River Subbasin Water Use

Water resources in the Cape Fear River Basin include surface and groundwater, 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. Water users also rely on private groundwater well(s) used to supply water for residents and associated activities. 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 the North Carolina Department of Environmental Quality (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 and ground water resources and calculating the volume of water moving through a system. For agriculture water use, the North Carolina Department of Agriculture & Consumer Services (NCDA&CS) 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.

#### 1.13.1 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 Lower Cape Fear River subbasin. Per North Carolina General Statute §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.

Twenty water systems are included in the Lower Cape Fear River subbasin. Based on the information reported by users, there are no apparent water quantity supply issues in the Lower Cape Fear River subbasin, not considering domestic users, non-reporters, other unknown usages, and ecological flows. The 2020 Lower Cape Fear River subbasin population served by public water supply systems was 249,747.

The public water supply systems in this subbasin had a combined average daily water demand of 27.78 MGD in 2020. Comparing this to the 137.93 MGD total available supply reported by these 20 public water systems in 2020, the combined average daily demand of the public water supply systems in the Lower Cape Fear River subbasin was about 20% of available supply. The Cape Fear Public Utility Authority – Wilmington is the largest system in the subbasin with an average daily water demand in 2020 of 12.0 MGD, or approximately 43% of the combined subbasin demand. A detailed description of the public water supply availability, demand, and projections for the Lower Cape Fear River subbasin is in Chapter 5.

### 1.13.2 Interbasin Transfer Certificates

The North Carolina Legislature adopted the Regulation of Surface Water Transfers Act (NCGS §143-215.22L) in 1993. The intent of the law is to regulate large surface water transfers between river basins by requiring a certificate from the Environmental Management Commission (EMC). [NCGS §143-215.22G](#) established 38 interbasin transfer (IBT) basins. An IBT certificate is required for a transfer greater than 2.0 million gallons per day (MGD) between any of the defined IBT river basins. In the Cape Fear River (2-3) basin, which has a portion that overlaps reasonably well with the Lower Cape Fear River subbasin (03030005), there are two IBT Certificates for the Brunswick County, as well as Pender County Utilities and Towns of Burgaw, Topsail Beach, Surf City and Wallace and Utilities Incorporated.

The Brunswick County IBT Certificate granted the request to transfer a maximum of 17 MGD, from the Cape Fear (2-3) “source” basin to Shallotte River (9-4) and Waccamaw River (9-3) “receiving” IBT basins. This IBT certificate was issued in 2013. Based on the information reported in 2020, the annual average IBT basin transfer from the Cape Fear (2-3) was 7.228 MGD to the Shallotte River (9-4) and 1.515 MGD to the Waccamaw River (9-3).

The Pender County Utilities and Towns of Burgaw, Topsail Beach, Surf City and Wallace and Utilities Inc. IBT certificate granted the request to transfer a maximum of 14.5 MGD from the Cape Fear (2-3) “sources” basin to South River (2-4), Northeast Cape Fear (2-5), and New River (2-6) “receiving” IBT basins. This IBT certificate was issued in 2018. Based on information reported in 2020, the annual average IBT basin transfer from the Cape Fear (2-3) to Pender County customers was 1.28 MGD. More information about IBT Certificates in the Cape Fear River Basin can be found in Chapter 5.

## 1.14 Protecting Water Resources in the Lower Cape Fear River Watershed

DWR’s Basin Planning Branch (BPB) continually works with several federal, state, and local agencies as well as numerous 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 nutrient and sediment loads to receiving streams. This also includes identifying ways to reduce peak stormwater flows, managing existing water supplies, and identifying future needs.

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

- When resources allow, re-establish older and/or identify locations for new biological monitoring stations to better understand existing water quality conditions in the Lower Cape Fear subbasin, particularly in higher watersheds and within watersheds where there is limited water quality data.
- Most of the ambient monitoring stations in this subbasin are on the mainstem. When resources allow, re-establish a station on Livingston Creek and add additional ambient stations in areas identified (Natmore Creek, Town Creek, etc.) to help identify pollutant sources and inform BMP implementation recommendations.
- Re-establish routine metals monitoring using the dissolved metals standard criteria. There are many historic total metals impairments that need to be verified using the dissolved method as well as the need to understand the impact metals are having on aquatic environments throughout the Cape Fear River Basin including the Lower Cape Fear River Estuary.
- Watershed evaluations should be conducted to determine the source of rising TKN levels.
- 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.
- The Town of White Lake should repair its collection system leakage issue and work with residents to develop a watershed action plan to reduce nutrients from all sources including stormwater and lawn fertilizers.
- 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).
- A conditions assessment should be completed for Jones and Salters lakes and Harrison, Ellis, and Turnbull creeks to determine if these waterbodies should be reclassified to Sw.
- DWR supports the recommendations of the [City of Wilmington's Greenfield Lake 9-Element Restoration Plan](#), including monitoring, education, BMP installation, and assessment of the efficacy of individual BMPs outlined to address the chlorophyll *a* and algal bloom issues in Greenfield Lake. Examples of nonpoint source management measures recommended in the plan include the use of riparian buffers, constructed wetlands, and floating macrophyte islands.
- An inventory and assessment of all coastal facilities and infrastructure that store, treat, or transport waste is needed to identify the risk factor for storm-related breaches or leaks. High-risk facilities and infrastructure should be prioritized for fortification and improvement to keep waste from being released into the environment during future intense storm events.
- Basin planning supports the implementation of the North Carolina Coastal Habitat Protection Plan (CHPP). The CHPP is a guidance document that addresses habitat and water quality efforts needed to protect, enhance, and restore fish habitat along North Carolina's coasts. The goal is to improve coastal fisheries through habitat protection and enhancement efforts. See Chapter 4, Section 4.6, for a list of individual recommendations.
- DWR will continue to explore potential paths to address the low DO and pH issues in the estuary that are protective of all uses including the endangered and migratory fish species.
- DEQ will continue to ensure Chemours complies with NPDES permits and state and federal water quality standards as they are developed.

- DEQ will continue to work with the Secretaries' Science Advisory Board to understand how to manage emerging compounds to protect public health and the environment.
- As directed by the EPA, DWR will continue to work with the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) to develop appropriate instream criteria and response variables to accurately assess the health and protect both small streams and large riverine systems. This could include the development of TMDLs and/or nutrient management strategies as needed to reduce nutrient loading from point and nonpoint sources to protect designated uses throughout the basin.
- DWR should consider modifying the chlorophyll *a* criteria to better protect flowing riverine systems in the Cape Fear River Basin.
- Existing WWTPs are encouraged to pursue nutrient optimization to improve nutrient removal processes at existing treatment plants. This should include an evaluation of existing treatment components and operations and identifying additional opportunities to improve and optimize nitrogen and phosphorus reduction. Existing WWTPs are also encouraged to develop a standard operating procedure to mitigate treatment inefficiencies associated with staff turnover and promote consistent high performance.
- Publicly Owned Treatment Works (POTWs) must work with DWR to determine if their Pretreatment Program is sufficiently evaluating indirect dischargers to protect against accepting waste with potential emerging contaminants.

## 1.15 References

Atlantic State Marine Fisheries Commission. (2009) *Atlantic Coast Diadromous Fish Habitat: A Review of Utilization, Threats, Recommendations for Conservation, and Research Needs. Habitat Management Series #9*. January 2009.

[https://web.archive.org/web/20210408082618id/http://www.asmfc.org/files/Habitat/HMS9\\_Diadromous\\_Habitat\\_2009.pdf](https://web.archive.org/web/20210408082618id/http://www.asmfc.org/files/Habitat/HMS9_Diadromous_Habitat_2009.pdf)

Beach, D. (2002). *Coastal Sprawl: the Effects of Urban Design on Aquatic Ecosystems in the United States*. Pew Oceans Commission, Arlington VA.

Biesecker, M. and Suderman A. (2018). North Carolina river swirls with gray muck near flooded coal ash dump. Associated Press – News Channel abc <https://wcti12.com/nc-river-swirls-with-gray-muck-near-flooded-coal-ash-dump>

Bowen, J.D., S. Negusse, J.M. Goodman, B. Duclaud, M. Robin, and J. Williams. 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. Department of Civil and Environmental Engineering, William States Lee College of Engineering, University of North Carolina at Charlotte. 247 pp.

Breisinger, H. (2021). *North Carolina's shoreline estuaries are transforming into "ghost forests," by why?* WHQR Public Media. <https://www.whqr.org/local/2021-06-03/north-carolinas-shoreline-estuaries-are-transforming-into-ghost-forests-but-why>

Deininger, A., Kaste, Ø., Frigstad, H., Austnes, K. (2020) Organic nitrogen steadily increasing in Norwegian rivers draining to the Skagerrak coast. *Nature Scientific Reports* 2020, 10:18451.  
<https://doi.org/10.1038/s41598-020-75532-5>

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.  
<https://water.usgs.gov/nawqa/nutrients/pubs/circ1350/>

Duke Energy. (n.d.). Sutton Plant. Retrieved March 29, 2023, from <https://www.duke-energy.com/our-company/about-us/power-plants/sutton-plant> .

Ensign, S. H., J. N. Halls, and M.A. Mallin. 2004. *Application of digital bathymetry data in an analysis of flushing times of two large estuaries*. *Computers & Geosciences* 30: 501-511.

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](https://services.arcgis.com/P3ePLMYs2RVChkXj/arcgis/rest/services/USA_Census_2020_Redistricting_Blocks/FeatureServer)

Familkhalili, R., and S. A. Talke (2016). *The effect of channel deepening on tides and storm surge: A case study of Wilmington, NC*. *Geophys. Res. Lett.*, 43, 9138–9147, doi:10.1002/2016GL069494.

Fink, J. (2018). *Florence Flooding Causes Dam Breach in Duke Energy North Carolina Power Plant, Possible Coal Ash Spill Into Cape Fear River*. *Newsweek*. <https://www.newsweek.com/florence-flooding-causes-dam-breach-duke-energy-north-carolina-power-plant-1133923>

Frey, D.G. (1949). *Morphometry and hydrography of some natural lakes of the North Carolina coastal plain: the bay lake as a morphometric type*. *Journal of the Elisha Mitchell Scientific Society*. 65(1), pp 1-37.

Galli, J. (1991). *Thermal Impacts associated with Urbanization and Stormwater Management Best Management Practices*. Metropolitan Washington Council of Governments, Maryland Department of Environment: Washington, D.C.

Giese, G. L., H. B. Wilder, and G. G. Parker (1985). *Hydrology of major estuaries and sounds of North Carolina*. United States Geological Survey Water-Supply, (8.1).

Gori, A., N. Lin, and J. Smith. 2020. *Assessing compound flooding from landfalling tropical cyclones on the North Carolina coast*. *Water Resources Research*, 56, e2019WR026788.  
<https://doi.org/10.1029/2019WR026788>.

Graham, T. 2009. *Nitrate recycling versus removal in the Cape Fear River estuary*. A Thesis Submitted to the University of North Carolina Wilmington in Partial Fulfillment of the Requirements for the Degree of Master of Science. Center for Marine Science. UNC-Wilmington. 66pp.

Griffith, G.E., Omernik, J. M, and Comstock, J. A. (2002). *Ecoregions of North Carolina Regional Descriptions*  
<https://www.epa.gov/eco-research/ecoregion-download-files-state-region-4#pane-31>

Hall, N. (2021). [WRRR Report No. 485](#). *Understanding thermal stratification as a key driver of Harmful cyanobacteria blooms on the Cape Fear River, NC*. January 2021.

Hall, N., and Rosman, J. (2022). Annual report for cooperative agreement W9126G-21-2-0035. *Understanding thermal mixing, water quality improvements and algae dynamics with the pulsing of releases from Jordan Reservoir*. October 2022

Harden, S. (2015). *Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Feeding Operations*. (Scientific Investigations Report 2015-5080). U.S. Department of Interior, U.S. Geological Survey. <https://pubs.usgs.gov/sir/2015/5080/pdf/sir2015-5080.pdf>

Hines, D. E., J. A. Lisa, B. Song, C. R. Tobias, and S. R. Borrett. 2012. *A network model shows the importance of coupled processes in the microbial N cycle in the Cape Fear River Estuary*. *Estuarine, Coastal and Shelf Science* 106:45-57.

Holman, V. (2022). *Ghost Whisperers*. Salt Magazine. <http://www.saltmagazinenc.com/ghost-whisperers/>.

Isaacs, J.D., Strangman, W.K., Barbera, A.E., Mallin, M.A., McIver, M.R., Wright, J.L. (2014). *Microcystins and two new micropeptin cyanopeptides produced by unprecedented Microcystis aeruginosa blooms in North Carolina's Cape Fear River*. *Harmful Algae* 31:82-86. January 2014.

Lauristen D. (2020). *Report to Town of White Lake*. October 2020. <https://img1.wsimg.com/blobby/go/ea202b16-fcb4-441f-a213-a86fa0dc73b9/Report%20to%20Town%20of%20White%20Lake--October%202020-com.pdf>

Mallin, M. A., L. B. Cahoon, M. R. McIver, D. C. Parsons and G. C. Shank. (1997). *Nutrient limitation and eutrophication potential in the Cape Fear and New river estuaries*. Report Number 313. Center for Marine Science Research. UNC-Wilmington. WRRR Project No. 70136. September 1997.

Mallin M. A., McIver M. R., Ensign S. H., Cahoon L. B. (2004). *Photosynthetic and Heterotrophic Impacts of Nutrient Loading to Blackwater Streams*. *Ecological Applications*. Vol. 14, No. 3 (June 2004), pp. 823-838.

Mallin, M., M. McIver, E. Wambach, and A. Robuck. (2016). *Algal blooms, circulators, waterfowl, and eutrophic Greenfield Lake, North Carolina*. *Lake and Reservoir Management*, 32:2, 168-181. <https://uncw.edu/cms/aelab/reports%20and%20publications/2016/mallin%20et%20al%20greenfield%20lake%20paper%20lr%202016.pdf>

McAdory, Jr., R. T. 2000. *Cape Fear-Northeast Cape Fear River, North Carolina: numerical model study*. U.S. Army Corps of Engineers. ERDC/CHL TR-00-18. August 2000. 95 pp.

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

NC DEQ, Division of Water Resources. (April 1, 2019). *Survey of Surface Water Quality Associated with Hurricane Florence, September 2018*. [https://files.nc.gov/ncdeq/Environmental%20Management%20Commission/Water\\_Quality\\_Committee](https://files.nc.gov/ncdeq/Environmental%20Management%20Commission/Water_Quality_Committee)

[Meetings/2019/may/Survey-of-Surface-Water-Quality-Associated-with-Hurricane-Florence-September-2018-Final.pdf](#)

NC DEQ, Division of Water Resources. (September 2019). *2018 White Lake Monitoring Report White Lake, Bladen County, NC*. <https://deq.nc.gov/media/14616/download>

NC DEQ. Division of Water Resources. (2020). *Report of Proceedings on the Removal of the Swamp Classification and Removal of a Part of a Water Quality Management Plan for a Cape Fear River Segment in Brunswick and New Hannover Counties (Cape Fear River Basin)*. October 20, 2020. (Attached to May 2021 EMC meeting agenda.)

[https://files.nc.gov/ncdeq/Environmental%20Management%20Commission/EMC%20Meetings/2021/may2021/attachments/AttachA\\_to\\_21-15\\_LCFR\\_final\\_ROP\\_for\\_EMC-reduced\\_size.pdf](https://files.nc.gov/ncdeq/Environmental%20Management%20Commission/EMC%20Meetings/2021/may2021/attachments/AttachA_to_21-15_LCFR_final_ROP_for_EMC-reduced_size.pdf)

NC DEQ – Division of Waste Management and Water Resources. (2023, March 10). Chemours Groundwater Extraction and Conveyance (GWEC) System Introduction and Barrier Wall Construction. NC DEQ All-Hands Meeting Presentation, Raleigh.

NC DEQ. (2016). *North Carolina Coast Habitat Protection Plan (CHIPP)*. Source Document 2016. <https://www.deq.nc.gov/marine-fisheries/coastal-habitat-protection-plan/2016-chpp-source-document/open>

NC DEQ. (2022). 2022 Water and Fish Collection Project – Status Update. Presentation, Raleigh [PowerPoint Presentation \(nc.gov\)](#)

DHHS Algal Blooms website [https://epi.dph.ncdhhs.gov/oee/a\\_z/algal\\_blooms.html](https://epi.dph.ncdhhs.gov/oee/a_z/algal_blooms.html)

NC DHHS. (2018). *Health Consultation: Evaluation of Fish and Shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near the Kerr-McGee NPL site*. [\\*Kerr-McGee Fish HC \(cdc.gov\)](#)

NC DHHS. (2019). *How are Fish Consumption Advisories Developed?*. [NC DPH: Occupational & Environmental Epidemiology: How Are Fish Consumption Advisories Developed? \(ncdhhs.gov\)](#)

NC DHHS. (Oct 2021). *Fish Consumption Advisories*. <https://epi.dph.ncdhhs.gov/oee/fish/advisories.html#top>.

NC DHHS. (2023a). *Appendix A. Summer 2022 Cape Fear River Freshwater Fish Collection*. [Appendix A 7 11 23.pdf \(ncdhhs.gov\)](#)

NC DHHS. (2023b). *Appendix B. Calculation of Fish Advisories (July 2023)*. [Appendix B 7 11 23.pdf \(ncdhhs.gov\)](#)

NC DMF. (2020-a). *Report of Sanitary Survey Area B-1 Southport Area May 2015 through July 2020*. <https://digital.ncdcr.gov/digital/collection/p16062coll47/id/31655/rec/1>

NC DMF. (2020-b). *Report of Sanitary Survey Area B-2 and B3 Cape Fear River Area Buzzards Bay and The Basin June 2015 through September 2020*. <https://digital.ncdcr.gov/digital/collection/p16062coll47/id/31737/rec/1>

NC DMF. (2020-c). *Report of Sanitary Survey Area B-4 Cape Fear Area July 2015 through October 2020*. <https://digital.ncdcr.gov/digital/collection/p16062coll47/id/31365/rec/52>

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 \(nc.gov\)](#)

NC DWR, Water Sciences Section, Intensive Survey Branch. (June 4, 2009). *Lake & Reservoir Assessments Cape Fear River Basin*. [Microsoft Word - CAPE FEAR RIVER BASIN 2008.doc \(nc.gov\)](#)

NC DWR, Water Sciences Section, Intensive Survey Branch. (January 9, 2014). *Lake & Reservoir Assessments Cape Fear River Basin*. [download \(nc.gov\)](#)

NC DWR, Water Sciences Section. (December 2017) *2017 White Lake Water Quality Investigation, White Lake, Bladen County (Cape Fear Basin)*. <https://www.deq.nc.gov/water-quality/environmental-sciences/isu/white-lake-2017-wq-report-final-121217/download>

NC DWR, Water Sciences Section, Intensive Survey Branch. (October 30, 2018). *Lake & Reservoir Assessments Cape Fear River Basin*. [CPF\\_2018Final.pdf \(nc.gov\)](#)

NC DWR. (2020, February 12). Fact Sheet for NPDES Permit No. NC0089915. The Chemours Company / Chemours Fayetteville Works. [download \(nc.gov\)](#)

NC One Map. (2010). *2010 Census Block* [GIS Feature Service Layer]. Retrieved from: [https://services.nconemap.gov/secure/rest/services/NC1Map\\_Census/MapServer/7](https://services.nconemap.gov/secure/rest/services/NC1Map_Census/MapServer/7)

NC Ports. 2023. <https://ncports.com/>. Accessed August 2, 2023.

Shank, C., Zamora, P. (2019). *Influence of groundwater flows and nutrient inputs on White Lake water quality*. Final Report. April 1, 2019

Shankar, S., Shanker U., Shikha. (2014). Arsenic Contamination of Groundwaer: a Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation. *The Scientific World Journal*. 2014:304524. doi: 10.1155/2014/304524. Epub 2014 Oct 14. PMID: 25374935; PMCID: PMC4211162. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4211162/#:~:text=The%20main%20anthropogenic%20sources%20for,of%20As%20in%20the%20environment>

Shapiro-Garza, E., Rajae M., Cohen S., Klein C. and Joyce A. (2022) *Subsistence Fish Consumption on the Lower Cape Fear River, Summary of Research 2016-2022*. Duke University Superfund Research Center and Oakland University. [Subsistence-Fish-Consumption-on-the-lower-Cape-Fear-River\\_report.pdf \(duke.edu\)](#)

Still, J. F. (2019). *Brunswick County to fund city-wide sewer study in Boiling spring Lakes, expansion planned*. June 19, 2019Port City Daily. <https://portcitydaily.com/local-news/2019/06/19/brunswick-county-to-fund-city-wide-sewer-study-in-boiling-spring-lakes-expansion-planned/>

University of North Carolina. (n.d.). *Carolina Demography First look at 2020 Census for North Carolina*. Accessed May 3, 2023. [First look at 2020 Census for North Carolina | Carolina Demography \(ncdemography.org\)](#)

US Depart of Agriculture (USDA). (2017). Appendix B. General Explanation and Census of Agriculture Report Form. [usappxb.pdf \(usda.gov\)](#)

Wells, B.W., Boyce S.G. (1953). *Carolina bays: additional data on their origin, age and history*. Journal of the Elisha Mitchell Scientific Society. 69(2), pp 119-141.

WETC News 6. (September 22, 2022). *Boiling spring lakes dam restoration awarded \$14.9 million federal grant*. <https://www.wect.com/2022/09/22/boiling-spring-lakes-dam-restoration-awarded-149-million-federal-grant/#:~:text=%E2%80%9CFour%20years%20ago%2C%20Hurricane%20Florence,du%20to%20the%20damage%20done>.

Whalen, S.C., and Dubbs, L.L., (2005). *Influence of Nutrient Reduction, Light and Light-Nutrient Interactions on Phytoplankton Standing Stock, Primary Production and Community Composition in the Middle Cape Fear River, North Carolina*. Final Report September 2005., UNC Department of Environmental Sciences and Engineering.

Vengosh A., Cowan. E.A., Coyte, R.M., Kondash, A.J., Wang, Z., Brandt, J.E and Dwyer, G.S. (2019). *Evidence for Unmonitored Coal Ash Spills in Sutton Lake, North Carolina: Implications for Contamination of Lake Ecosystems*; Science of the Total Environment, May 24, 2019. DOI: 10.1016/j.scitotenv.2019.05.188

Velma V., Vutukuru S., Tchounwou P. (2009, April-June). Ecotoxicology of hexavalent chromium in freshwater fish: a critical review. Rev Environ Health. *National Library of Medicine*. 24(2):129-45. doi: 10.1515/reveh.2009.24.2.129. PMID: 19658319; PMCID: PMC2860883. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2860883/>

Xia, M., L. Xie, and L.J. Pietrafesa. 2007. *Modeling of the Cape Fear River Estuary plume*. Estuaries and Coasts. 30(4): 698-709.

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