

**BASINWIDE WATER RESOURCES
MANAGEMENT PLAN**

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

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

**Draft
 Chapter 2
 Cape Fear River Basin
 Water Quality Monitoring and
 Assessment**



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2 Water Quality Assessment and Monitoring

Surface water quality is assessed every two years to fulfill the reporting requirements of Section 303(d) and 305(b) of the Federal Clean Water Act (CWA). To determine how well waterbodies are meeting their best-intended use, chemical, physical and biological parameters are regularly assessed by the Division of Water Resources (DWR). Where enough samples exist, waterbodies are determined to be meeting or exceeding criteria based on a five-year dataset, assigned waterbody classification, and existing water quality standards. Impaired waters are waterbodies where water quality samples are exceeding water quality standards for a particular parameter. Procedures used to evaluate water quality and assign categories are explained in detail in the [Integrated Report \(IR\) methodology](#). The Cape Fear River Basin plan used the [2022 IR](#). The 2022 IR data window was 2016-2020.

2.1 Surface Water Classifications and Water Quality Standards

North Carolina's Water Quality Standards Program adopted classifications and water quality standards for all the state's river basins in 1963. The program remains consistent with the Federal Clean Water Act and its amendments. Water quality classifications and standards can be modified and supplemented during the triennial review process to provide improved protection of water uses including water supply waters, high quality waters (HQW), and unique waters with outstanding resource value (ORW).

Each primary and supplemental classification is assigned a set of water quality standards that establish the level of water quality that must be maintained to support the uses associated with each classification (*Table 2-1*). The standards for C and SC waters establish the basic protection level for all state freshwater and tidal saltwater surface waters, respectively. The remaining primary and supplemental classifications have more stringent standards than for C and SC, and therefore, require higher levels of protections for additional uses. Sources of water pollution that preclude any of the best uses of waters on either a short-term or long-term basis shall be deemed to violate a water quality standard. These standards include the following components:

- *Designated uses represent the best usage for waters in the State that are to be protected. North Carolina's designated uses include aquatic life and recreation. Other designated uses are recognized in the State's water quality standards such as drinking water supply, trout, and shell fishing.*
- *Numeric values and narrative statements are established for chemical, physical, and biological parameters to protect the best usage of surface water bodies from pollution for each classification.*
- *Land management strategies aimed at controlling point and nonpoint source pollution, such as setbacks and density limits, are also established to protect the best usage of waters.*
- *The State's anti-degradation policy is implemented by the NPDES permitting section which allows for protection of water quality above the minimum required for a classification.*

A full description of the surface water quality standards program is available online through the [Classification & Standards Branch](#) website. To view the surface water quality standards rules, see [15A NCAC 02B .0200](#) and [.0300](#). A statewide [NC Surface Water Classifications](#) map is also available.

Table 2-1: North Carolina Primary and Secondary Classifications for Surface Waters

Primary Classifications	
Class	Designated Uses
C	Freshwater (FW): Aquatic life propagation, survival, and maintenance of biological integrity (including fishing and fish); wildlife; secondary contact recreation; and agriculture.
B	Primary contact recreation and Class C uses.
WS-I Through WS-V	Drinking, culinary or food processing uses and Class C uses. WS-I and WS-II waters are also HQW.
SC	Saltwater(S): Aquatic life propagation, survival, and maintenance of biological integrity (including fishing, fish, and Primary Nursery Areas (PNAs)); wildlife; and secondary contact recreation.
SB	Primary contact and protected for all SC uses
SA	Market shellfishing and Class SC and Class SB uses. SA waters are also HQW.
Supplemental Classifications	
NSW	Waters experiencing or subject to excessive growths of microscopic or macroscopic vegetation.
ORW	Waters of exceptional State or national recreational or ecological significance that require additional protection to maintain existing uses.
HQW	Waters rated excellent based on biological and physical/chemical characteristics through monitoring or special studies; or primary nursery areas (PNA) and other functional nursery areas designed by the Marine Fisheries Commission or the Wildlife Resources Commission.
Sw	Waters that have natural characteristics due to topography, such as low velocity, dissolved oxygen, or pH, that are different from streams draining steeper topography.
Unique Wetlands (UWL)	Wetlands of exceptional state or national ecological significance. These wetlands may include wetlands that have been documented as habitat essential for the conservation of state or federally listed threatened or endangered species.

Class C (Aquatic Life Propagation and Secondary Recreation)

Waters classified as Class C are protected for aquatic life propagation, survival, and maintenance of biological integrity (including fishing and fish); wildlife; secondary contact recreation; and agriculture. This classification provides the basic protection level for all state freshwater surface waters. In the Cape Fear River Basin there are 6,611 freshwater (FW) miles and 34,932.5 FW acres of class C waters. The Upper Cape Fear River subbasin (HUC8 03030004) has the most miles FW classified rivers, creeks, and streams at 1,367.7, while the Lower Cape Fear subbasin (HUC8 03030005) has the least FW miles, just 671.9. The Haw River subbasin (HUC8 03030002) has the most FW acre lakes and reservoirs, 19,144.2. All of the subbasins have classified FW acre lakes and reservoirs except for the Northeast Cape Fear (HUC8 03030007) which has none.

Class B (Primary Contact Recreation)

Waters classified as Class B are protected for primary contact recreation which includes swimming, diving and similar uses involving human body contact with water where such activities take place in an organized or on a frequent basis must meet water quality standards for fecal coliform bacteria. Sewage and all discharged wastes into Class B waters must be treated to avoid potential impacts to the existing water quality. In the Cape Fear River Basin there are 197.6 FW miles and 13,767.3 FW acres of class B waters. All HUC8 subbasins in the Cape Fear have some class B waters. The Upper Cape Fear River subbasin has the highest percent of Class B FW miles at 8% and over 100 FW miles; the rest of the subbasins have just one to three percent of streams classified as B. Approximately 60% of the acres in the Haw River subbasin, close to 50% of FW acres in the Lower Cape Fear River subbasin, and close to 30% of the FW acres in the Black River (HUC8 03030006) subbasin are class B. The rest of the subbasins have less than 10% or no class B FW acres.

Class SC (Tidal Salt Waters)

Waters classified as Class SC are tidal saltwaters protected for aquatic life propagation, survival, and maintenance of biological integrity (including fishing, fish, and Primary Nursery Areas [PNAs]); wildlife; secondary contact recreation. This classification provides the basic protection level for all saltwaters in the State. In the Cape Fear River Basin there are 24,821.9 class SC saltwater (S) acres, mostly occurring in the Lower Cape Fear River subbasin (24,235.7 S acres), with the rest located in the Northeast Cape Fear subbasin (HUC8 03030005), 375.6 S acres.

Class SB (Tidal Salt Waters Primary Contact Recreation)

Waters classified as Class SB are tidal saltwaters protected for primary contact recreation. Primary contact recreation activities include swimming, diving and similar uses involving human body contact with water where such activities take place in an organized or on a frequent basis. Class SB waters are also protected for Class SC uses. In the Cape Fear River Basin there are no class SB saltwater acres. However, 20.1 miles of the Atlantic Coastline are classified as SB.

Class SA (Tidal Salt Waters Commercial Shellfish Harvesting or Marketing)

Waters classified as SA are tidal saltwaters that are used for commercial shellfishing or marketing purposes. They are also protected for all Class SC and Class SB uses. All SA waters also carry the

supplemental classification of High Quality Waters (HQW). In the Cape Fear River Basin there are 8,909.9 class SA saltwater acres all located in the Lower Cape Fear subbasin.

WS (Water Supply)

The Water Supply (WS) classification, for WS-I to WS-V (described individually below), is designated for drinking, culinary, food processing, and other Class C uses. There are 2,346.9 freshwater (FW) stream miles and 28,984.3 FW reservoir acres classified for water supply in the Cape Fear River Basin. The Haw, Deep, Upper and Lower Cape Fear subbasins have WS classified waterbodies. The Haw River subbasin has the most WS FW miles and FW acres with nearly 100% of the waterbodies in that subbasin classified as WS. Most of the lake and reservoir FW acres in both the Upper Cape Fear and Deep subbasins and 41% of the Upper Cape Fear and 34% of the Deep subbasins' river and stream FW miles are WS class waters. Additionally, 20% of the FW miles in the Lower Cape Fear River are also classified WS.

Approximately 84.1 FW stream miles and 21,822.8 reservoir acres of the WS waters are in a Critical Areas. A WS Critical Area (CA) is designated within one-half mile and draining to a WS intake or WS reservoir within WS-II, WS-III and WS-IV watersheds. The water supply restrictions applied in the CA are more stringent than the water supply restrictions applied in the remainder of the watershed draining to a WS intake or WS reservoir. The most CA occurs in the Haw, 17,744.4 FW acres equivalent to 93% the FW acres in that subbasin. Additionally, most of the FW acres in the Deep, 99% or 4,052.7 FW acres, are also classified as CA.

More information about specific WS (WS-I to WS-IV) and CA classified waters is available in the subbasin chapters.

Class WS-I (Water Supply I)

This classification is restricted to waters used as a source of water supply for drinking, culinary, or food processing purposes and Class C uses. WS-I waters are generally located on land in public ownership and in undeveloped watersheds. Class WS-I waters are also classified HQW. There are no FW miles or FW acres classified as WS-I in the Cape Fear River Basin.

Class WS-II (Water Supply II)

This classification is restricted to waters used as a source of water supply for drinking, culinary, or food processing purposes where a WS-I classification is not feasible as determined by the Environmental Management Commission and Class C uses. Class WS-II waters are also classified HQW. In the Cape Fear River Basin there are 171.5 FW miles and 2,218.0 FW acres of class WS-II waters.

Class WS-III (Water Supply III)

This classification is restricted to waters used as a source of water supply for drinking, culinary, or food processing purposes where a WS-I or WS-II classification is not feasible as determined by the Environmental Management Commission and Class C uses. In the Cape Fear River Basin there are 583.7 FW miles and 4,907.2 FW acres of class WS-III waters.

Class WS-IV (Water Supply IV)

This classification is restricted to waters used as a source of water supply for drinking, culinary, or food processing purposes where a WS-I, WS-II or WS-III classification is not feasible as determined by the Environmental Management Commission and Class C uses. In the Cape Fear River Basin there are 896.7 FW miles and 17,488.6 FW acres of class WS-IV waters.

Class WS-V (Water Supply V)

This classification is restricted to waters that are protected as water supplies which are generally upstream and draining to Class WS-IV waters; waters previously used for drinking water supply purposes; or waters used by industry to supply their employees, but not for municipalities or counties, with a raw drinking water supply source, although this use is not restricted to WS-V classification, and Class C uses. In the Cape Fear River Basin there are 695.0 FW miles and 4,370.5 FW acres of class WS-V waters.

Nutrient Sensitive Waters (NSW)

Nutrient Sensitive Waters is a supplemental classification intended for waters needing additional nutrient management due to excessive growth of microscopic or macroscopic vegetation (i.e., algal growth, aquatic weeds, etc.). In the Cape Fear River Basin there are 1,259.4 FW miles and 19,144.2 FW acres of class NSW waters, all located in the Haw River subbasin/Jordan Lake watershed.

High Quality Waters (HQW)

The High Quality Waters (HQW) supplemental classification is intended to protect waters which are rated excellent based on biological and physical/chemical characteristics through monitoring or special studies; or primary nursery areas (PNA) and other functional nursery areas designated by the Marine Fisheries Commission (MFC) and the Wildlife Resources Commission (WRC). In the Cape Fear River Basin there are 24,006.6 acres of PNAs. Also, waters classified as Class WS-I, WS-II, SA, or ORW are HQW. In the Cape Fear River Basin there are 325.3 FW miles, 2,479.9 FW acres and 8,930.4 S acres classified as HQW waters. Over half HQW FW miles and most of the FW acres are located in the Haw River subbasin. The HQW S acres are entirely located in the Lower Cape Fear subbasin, 8,930.4 S acres equivalent to 38% of that subbasin's saltwater waterbodies.

Outstanding Resource Waters (ORW)

The Outstanding Resource Waters (ORW) supplemental classification is intended to protect waters of exceptional state or national recreational or ecological significance that require additional protection to maintain existing uses. ORW is a subset of HQW. In the Cape Fear River Basin there are just 129.5 FW miles classified as ORW, all located along the Black and South rivers in the Black River subbasin and equivalent to 13% the Black River's FW miles.

Swamp Waters (Sw)

The Swamp (Sw) supplemental classification is intended to recognize those waters that have natural characteristics due to topography, such as low velocity, dissolved oxygen, or pH, that are different from

streams draining steeper topography. In the Cape Fear River Basin there are 2,492.3 FW miles, 3,286.1 FW acres, and 576.3 S acres of class Sw waters. Sw classified waters predominantly occur in the lower half of the basin in the Lower Cape Fear, Black and Northeast Cape Fear subbasins. Most of the FW miles are found in both the Black (1,025.2 FW miles) and Northeast Cape Fear (1,102.7 FW miles) and most of the FW acres are also found in the Black (2,030.6 FW acres), additionally about half of the FW miles and a third of the FW acres in the Lower Cape Fear River Basin are classified as Sw.

Unique Wetlands

The Unique Wetland (UWL) supplemental classification is intended for unique wetlands that are of exceptional state or national ecological significance, which require special protection to maintain existing uses. Class UWL wetlands may include wetlands that have been documented as habitat essential for the conservation of state or federally listed threatened or endangered species. Statewide, 35 wetlands were reclassified to UWL 15 NCAC 02B .0309 on November 1, 2007, ten of these sites are in the Cape Fear River Basin, two in the Upper Cape Fear River subbasin, seven in the Lower Cape Fear River subbasin, and one in the Northeast Cape Fear River subbasin (*Table 2-2*).

Table 2-2: Unique Classified Wetlands in the Cape Fear River Basin

HUC8	Subbasin	Site	County	Habitat
3020004	Upper Cape Fear River	Bower's Bog	Moore	sand seep wetland
3020004	Upper Cape Fear River	Weymouth Woods	Moore	sand seep wetland
3040005	Lower Cape Fear River	Jones Lake Bay	Bladen	bay forest, peatland Atlantic white cedar forest, natural lake shoreline
3040005	Lower Cape Fear River	Salters Lake Bay	Bladen	bay forest, low pocosins, natural lake shoreline
3040005	Lower Cape Fear River	Bushy Lake Bay	Cumberland	low pocosin
3040005	Lower Cape Fear River	Military Ocean Terminal at Sunny Point vernal pools	New Hanover	lime sink depressions
3040005	Lower Cape Fear River	Lily Pond at Carolina Beach State Park	New Hanover	lime sink depressions
3040005	Lower Cape Fear River	Fly Trap Savannah	New Hanover	wet pine savannah
3040005	Lower Cape Fear River	Grassy Pond	New Hanover	lime sink depressions
3020007	Northeast Cape Fear River	Neck Savanna	Pender	wet pine savannah

Reclassifications

Reclassifications from 2002 to 2022 are shown in Table 2-3. On August 11, 2009, Jordan Water Supply Nutrient Strategy rules went into effect. These included reclassification of “Jordan Reservoir and all waters draining to it having been supplementally classified as Nutrient Sensitive Waters (NSW)” and “waters supply waters designated WS-II, WS-III and WS-IV within Jordan watershed shall retain their classifications. The remaining waters in the Jordan watershed are classified as WS-V” (15A NCAC 02B .0262).

Table 2-3: Cape Fear River Basin Reclassifications 2005-2022

Main Waterbody	County	Class Change From	Class Change To	NC Effective Date	Stream Index/ Assessment Unit #	HUC-8
Cape Fear River	Bladen, Cumberland	C	WS-IV	1/1/2009	18-(26.25)*	03030005
		C	WS-IV; CA	1/1/2009	18-(26.5)*	03030005
Jordan Lake Tributaries*	Several	C; NSW	WS-V; NSW	8/11/2009	*	03030002
		B NSW	WS-V; B; NSW	8/11/2009	*	03030002
Haw River	Chatham	WS-IV	WS-IV; CA	9/1/2009	16-(28.75)*	03030002
Haw River	Several	WS-V	WS-IV	3/1/2012	16-(6.5)*	03030002
		WS-V	WS-IV; CA	3/1/2012	16-(10)*	03030002
Cape Fear River	Brunswick, New Hanover	SC	SC; Sw with WQMP	6/30/2017	18-(71)	03030005
Sandy Creek	Randolph	WS-III	WS-III; CA	11/1/2019	17-16-(3.5) (reclass correction)	03030003
Cape Fear River	Brunswick, New Hanover	SC; Sw with WQMP	SC with WQMP	7/1/2021	18-(71)	03030005

* See the Chapter 2 Appendix for tributaries included in reclassification (by sorted by effective date); Classifications include C (freshwater), B (freshwater recreation), WS (Water Supply), CA (Critical Area), SC (salt water), NSW (Nutrient Sensitive Waters); WQMP = Water Quality Management Plan.

2.2 Interpreting Data

The water quality assessment process is a framework used by DWR to interpret data and information to determine if a waterbody is meeting water quality standards. Water quality is assessed every two years in the [Integrated Report \(IR\)](#), which is provided to the U.S. Environmental Protection Agency (EPA) to fulfill the reporting requirements of Section 303(d) and 305(b) of the Federal Clean Water Act (CWA). The IR is published in even-numbered years after EPA approval of the corresponding 303(d) List of Impaired Waters. Each IR generally covers a 5-year time-period, although for assessments with no new data, the previous assessment is carried forward. Procedures used to evaluate water quality and assign categories

are explained in detail for each year's [IR Methodology](#). For the purposes of this report, the [2022 IR](#) and associated methodology was used (5-year data window was 2016-2020).

In North Carolina, criteria are established to protect the [surface water classification](#), or designation, of a waterbody. In the Cape Fear River Basin, water quality was assessed for aquatic life, recreation, fish consumption, human health, and shellfish harvesting. Waterbodies referred to as "Assessment Units (AUs)" in the IR, are regularly monitored in the field for biological, chemical, and physical criteria. Monitoring data is used to assess each AU based on the parameter of interest for the IR and are found to be (see [Table 2-4](#)):

- Meeting Criteria (meeting standards, Category 1)
- Exceeding Criteria (exceeding standards, also referred to as impaired, Category 4, 5, or 5r)
- Data Inconclusive (data does not allow for an assessment to be made, Category 3)

For the IR, each station's ambient monitoring data are analyzed for percent exceedance of the state standard for individual parameters within a five-year period. In general, if more than 10% of the samples exceed the standard for a water quality parameter with 90% statistical confidence, the AU is considered to be Exceeding Criteria, or impaired, for that parameter. The IR methodology also addresses less common situations including small datasets (<10 samples) and datasets with >10 samples with >10% exceedance but <90% confidence. The standard for fecal coliform bacteria (FCB) is also calculated differently than other ambient parameters as it relies on a 5-in-30 sampling regime, which is the collection of 5 samples within a 30-day period. More information on chemical and physical ambient water quality standards is covered in Section 2.5 and DWR's [Surface Water Standards](#) webpage.

Biological (benthic and fish community) samples are given a bioclassification based on the data collected at the site by DWR biologists. Most wadable, flowing stream sites are assigned a bioclassification of Excellent, Good, Good-Fair, Not Impaired, Not Rated, Fair or Poor. Swamp stream bioclassifications for benthos fall into three categories: Natural, Moderate, and Severe. [Table 2-4](#) summarizes how the bioclassifications are interpreted by the IR. Biological monitoring is covered further in the next section.

Fish consumption advisories are based on advisory reports collected from the North Carolina Department of Health and Human Services. Any AU with a fish consumption advisory and site-specific fish tissue data is Exceeding Criteria ([Table 2-4](#)).

The Division of Marine Fisheries (DMF) monitors and classifies coastal waters for shellfish harvesting (see Section 2.4). Shellfish growing areas may be considered meeting or exceeding criteria on the IR ([Table 2-4](#)).

There are several approaches that DWR uses to restore and protect water resources in North Carolina that are generally referred to as Watershed Action Plans (WAPs). WAPs rely on existing approaches such as Total Maximum Daily Load (TMDL) or existing management strategies but includes voluntary restoration and protection approaches as well.

A TMDL is usually developed to address one parameter that is not meeting water quality standards. In the Integrated Report (IR), the waterbody/parameter combination would be in Category 4t, 3t or 1t

depending on current assessment data. An EPA-approved TMDL removes a waterbody/pollutant combination from the 303(d) list (Category 5). A link to the Cape Fear River Basin TMDL page is [here](#).

Table 2-4: Water Quality Assessments and Categories for the 2022 Integrated Report

Biological Rating (Bioclassification)	Fish Consumption	Shellfish Harvesting Area	Ambient Water Quality Dataset	Integrated Report Category
Excellent/Natural	AU as site specific fish tissue data and Fish Consumption Advisory no longer in place	Growing area is classified as Approved	Dataset Meets Criteria	Category 1
Good				
Good-Fair				
Not Impaired				
Not Rated			Does not Meet OR Exceed Criteria Dataset Inconclusive	Category 3
Fair	AU as site specific fish tissue data and Fish Consumption Advisory in place	Class SA water and Growing area classified as Not Approved	Exceed Criteria	Category 4, 5, and 5r
Poor				

A management strategy is also usually developed to address one parameter that is not meeting water quality standards. However, because management strategies are more programmatic, multiple parameters could be addressed. Management strategies can be in the form of state rules or restoration programs developed and implemented by local governments. In the Integrated Report, the waterbody/parameter combination would be in Category 4b, 3b or 1b depending on current assessment data. These management strategies require a regular audit to ensure implementation is proceeding according to the plan schedule. An EPA-approved management strategy often removes a waterbody/pollutant from the 303(d) list. Because of the Integrated Reporting category assignment, management strategies are usually referred to as 4b demonstrations.

Voluntary restoration or protection WAPs are developed in a similar manner as TMDLs and management strategies, however, due to the voluntary nature of these plans, EPA does not approve them for removal from the 303(d) list if the waterbody/parameter is exceeding criteria. The Integrated Report category for these waterbody/parameter combinations is Category 5r.

The 2022 Integrated Report for the Cape Fear River Basin is summarized on [Table 2-5](#) and displayed on [Figure 2-1](#). Monitoring data was available for 40% of the freshwater (FW) miles of rivers and streams, 82% of the FW acres of lakes and reservoirs, and almost all of the saltwater (SW) acres of estuaries. The 2022 IR found nearly a quarter of the monitored FW miles (644 FW miles), 44% of the FW acres (12,429 FW acres), and 39% of SW acres (9,543 SW acres) were exceeding criteria/impaired and not meeting their intended uses. These impairments include AUs that are exceeding criteria and 303(d) listed (Category 5), exceeding criteria with a TMDL or management strategy (Category 4), or exceeding criteria with a Voluntary Restoration Plan (Category 5r).

Many of the impairments on the 2022 IR were found in association with urban areas although some were found in more rural agricultural areas ([Figure 2-1](#)). The most impairments were found in the upper third

of the subbasin in Haw and Deep River subbasins. The Haw River subbasin accounted for close to half (47.9%) of the impaired FW miles and over 90% of the FW acres and the Deep River subbasin accounted for another quarter (25.5%) of the impaired FW miles, but just 0.5% of the FW acre impairments. The Upper Cape Fear River subbasin had 6.2% of the FW miles and 1% of the FW acre impairments, the Lower Cape Fear River subbasin had 2.3% of both the FW miles and FW acre impairments and 100% of the SW acre impairments, the Black River subbasin had 4.6 % of the FW acre impairments, and the Northeast Cape Fear River subbasin had 18.1% of the FW mile impairments. See the subbasin chapters for further information on the HUC8 level 2022 Integrated Report summary results.

A breakdown of the 2022 exceedances by parameter is shown in *Table 2-6*. Maps of individual parameters are available the Chapter 2 Appendix. FW mile impairments to rivers, creeks, and streams were most frequently caused by benthos communities, 390.6 FW miles (*Table 2-6*). The most common impairment to FW acres was due to chlorophyll *a*, 11,724 FW acres, and the most common impairment to SW acres was due to copper, 5,568 SW acres, closely followed by dissolved oxygen 5,026 SW acres.

Table 2-5: Cape Fear River 2022 Integrated Summary

Assessment Unit ¹	Map Color	FW Miles ²	FW Acres ²	SW Acres ^{2,3}
Total	All Colors Combined	6,611.1	34,932.4	24,821.9
Total Monitored	Combined Blue, Gray, Red, Purple, Pink	2,649.4	28,492.1	24,235.7
Not Monitored	Green	3,961.7	6,440.3	586.2
Meeting Criteria (Category 1)	Blue	922.3	1,630.9	14,316.8
Data Inconclusive (Category 3)	Gray	1,083.0	14,432.1	375.6
Exceeding Criteria 303(d) (Category 5) ³	Red	590.9	1,160.5	9,543.3
Exceeding Criteria with Watershed Action Plan (Category 5r)	Purple	7.4	0	0
Exceeding Criteria with TMDL (Category 4)	Pink	45.8	11,268.6	0
Exceeding Criteria (Combined Category 4, 5, and 5r) ³	Combined Red, Purple, Pink	644.1	12,429.1	9,543.3
% Exceeding of Monitored Exceeding (Combined Category 4, 5, and 5r)	Combined Red, Purple, Pink / Total	24.3%	43.6%	39.4%

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

² FW - Freshwater, SW -Saltwater

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

Figure 2-1: Cape Fear River Subbasin 2022 Integrated Report Map

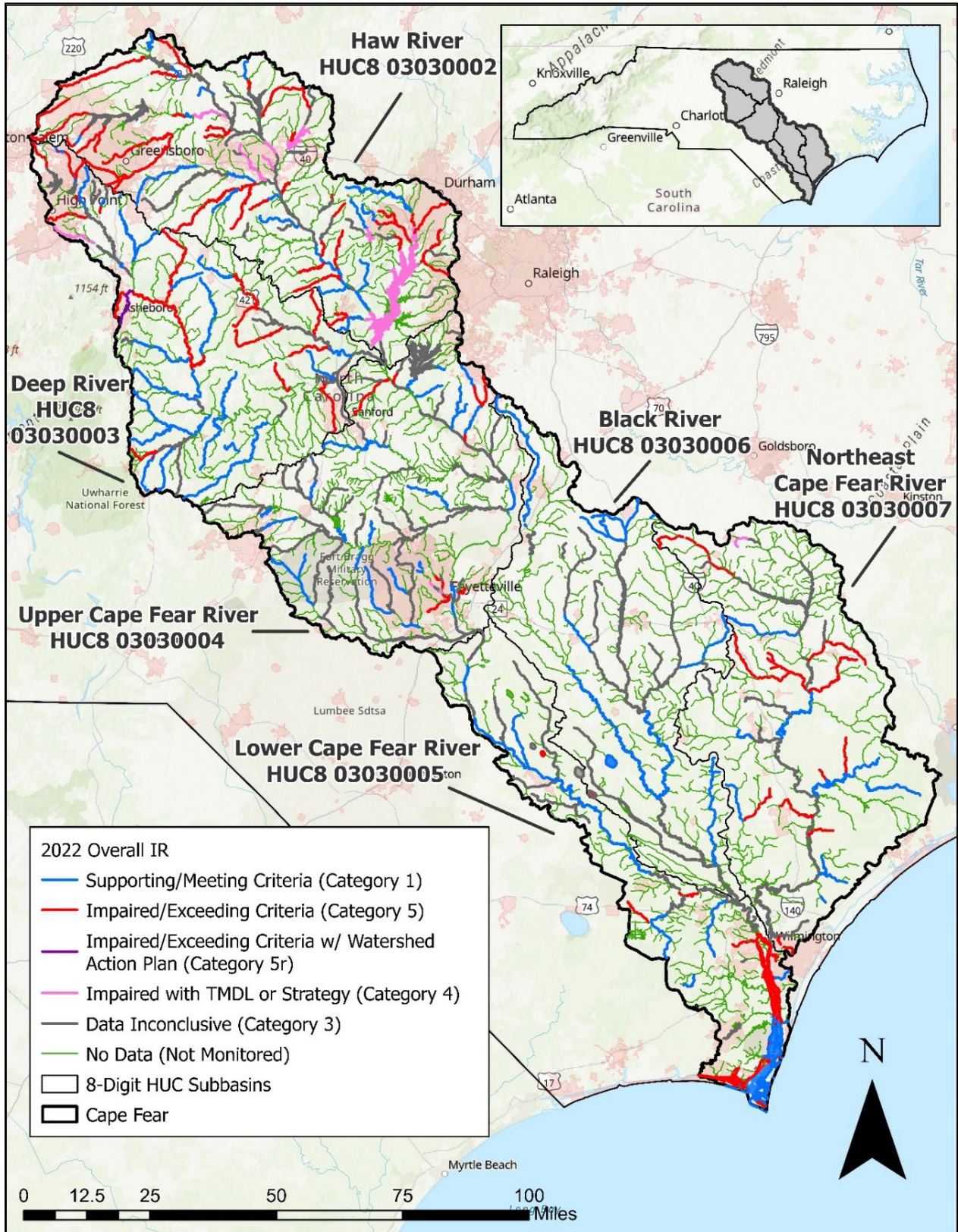


Table 2-6: Cape Fear River Basin 2022 Impairments by Parameter (Category, 4, 5, and 5r)

Tab	FW Miles ³	FW Acres ³	SW Acres ^{3,4,5}
Aquatic Passage	8.6	0.0	0.0
Arsenic (10 µg/l, HH, NC)	0.0	0.0	715.1
Arsenic Fish Consumption Advisory (Advisory, FC, NC)	5.1	0.0	350.6
Benthos (Nar, AL, FW)	390.6	0.0	0.0
Chloride (230 mg/l, AL, FW)	3.4	0.0	0.0
Chlorophyll <i>a</i> (40 µg/l, AL, NC)	34.0	11,723.6	0.0
Copper (3 µg/l, AL, SW)	0.0	0.0	5,567.7
Copper (7 µg/l, AL, FW)	59.7	0.0	0.0
Copper Dissolved Chronic (Calculated, AL, FW)	7.5	0.0	0.0
Dissolved Oxygen (4 mg/l, AL, FW)	24.4	0.0	0.0
Dissolved Oxygen (5 mg/l, AL, SW)	0.0	0.0	5,025.6
Fecal Coliform (GM 200/400 5 in 30, REC, FW)	52.3	0.0	0.0
Fecal Coliform (GM 200/400, REC, FW)	55.2	0.0	0.0
Fish Community (Nar, AL, FW)	127.8	0.0	0.0
Hexavalent Chromium Fish Consumption Advisory (Advisory, FC, NC)	5.1	0.0	350.6
Hydraulics	8.6	0.0	0.0
Mercury (0.012 µg/l, FC, FW)	1.9	0.0	0.0
Nickel (8.3 µg/l, AL, SW)	0.0	0.0	715.1
pH (4.3 s.u., AL, Sw)	13.0	576.1	0.0
pH (6 s.u., AL, FW)	1.9	214.1	0.0
pH (6.8 s.u., AL, SW) ⁵	0.0	0.0	743.7
pH (9.0 s.u., AL, FW)	0.0	2,761.9	0.0
Shellfish Growing Area Status (Fecal, SH, SA)	0.0	0.0	2,408.6
Total Nitrogen	0.0	11,375.9	0.0
Total Phosphorus	0.0	11,375.9	0.0
Total Suspended Solids (TSS)	3.9	3,644.9	0.0
Turbidity (25 NTU, AL, FW acres & SW)	0.0	3,752.1	0.0
Turbidity (50 NTU, AL, FW miles)	30.6	0.0	0.0

Tab	FW Miles ³	FW Acres ³	SW Acres ^{3,4,5}
Zinc (50 µg/l, AL, FW)	14.6	0.0	0.0

¹ Waterbody Uses: HH – Human Health, AL – Aquatic Life, FC – Fish Consumption, SH - Shellfish Harvesting, REC – Recreation.

² Other: GM – Geometric Mean, Nar – Narrative

³ Waterbody Type: FW – Freshwater, SW - Saltwater, Sw - Swamp Waters, SA - Shellfish Area, NC - All North Carolina waters.

⁴ Added Brunswick River's (18-77a and 18-77b) 743.7 SW acres not originally captured on 2022 IR category 5 list or total classified SW acres; 60.6 SW acres added to Arsenic Fish Consumption; 743.7 SW acres added to DO; 60.6 SW acres added to Hexavalent Chromium Fish Consumption; 743.7 SW acres added to pH (6.8).

⁵ Not captured in pH (6.8 s.u., AL, SW) totals in table for 4,281.8 SW acres of the Cape Fear River near Wilmington (AU#'s 18-(71)a1, 18-(71)a2a, 18-(71)a2b, 18-(71)a3, 18-(71)a4, 18-(71)a5). 4,282.8 SW acres were not captured on 2022IR category 5 list. Originally assessed using swamp criteria (<4.3) instead of SC criteria (<6.8). A correction will be made to the 2024IR. This is the same area impaired for low dissolved oxygen; therefore, this area is captured in the overall total impairment acres in the basin.

2.3 Biological Monitoring Data

Biological communities are highly sensitive to changes in water quality and can reflect both long and short-term environmental conditions. North Carolina and the Cape Fear River Basin have experienced intense rains and prolonged droughts (see Chapter 1) that can affect water quality and aquatic life. High flows during intense rain events can degrade aquatic habitats through excess erosion and aggradation (burying or embedding) of critical habitat, and increased loading of pollutants, while low flows during drought conditions can cause pollutants to concentrate, temperatures to warm, and dissolved oxygen levels to decrease causing stress to aquatic life. The [North Carolina Climate Science Report](#) found temperatures have warmed and heavy rainfall events have increased in recent years. The report also found it is *very likely* that temperatures and extreme precipitation frequency and intensity will increase, and it is *likely* droughts will become more frequent and intense in the future (see Chapter 1 for more information). The 2022 IR reported 127.8 FW miles impaired for fish community and 390.6 FW miles impaired for benthos in the Cape Fear River Basin, as was discussed in the previous section. The Haw River subbasin has the most biology impairments with 57% of the benthos impairments, 222.6 FW miles, and 55% of the fish community impairments, 70.8 FW miles.

The Water Sciences Section (WSS) [Biological Assessment Branch \(BAB\)](#) is charged with evaluating the water quality of North Carolina's rivers and streams. [BAB](#) has developed biocriteria also called Indices of Biotic Integrity (IBIs), to evaluate and compare wadable streams and rivers across the state that have very different ecoregions, habitats, and species assemblages. Benthos and fish community survey information is collected on species richness (i.e., diversity), abundance, and composition as well as site stream or water conditions such as stream habitat, physical and chemical water quality data, stream width, and flow regime. Survey results and the presence of pollution indicator species are used to calculate an IBI score. The IBI score is then assigned a descriptive rating or bioclassification. Methodologies for field sampling, IBI score calculation, and bioclassification assignment, have some variation according to ecoregion, season, and stream condition (e.g., local habitat, flow, width, watershed size, etc.). For specific methodology defining how these ratings are given, refer to the [Benthic Standard Operating Procedures \(SOP\)](#) or the [Fish Community SOP](#) available through WSS.

The [BAB](#) 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. The results of the previous monitoring cycle, completed in 2003, were evaluated as a point of comparison. *Table 2-7* shows the number of biology stations monitored in the Cape Fear from 2003 to 2021. The cycle monitoring years had 196 stations in 2003, 82 stations in 2008, 104 stations in 2013, and 82 stations in 2018. An additional 208 stations were monitored during non-cycle years. Drought conditions in 2002 resulted in some of the basin cycle 2003 fish community sampling being extended 2004, similarly, drought conditions in 2008 extended sampling for both fish community and benthos into 2009. “Basin” study sites are often re-monitored during cycle years, even during the same cycle year depending on field conditions or during a non-cycle year as happened with some sites in 2004 and 2009. Overall, there has been a greater than 50% decrease in biology monitoring between 2003 and 2018 due to a loss of funding and staff positions, even with some of the regular 2003 sampling being moved into the following year.

Figure 2-2 and *Figure 2-3* displays a maps of all benthic and fish community sites’ most current ratings including a few special studies done after 2018. All individual monitoring results collected from 2003 to 2021 for each station are in Chapter 2 Appendix. The largest concentration of fair and poor rated sites occurred near urban centers, particularly in the Deep and Haw River subbasins near Greensboro, other urban areas including Burlington, Chapel Hill, Fayetteville, and Wilmington also had a number of fair, poor, or severe rated sites. Several other severe or poor rated benthic sites occurred in the Northeast Cape Fear subbasins rural agricultural areas. Some of the areas in and around the Department of Defense Fort Liberty Military Installation in the Upper Cape Fear River subbasin had several excellent and good rated biology stations.

Table 2-7: Cape Fear River Basin Biology Monitored Stations

Year	Fish Community Stations	Benthic Stations			Total Biology Stations
		Basin	Special Study	Total Benthic*	
2002	6	5	20	25	31
2003	55	84	61	141	196
2004	22	0	4	4	26
2005	1	0	3	3	4
2006	0	0	19	19	19
2007	0	0	13	13	13
2008	31	38	13	51	82
2009	33	28	8	35	68
2010	1	0	11	11	12
2011	0	0	1	1	1
2012	0	0	5	5	5
2013	41	60	3	63	104

Year	Fish Community Stations	Benthic Stations			Total Biology Stations
		Basin	Special Study	Total Benthic*	
2014	6	0	3	3	9
2015	1	0	3	3	4
2016	0	0	10	10	10
2017	0	0	1	1	1
2018	29	52	1	53	82
2019	0	0	1	1	1
2021	0	0	4	4	4

*Some Benthic Stations were assigned a Basin and Special Study designation in the same Year.

2.3.1 Benthic Macroinvertebrate

Benthic macroinvertebrate communities are composed of aquatic insects and crustacean species such as crayfish, mollusk-like mussels, clams, snails, and aquatic worms. Aquatic benthic species are useful for biological monitoring as they are found in all aquatic environments, are less mobile than many other groups of organisms and are easily collectable. Aquatic benthic communities respond to a wide array of potential pollutants. The sedentary nature of benthic macroinvertebrates also ensures that exposure to a pollutant or stress in the environment accurately shows local conditions and allows for the comparison of sites, even within near proximity of each other. BAB biologists incorporated species richness, abundance, composition, and pollution indicator species into the benthic biocriteria used to calculate Index of Biological Integrity (IBI) scores and bioclassification ratings. Certain species of benthos, like mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), referred to in combination as EPT, are typically highly sensitive to pollution. Their presence or absence can be an indicator of exceptional water quality or an impairment. EPT species presence has been incorporated into the biocriteria and is used to evaluate some monitoring sites. Biocriteria (i.e., the methods used to calculate the IBI score), bioclassification assignment, and sampling methodology can vary with region and stream condition. North Carolina uses assessment units (AUs) to identify bodies of water. AUs that have Excellent, Good, Natural or Moderate bioclassification ratings will consistently contain diverse, stable, and pollution-sensitive communities of aquatic benthic macroinvertebrates.

BAB has Standard Operation Procedures (SOP) in place for monitoring benthic communities. It includes methodology for Swamp, Full-Scale, EPT, and Qual 4 monitoring. Swamp streams are classified by BAB as streams within the coastal plain ecoregion with little to no visible flow during certain parts of the year. Little or no flow usually occurs during summer months, but flowing water should be present in swamp streams during winter months. Samples are collected during winter months (February to early March) because sampling during these high-flow months provides the best opportunity for detecting differences in naturally occurring communities. Swamp stream bioclassification falls into three categories: Natural, Moderate and Severe, but swamp streams will receive a Not Rated bioclassification if the pH value is 4.0 or lower. Those below 4.5 are also difficult to evaluate. The Swamp methodology was primarily used on some sites in the Northeast and Black River subbasins.

Figure 2-2: Benthic Macroinvertebrate Sampling Sites Cape Fear River Basin

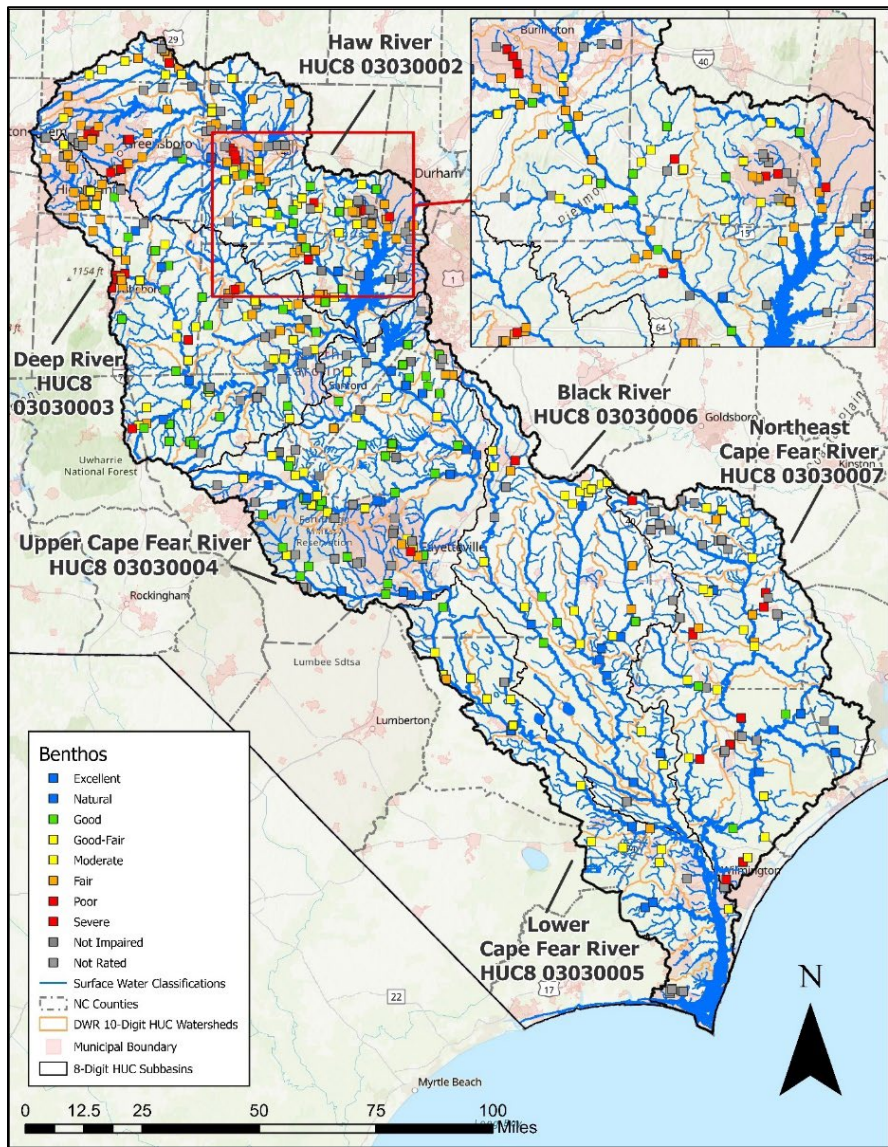
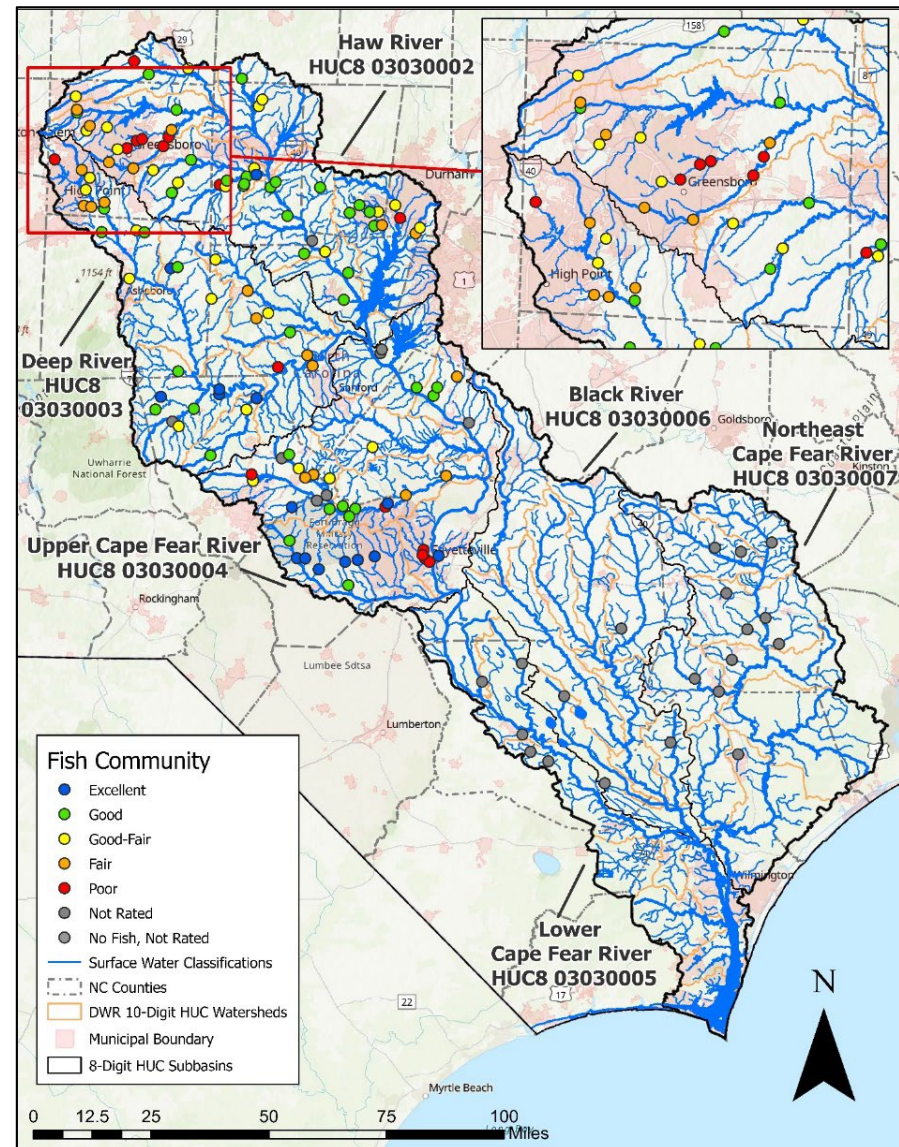


Figure 2-3: Fish Community Sampling Sites Cape Fear River Basin



The Full-Scale method can be used to assign water quality ratings (bioclassifications) to most wadable flowing streams and rivers in North Carolina. This methodology is applicable for most between-site and/or between-date comparisons and should be used for all evaluations of impaired streams (those on the state 303(d) list) for which the drainage area is over 3.0 square miles.

The EPT method is an abbreviated version of the Full-Scale method, both in field collection methods and species evaluation and is used to quickly determine between-site differences in water quality using solely EPT species. The Qual 4 method also uses abbreviated field collection methods but evaluates all species. It is particularly useful for watershed or basin assessment studies with large numbers of sites, or emergency sampling where it is desirable to rapidly assess the effect of spills, unusual discharges, etc. For specific methodology defining how these ratings are given, refer to the [Benthic Standard Operating Procedures \(SOP\)](#).

The basin site monitoring results for the entire Cape Fear River Basin for the four cycle years and 2009 are displayed in *Figure 2-4* (also see *Table 2-7*). 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. The Good-Fair/Moderate bioclassification was the most common rating in 2003 and 2008-2009, however, the Fair bioclassification was the most common rating in 2013 and 2018. *Figure 2-5* displays the percentage of samples meeting, exceeding, and not rated for each of four monitoring cycles, the 2013 and 2018 cycles had notably higher exceedance rates than 2003 and 2008. *Figure 2-6* breaks down the same percentages by HUC8 subbasin. At the HUC8 subbasin scale, the Haw River subbasin had a comparatively higher percent of stations exceeding criteria (i.e., rating as fair or poor), in comparison with the other subbasins every monitoring year. More information on the benthic monitoring results in the Cape Fear River Basin can be found in the subbasin watershed chapters.

Figure 2-4: Benthos Bioclassification Ratings 2003, 2008-2009, 2013, and 2018 for Basin Sites

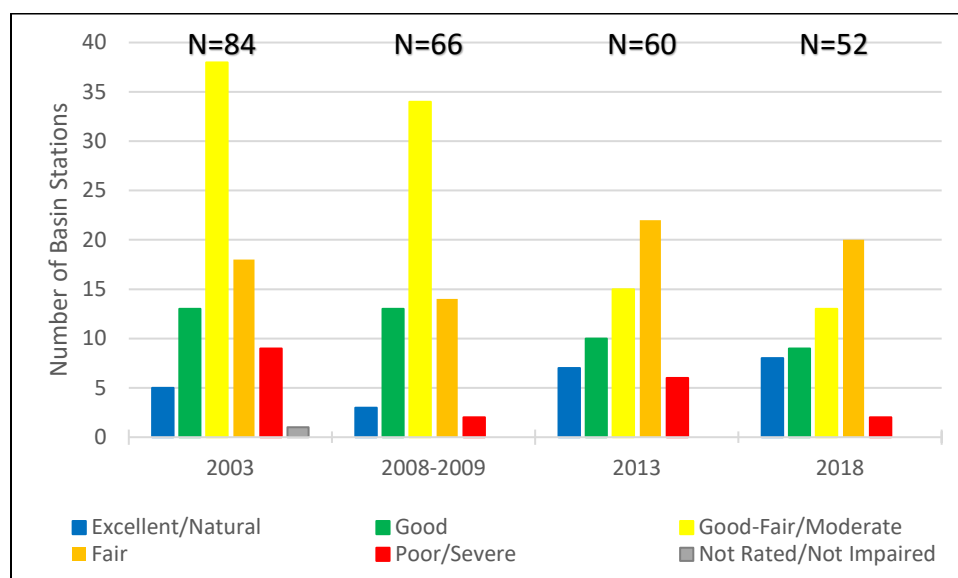


Figure 2-5: Percent Benthos Stations Meeting, Exceeding, & Not Rated 2003, 2008-2009, 2013, 2018 for Basin Sites

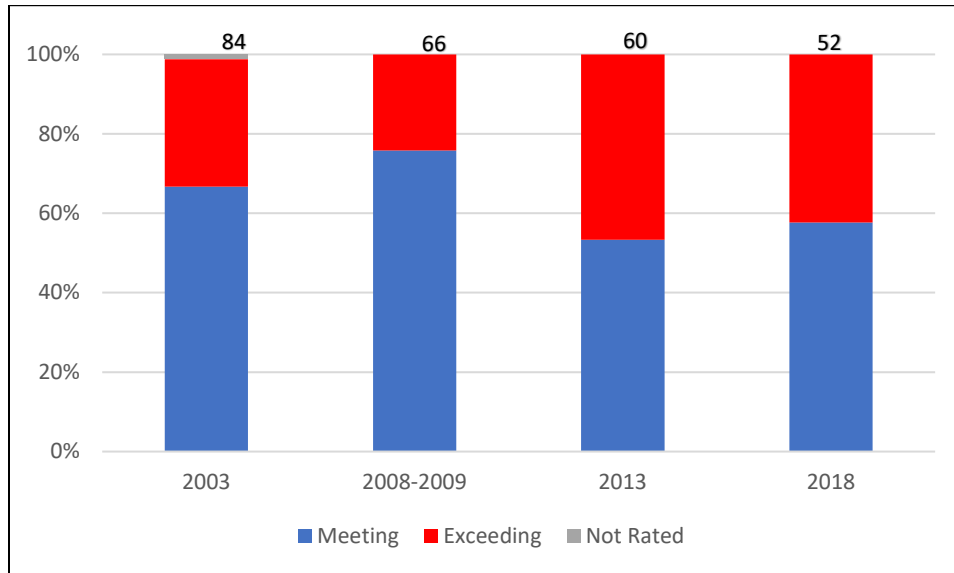
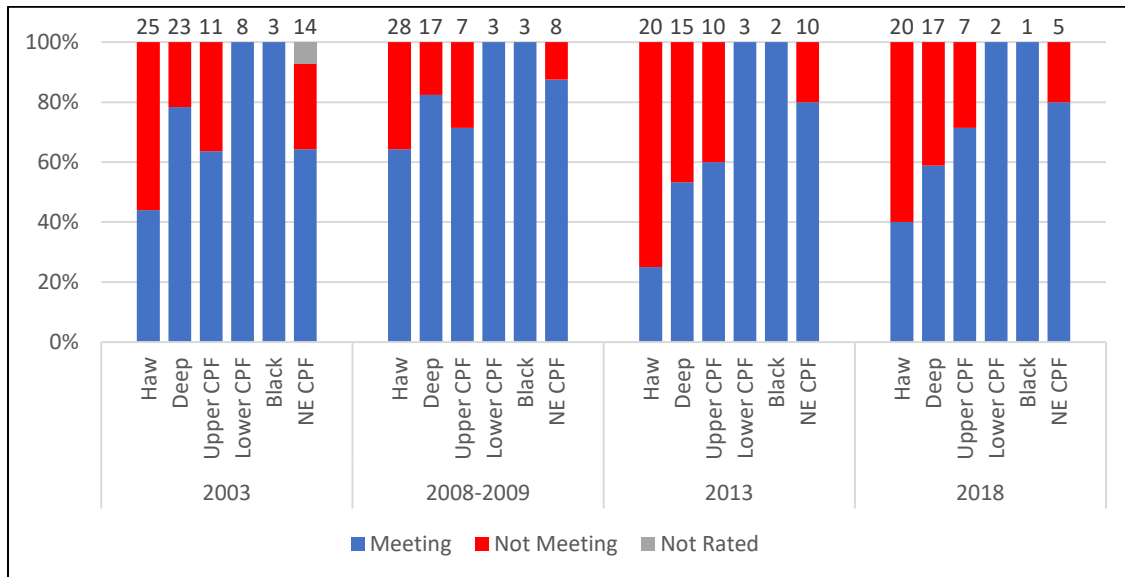


Figure 2-6: Percent Benthos Stations Meeting, Exceeding, & Not Rated 2003, 2008-2009, 2013, 2018 by HUC8 for Basin Sites



There is some variability in the basin monitoring sites chosen for monitoring cycle years 2003, 2008-2009, 2013, 2018 in Figures 2-4 to 2-6.

One station result per cycle year for 2003, 2013, 2018 and one station result for combined years 2008-2009 was used in graph data. The most recent result for stations sampled >1 time per year (years for 2008-2009) was used for graph data OR for stations sampled three or more times the most common result was used when applicable.

Sites rated as "Not impaired" were tallied at "Meeting Criteria" in Figures 2-4 to 2-6.

2.3.2 Fish Communities

Fish community monitoring uses the North Carolina Index of Biological Integrity (NCIBI) which incorporates information about species richness and composition, trophic composition, fish abundance, and fish condition. The NCIBI summarizes the effects of comprehensive influences upon aquatic faunal communities such as water quality, energy source, habitat quality, flow regime, and biotic interactions.

Fish occupy the upper levels of the aquatic food chain and can be affected both directly and indirectly by changes that occur in stream systems. Similar to the benthos biocriteria, BAB biologists incorporated information on species richness, abundance, composition, and pollution indicator species, along with information on species trophic level, reproductive function, and fish condition into the fish community biocriteria. Certain species including darters, bass, trout, and sunfish are more sensitive to habitat disturbance and pollution and are also accounted for in the biocriteria. The biocriteria also evaluates the effects of all classes of factors that influence the fish community such as water quality, energy source, habitat quality, flow regime, and biotic interactions. For this reason, not all changes in the fish community are related to water quality. Biotic index scores are a measure of the ecological health of the waterbody and may not directly correlate to water quality. For example, a stream with excellent water quality, but poor fish habitat, may not be rated excellent with this index. However, a stream which had an excellent bioclassification rating should be expected to have excellent water quality. The NCIBI has not been developed for the - Coastal Plain (Chowan, Neuse, Pasquotank, Roanoke, Tar, White Oak, and Lumber River basins)–due to staffing and other limitations. In the Cape Fear River Basin, the Lower Cape Fear River, Black, and Northeast Cape Fear River Basin sites do not have ratings.

As fish spend their entire lives in water, chemicals that occur within their aquatic environments can be incorporated into their tissues over time. Contamination of aquatic resources including freshwater, estuarine, and marine fish and shellfish species have been documented for heavy metals, pesticides, and other complex organic compounds such as PCBs. Fish tissue monitoring data is primarily used by the NC Division of Public Health for human risk assessments related to fish consumption, and when necessary for issuing fish consumption advisories in North Carolina.

Additional information about wadable streams fish community assessments can be found on DWR's [WSS website](#).

The overall basinwide monitoring results for the four cycle years and 2004 and 2009 are displayed in *Figure 2-7* (also see *Table 2-6*). Monitoring results for 2003 to 2004 and 2008 to 2009 were combined for data used in the graphics. The 2004 and 2009 years were used in the analysis as monitoring was not completed during regular cycle years. The Good and Good-Fair bioclassification ratings were the most common rating except in 2008-2009 when there were more Excellent and Not Rated. *Figure 2-8* displays the percentage of samples meeting, exceeding, and not rated for each of the monitoring cycles across the basin, the 2018 cycle had the highest exceedance rate with close to 25% of the monitored sites rating as Fair or Poor. *Figure 2-9* breaks down the same percentages by HUC8 subbasins. The Deep River subbasin had the highest percent of stations exceeding criteria in 2003-2004 and 2018, the Haw River subbasin had the highest percent of stations exceeding criteria in 2008 and 2013, and the Upper Cape Fear River subbasin was a close second in 2008-2009 and 2018. More information on fish community monitoring results in the Cape Fear River Basin can be found in the subbasin watershed chapters.

Figure 2-7: Fish Community Bioclassification Ratings 2003-2004, 2008-2009, 2013, and 2018

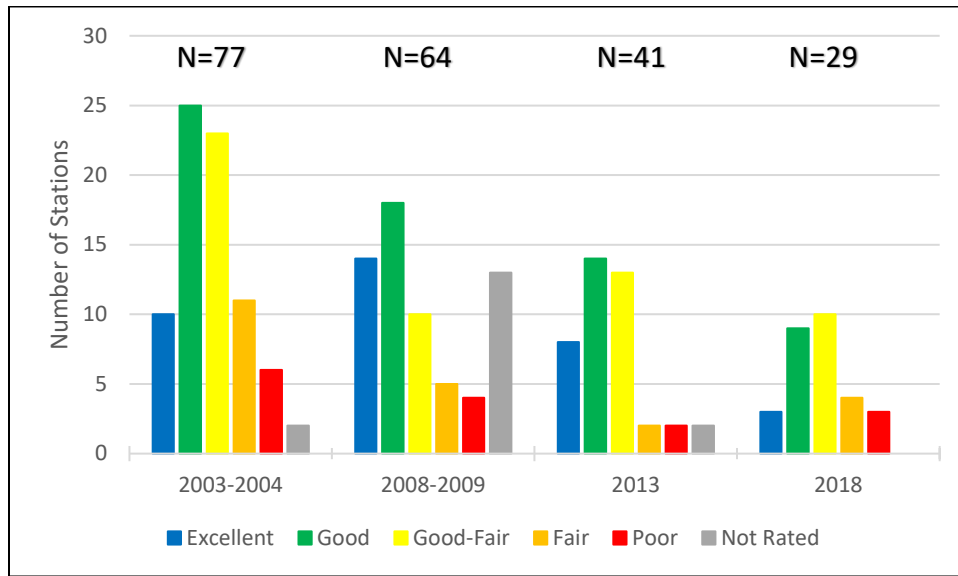


Figure 2-8: Percent Fish Community Stations Meeting, Exceeding, and Not Rated 2003-2004, 2008-2009, 2013, 2018.

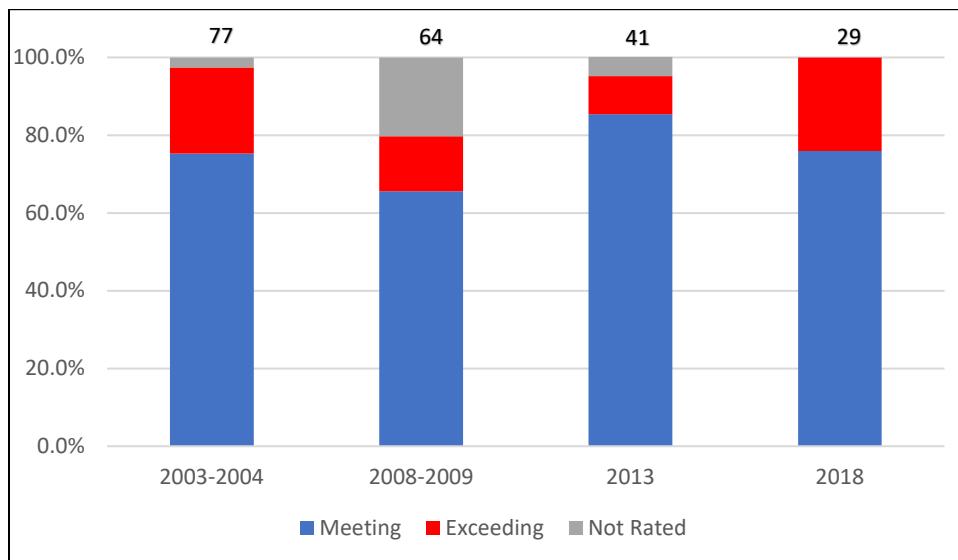
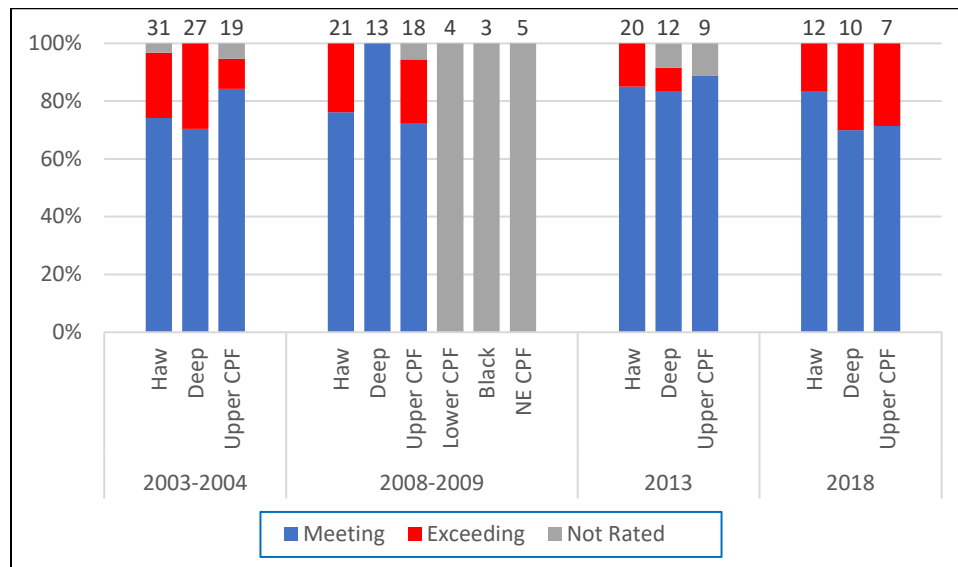


Figure 2-9: Percent Fish Community Stations Meeting, Exceeding, and Not Rated 2003-2004, 2008-2009, 2013, 2018 by HUC8.



There is some variability in the basin monitoring sites chosen for monitoring cycle years 2003, 2008-2009, 2013, 2018 in Figures 2-7 to 2-9.

One station result per cycle year for 2013 and 2018 and one station result for combined years 2003-2004 and 2008-2009 was used in graph data. The most recent result for stations sampled >1 time per year (years for 2003-2004 and 2008-2009) was used for graph data OR for stations sampled three or more times the most common result was used when applicable.

Sites rated as "Not impaired" were tallied at "Meeting Criteria" in Figures 2-7 to 2-9.

2.4 Shellfish Growing Areas

North Carolina coastal waters are known for their plentiful supply of shellfish such as clams, oysters, and mussels. Shellfish are filter feeders that pump water through their gills to gather food particles to survive. The pumping action can also take up and concentrate bacteria, viruses, or other harmful pollutants in the water. Shellfish that contain high concentrations of bacteria or viruses can cause severe illness when consumed raw or undercooked so areas available for harvest need to meet strict bacteria standards. The [Shellfish Sanitation and Recreational Water Quality Section](#) of the 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 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 (also see Chapter 2).

The [Shellfish Sanitation Program](#) is conducted in accordance with the guidelines set by the Interstate Shellfish Sanitation Conference and contained in the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish Model Ordinance. This National Shellfish Program is administered by the U.S. Food and Drug Administration. 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 volume and duration of pollutant delivery and flooding.

Bacteriological surveys are the collection of water samples from all shellfish growing areas. A minimum of six sets of water samples are collected from each sampling station on a random schedule to assess the overall quality of the waters for classification. Approved shellfishing waters must meet a bacteriological standard over the survey period of a median or geometric mean of not more than 14 Most Probable Number (MPN)/100 mL or a 90th percentile not to exceed 43 MPN/100 mL. Sanitary Survey Reports include an analysis of the data to determine the appropriate shellfish growing area classification. Additionally, bacteriological data is reviewed annually to ensure that the growing area classification remains appropriate.

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 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.

Several divisions and agencies within DEQ have jurisdiction over marine fisheries, water quality and coastal management. Representatives from these agencies develop and implement the Coastal Habitat Protection Plan (CHPP) (see DMF [CHPP website](#)). The [CHPP source document](#) is a guidance document that addresses habitat and water quality efforts needed to protect, enhance, and restore fish habitat along North Carolina's coasts (NCDEQ 2016). More information about the CHPP can be found in Chapter 4.

As of 2022, the Cape Fear River Basin has seven Shellfish Growing Areas (SGA) with one that is entirely open, [B3](#) (“The Basin” harvest area), located in the Fort Fisher State Recreation Area, two that partially open, [B2](#), located 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 2-8*). The SGAs are primarily located in the Lower Cape Fear subbasin (HUC8 03030005); however, the upper portion of the B10 SGA covers some areas in the Black (HUC8 03030006) and Northeast Cape Fear (HUC8 03030007) subbasins. Additionally most of [A3](#) is located in the Lumber River basin and most of [B5](#) is located in the White Oak River basin. See Chapter 9, Lower Cape Fear River subbasin for more details on Shellfish growing areas in the Cape Fear River Basin and a map of the region.

Table 2-8: Cape Fear River Basin Shellfish Growing Areas and Status

HUC8	Grow Area	Harvest Area Name	Harvest Area Classification	Harvest Area Status
03030005	A3	Intracoastal Waterway ¹	Prohibited	Closed
03030005	B1	Southport/ Elizabeth River/ IWW	Prohibited	Closed
03030005	B2	Baldhead Creek	Conditionally Approved - Closed	Closed
03030005	B2	Baldhead Island	Approved	Open
03030005	B2	Bald Head Island Marina	Prohibited	Closed
03030005	B3	The Basin	Approved	Open
03030005	B3	Wildlife Boat Ramp	Prohibited	Closed
03030005	B4	Cape Fear River	Prohibited	Closed
03030005	B4	Cape Fear River	Approved	Open
03030005	B5	Carolina Beach Harbor and Snow Cut ²	Prohibited	Closed
03030005 & 03030007	B10 ³	Cape Fear River	Prohibited	Closed

¹Only the very eastern portion (part of Stream Index 15-25) of the A3 Intracoastal Waterway located in the Cape Fear River Basin, the rest is in the Lumber River basin. Other A3 Harvest Areas, located only in the Lumber River Basin, are open.

²Just the Snow Cut (Stream Index 18-87-31.5) section of the B5 Carolina Beach Harbor and Snow Cut Harvest Area is located the Cape Fear River Basin, the rest is located in White Oak River basin. Other B5 Harvest Areas, located only in the White Oak River Basin, are open.

³The B10 SGA is entirely prohibited so sampling and Sanitary Survey reports have not been conducted in this SGA (pers. comm. Andrew Haines, July 21, 2022)

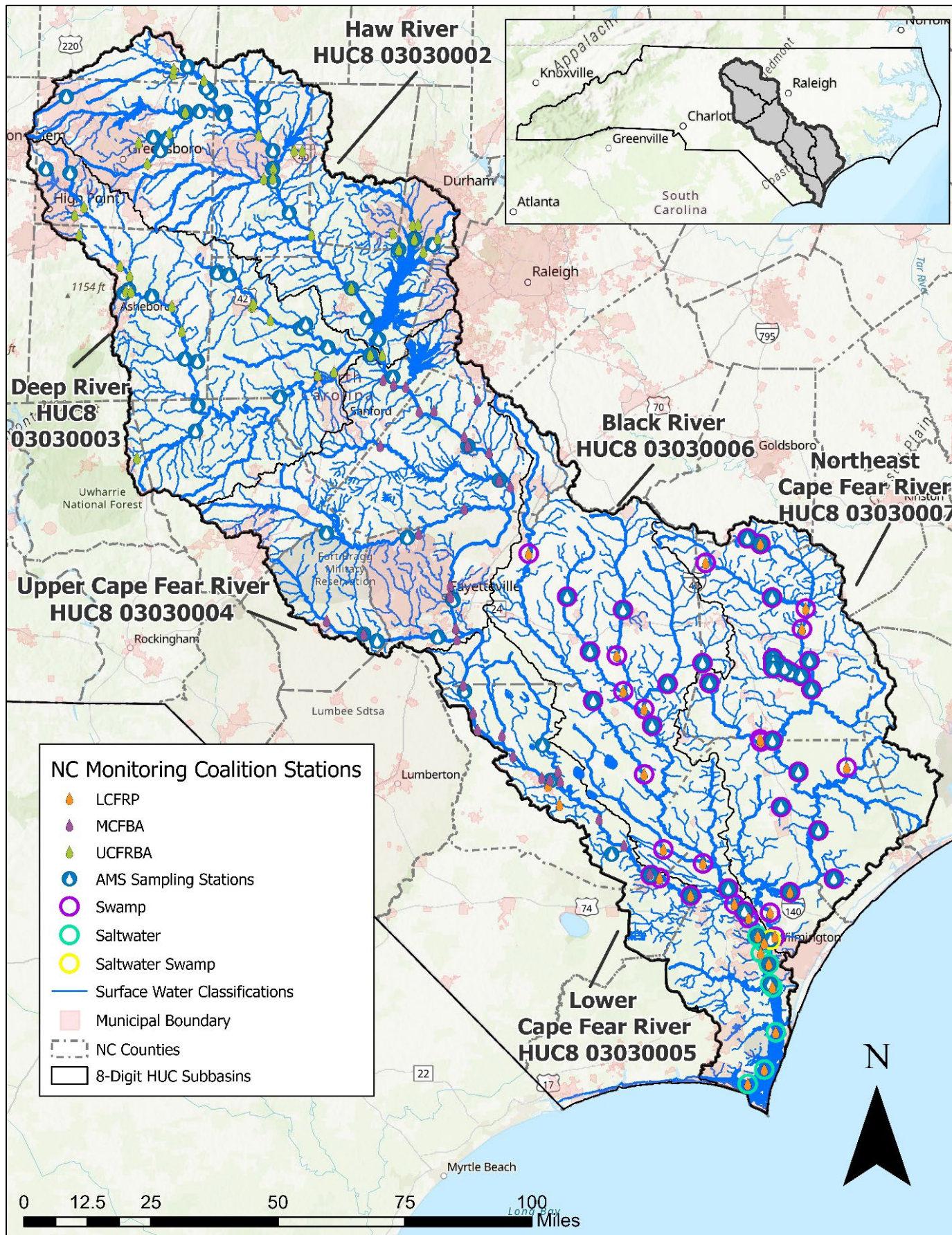
2.5 Ambient Monitoring Data

All parameters measured through the network of ambient monitoring stations are important to human health, aquatic life and/or the aquatic ecosystem, and many of the parameters are interrelated. Parameters collected at each site depend on the waterbody's (AU) classification, but typically include specific conductance/conductivity, dissolved oxygen, pH, temperature, turbidity, nutrients, and fecal coliform. Each waterbody classification has an associated set of water quality standards the parameter must meet to be considered supporting its designated use(s) (see Sections 2.1 and 2.2).

In the Cape Fear River Basin, from 2000 and 2020, water quality data was collected at 113 [Ambient Monitoring System \(AMS\)](#) stations and 143 coalition stations, 38 stations were co-located during some or all monitoring years. The AMS is a network of stream, lake, and estuarine stations strategically located for the collection of physical and chemical water quality data. The [Monitoring Coalition Program](#) is a voluntary, ambient monitoring program composed of public municipal and private industrial permit holders. Coalition members work with DWR to develop a monitoring network that uses strategically selected and mutually agreeable sampling locations to evaluate water quality beyond the point-source outfall. There are three coalitions active in the Cape Fear River Basin, the Upper Cape Fear River Basin Association (UCFRBA), the Middle Cape Fear Basin Association (MCFBA), and [Lower Cape Fear River Program \(LCFRP\)](#). As of 2020 there are 75 AMS and 104 coalition stations (40 UCFRBA, 33 MCFBA, and 31 LCFRP) with 12 being co-located (*Figure 2-10*). Additionally, 36 stations were sampled by DWR as part of the [Random Ambient Monitoring System \(RAMS\)](#) during the 2000-2020 time-period. RAMS is a component of the AMS and is a probabilistic monitoring initiative in which sampling locations are randomly selected and located on freshwater streams throughout the state. The stations are sampled once a month for two years and then retired. RAMS focuses on smaller streams and allows DWR to collect data on water quality parameters that are not evaluated through AMS and answer broad questions about water quality in North Carolina's smaller streams. Parameters collected through RAMS that are not collected through AMS include: chloride, fluoride, sulfate, dissolved organic carbon, and volatile organic compounds. Various special studies have also been conducted and in the Cape Fear River Basin since 2000 including studies for dissolved metals (see [Metals](#) in this section) and emerging contaminants (see Chapter 1). See Chapter 2 Appendix for a complete list and maps of the AMS, RAMs, and Coalition stations monitored in the Cape Fear River Basin from 2000-2020.

Most ambient stations are located in rivers and streams, and several are located in the estuary, canals, or lakes or reservoirs. Only two reservoir stations (B2450000 and B4614500) were included in the ambient station analyses shown in this section. There are other lake and reservoir monitoring stations, described in the next section, that were used for the Integrated Report. Water quality standards differ for freshwater, saltwater, and Swamp (Sw) classified waterbodies. In 2020, there were 119 freshwater, 10 saltwater (estuary), 39 freshwater Sw and one saltwater Sw unique stations (co-located stations were counted as one station) in the Cape Fear River Basin. The Sw classified stations were located in the lower part of the basin, in the Black and Northeast Cape Fear River subbasins, primarily, and the Lower Cape Fear River subbasin. All 10 saltwater stations were located in the Lower Cape Fear River subbasin, and the one saltwater Sw station was in the Northeast Cape Fear River subbasin.

Figure 2-10: Cape Fear River Basin Ambient Water Quality Stations



Most of the coalition ambient 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 0.1m (surface reading) and then at various depths depending on the waterbody and needs of the study being performed. 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 the basin plan 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.

An overall comparison of Cape Fear River HUC8 subbasin scale ambient water quality mean results for samples collected in the basin from 2016 to 2020 for pH, dissolved oxygen (DO), conductivity, nutrients, turbidity, Total Suspended Solids (TSS), and fecal coliform is shown in [Table 2-9](#). Only stations that had a minimum of five-years and 40 average day records were used in this analysis. The number of stations used in this five-year mean HUC8 analysis and a five-year mean HUC10 analyses for the same parameters is available in the Chapter 2 Appendix, also see the subbasin chapters. The Northeast Cape Fear River subbasin (HUC8 03030007) had the highest mean five-year results for conductivity, fecal coliform, total phosphorus (TP), ammonia (NH₃), and organic nitrogen (Total Kjeldahl Nitrogen [TKN] minus ammonia), while the Haw River subbasin (HUC8 03030002) had the highest mean five-year results for turbidity, TSS, total nitrogen (TN) and inorganic nitrogen (nitrite-nitrate [NO_x]).

Conductivity was comparatively higher in the Northeast Cape Fear River than in the other subbasins. High conductivity is associated with saltwater and pollutants such as chlorides, nutrients and TSS. The Northeast Cape Fear Rivers high conductivity level, 711 $\mu\text{S}/\text{cm}$, was primarily due to two outlier stations that receive saltwater influence (see Section 2.5.5). Additionally, two waterways (Panther Creek/Branch and the headwaters of the Northeast Cape Fear receive discharge from NPDES permitted facilities that have variances from the water quality standard for chloride concentrations resulting in elevated specific conductivity. The Haw River followed by the Deep River, had the next highest mean conductivity levels with 222 $\mu\text{S}/\text{cm}$ and 189 $\mu\text{S}/\text{cm}$ respectively ([Table 2-9](#)), both these subbasins had issues with nutrients, turbidity, and TSS.

The Northeast Cape Fear Rivers highest concentrated nitrogen results were 0.09 mg/L for NH₃ and 0.92 for TKN, however, the Black River (HUC8 03030006) results were nearly as concentrated with 0.07 mg/L for NH₃ and 0.86 for TKN. The mean TKN and NH₃ results were comparable in the Haw (HUC8 03030002), Deep (HUC8 03030003), and Lower Cape Fear (HUC8 03030005) subbasins and lowest in the Upper Cape Fear River (HUC8 03030004) subbasin ([Table 2-9](#)). The Haw Rivers highest concentrated results were 1.34 mg/L for inorganic nitrogen (NO_x) and 2.10 mg/L for TN. The mean results in the Deep River subbasin were nearly as concentrated with 1.32 mg/L for NO_x and 2.08 mg/L for TN. The Northeast Cape Fear River had comparatively lower NO_x and TN mean results (0.61 mg/L NO_x and 1.54 mg/L TN) while Lower Cape Fear and Black River subbasins had similar results that were less than the Northeast Cape Fear. The Upper Cape Fear had the lowest mean concentrations for NO_x (0.35 mg/L) and TN (1.0 mg/L) ([Table 2-9](#)).

The Northeast Cape Fear Rivers highest concentrated TP mean results of 0.21 mg/L were comparatively more than the second highest mean results of 0.15 mg/L that occurred in Lower Cape Fear. The Haw, Deep, and Black had similar TP results, ranging from 0.11 to 0.13 mg/L, and again, the Upper Cape Fear had the least concentrated mean results for TP, 0.07 mg/L (*Table 2-9*).

The Haw River had comparatively higher results than the other subbasins for turbidity with 20.19 mg/L and for TSS with 22.90 mg/L. The Deep River had the second highest results with 16.32 NTU for turbidity and 16.83 mg/L for TSS. TSS levels were similar to the Deep in the Upper Cape Fear (16.38 mg/L) and not collected in the other subbasins. The Upper Cape Fear and Lower Cape Fear River subbasins had the next highest turbidity levels with both being in the 13 mg/L range, while Black and Northeast Cape Fear River subbasins had the lowest turbidity levels, both under 7 mg/L (*Table 2-9*).

The fecal coliform mean level of 1,093 colonies/100 mL in the Northeast Cape Fear River subbasin was also comparatively higher than the other subbasins. The Haw, Deep, and Black River subbasins also had similar mean levels of fecal coliform, in the 700 colonies per 100 mL range, and the Upper and Lower Cape Fear River subbasins had the lowest results, both were less than 450 colonies/100 mL (*Table 2-9*).

Land use, land cover, permitted facilities, and USDA census are very different within six Cape Fear River subbasins (see Chapters 1 and 2). The Haw River subbasin is the most urbanized with close to 25% development, while the Deep is 15% developed and the Upper Cape Fear 18% developed. Between 2016 and 2019, 85% of the new development, close to eight square miles, occurred in Haw River subbasin. The lower three subbasins, the Lower Cape Fear, Black, and Northeast Cape Fear, are more rural with 10% or less development. These three subbasins are also located in the coastal plain where over one-third of the natural land cover is wetland.

In terms of permitted facilities, the Haw River subbasin has the most NPDES wastewater treatment plant (WWTP) facilities and accounts for over one-third of the permitted as-built point-source discharge (146.8 MGD) in the basin. The Haw River subbasin also has the most NPDES stormwater facilities (146) and half of the Cape Fear River Basin's Municipal Separate Stormwater Sewer Systems (MS4) communities (16 of 32). The Deep River subbasin has the second most stormwater facilities (146) and the Upper Cape Fear has the third most (130) stormwater facilities. The Haw and the Deep River subbasins also have more non-discharge and residual solids application field acreage than the lower subbasins, 6,288 and 4,449 acres respectively.

The Black and Northeast Cape Fear River subbasins had the highest percentage of land use in agriculture, 24% and 32% respectively, which was reflected in the permitting and USDA data. The Northeast Cape Fear and the Black River subbasins have a significant number of permitted Animal Feeding Operations, primarily swine. As of May 2022, these two subbasins combined, accounted for 47% of the permitted AFOs, 44% of the permitted liveweight, and 49% of the permitted lagoons and waste ponds for the entire state of North Carolina. The Black and Northeast Cape Fear River subbasins also each had over 3,000 acres permitted for the NPDES land application of residual solids and wastewater irrigation. Additionally, the 2022 USDA Census of Agriculture data indicated Duplin County, in the Northeast Cape Fear River subbasin, has the highest chicken/poultry (broilers, layers, pullets, and roosters) numbers in the state, 22 million for

inventory and 96 million for contract production. Sampson County in the Black River subbasin has the second highest poultry number in the state with 19.2 million in inventory and 76.8 million for contract production. Duplin and Sampson counties also had the highest swine number for a combined total of 3.7 million head in 2022, 76% of the total inventory reported in the Cape Fear River Basin and 47% of the NC statewide inventory totals.

The known information on land-use, land cover, permitted facilities, and USDA census data and the water quality results suggests the main drivers for pollutants are different in the upper portion of the basin where the Haw and Deep are located than the lower part of the basin where the Northeast Cape Fear and Black River subbasins are located. Point source dischargers and stormwater runoff from developed watersheds are the primary drivers affecting nutrients, turbidity, TSS, and fecal coliform bacteria in the upper subbasins. Non-point sources from agricultural lands are the primary drivers affecting pollutants in the Northeast Cape Fear and Black River subbasins. However, there are still some point sources and urban development also influencing nutrient and fecal coliform levels in these lower basins. It is likely a combination of point and non-point sources affecting the Upper and Lower Cape Fear River subbasins. Additionally, the wetlands in the lower part of the basin can affect organic nitrogen levels (TKN minus ammonia) as well as causing lower DO and more acidic pH levels.

A description of each parameter and a more in-depth summary of the monitoring results are provided in the following subsections. Maps have been developed for each parameter using recent 2016-2020 station data that highlights hotspot locations of pollutants that may be entering waterways. The station's exceedance rate for parameters with water quality standards (i.e., turbidity, pH, dissolved oxygen, and fecal coliform) or the station's 75th percentile for parameters without standards (i.e., nutrients) is mapped using representative symbol size classes. Percentiles are summary statistics that can be used to gain an understanding of the range of the data that is collected. The 75th percentile instream nutrient value is where 75% of all measurements taken are below this concentration and 25% of the measurements are above this concentration. The 75th percentile allows for a simple comparison between stations and a quick visualization of where higher concentrations (hotspots) can be found in the basin.

Graphs summarizing yearly HUC8 subbasin datasets were also developed with 2000 to 2020 data. Discharge data from the U.S. Geological Survey (USGS) gage Cape Fear River at Lock and Dam #1 near Kelly (02105769) in the Lower Cape Fear River is displayed on the graphs for comparing overall yearly stream flow differences. 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.

2.5.1 Turbidity

Turbidity is a measure of cloudiness in water and is often accompanied by excessive sediment deposits in the streambed. Excessive sediment deposited on stream and lake bottoms can choke spawning beds (reducing fish survival and growth rates), harm fish food sources, fill in pools (reducing cover from prey and high temperature refuges), and reduce habitat complexity in stream channels. Excessive suspended sediments can also make it difficult for fish to find prey and at high levels can cause direct physical harm, such as clogged gills. Sediments can also cause taste and odor problems, block water supply intakes, foul

treatment systems, and fill reservoirs. Soil erosion is the most common source of turbidity. Some erosion is a natural phenomenon, but human actions and land use practices can accelerate the process to unhealthy levels. Construction sites, mining operations, agricultural operations, logging operations, and

Table 2-9: Cape Fear River Basin HUC8 Subbasin Ambient Water Quality Means for 2016-2020

Cape Fear River (CFR) HUC 030300_ _	Number of Stations*	pH	DO (mg/L)	Conductivity (µS/cm)	NH ₃ (mg/L)	TKN (mg/L)	NOx (mg/L)	TN (mg/L)	TP (mg/L)	Turbidity (NTU)	TSS (mg/L)	Fecal Coliform (CFU/100 mL)	
CPF Basin Mean 030300*	140	6.84	7.83	217	0.06	0.77	0.84	1.61	0.13	14.52	19.17	668	
Haw River ¹	02	35	7.20	8.27	222	0.06	0.77	1.34	2.10	0.13	20.19	22.90	749
Deep River	03	24	7.16	8.34	189	0.06	0.76	1.32	2.08	0.11	16.32	16.83	732
Upper CPF	04	20	6.52	8.21	90	0.03	0.65	0.35	1.00	0.07	13.08	16.38	360
Lower CPF ²	05	30	6.74	7.20	117	0.06	0.75	0.53	1.29	0.15	13.64		423
Black River	06	14	6.14	7.06	101	0.07	0.86	0.43	1.29	0.13	4.83		754
Northeast CPF ³	07	17	6.47	6.96	711	0.09	0.92	0.61	1.54	0.21	6.45		1,093
Healthy Piedmont Stream**													
Minimally Impacted Streams***													
EPA Nutrient Criteria - Piedmont ⁺													
EPA Nutrient Criteria - Coastal Plain ⁺													

*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.

Lower portion of subbasin watershed influenced by salt water from Atlantic Ocean.

^ Portions of the subbasin influenced by Mount Olive Pickle NPDES permitted discharge. They have an NPDES permit variance for discharging high concentrations of salt in their wastewater. Lower portion of the watershed influenced by natural saltwater influences.

**DWQ ESS- ISU Special Study. March 24, 2004, Rocky River Survey (Chatham County) Subbasin 03-06-12.

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

+ 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 in comparison to the other HUC 8 watersheds.

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

¹The Haw River subbasin has one Reservoir station (Robeson Creek arm of Jordan Lake), all 34 other stations are River/Stream stations.

²The Lower CPF River subbasin includes nine Estuary stations, all 21 other stations are River/Stream stations.

³The Northeast CPF River subbasin includes one Estuary station, all 17 other stations are River/Stream stations.

excessive stormwater flow from impervious surfaces are all potential sources of erosion and turbidity in a stream channel.

Turbidity for freshwater streams shall not exceed 50 Nephelometric Turbidity Units (NTU) to avoid a violation of the state water quality standard. Tidal saltwater, lakes, and reservoirs, not designated as trout waters (Tr), shall not exceed 25 NTU. Freshwater streams with a supplemental classification of trout waters are the most protected with turbidity values not exceeding 10 NTU (15A NCAC 02B .0211). In 2022, there were 30.6 FW miles and 3,752.1 FW acres impaired for turbidity (*Table 2-6*). FW mile impairments were split between the Haw River (HUC8 03030002) and Deep River (HUC8 03030003) subbasins, all of the FW acre impairments were in the Haw River subbasin (*Figure 2-11*).

The Cape Fear River Basin turbidity levels have been highest from 2016 to 2020 in the Haw River subbasin, particularly in the Northeast Creek headwaters (Station B3660000) of Jordan Lake which had >20-30% exceedance over the 50 NTU standard. Additionally, some stations had >10-20% exceedance in southwest Durham and along the Haw River and various tributaries (*Figure 2-11*). Yearly HUC8 subbasin mean levels and exceedance rates for turbidity correlated with discharge in the Haw and Deep and to a lesser degree the Upper and Lower Cape Fear River subbasins indicating turbidity sources are primarily stormwater driven (*Figure 2-12*). Mean annual turbidity levels in the Haw and Deep varied from 15 to 20 NTUs most years, the Upper and Lower Cape Fear River subbasins generally ranged from 10 to 15 NTUs, and the Black and Northeast Cape Fear River subbasins were always below 10 NTUs (*Figure 2-12*).

The Haw River subbasin had the highest mean turbidity levels in recent years, especially in 2018 and 2020 when HUC8 means were over 25 NTUs, the Deep River subbasin had highest mean levels and exceedances during some years prior to 2010 (*Figure 2-12* and *Figure 2-13*). The Haw River subbasin has the most impervious surface with close to 25% of the land cover classified as development. This subbasin also accounts for over a third of the new development, 57 Mi², in the basin between 2001 and 2019, of which 7 Mi² were added in the last three years. The Haw River subbasin also has the highest total permitted discharge (146.8 MGD as-built), highest number of NPDES stormwater permits (274 permits), half the MS4 communities in the basin (16), and the highest acreage of non-discharge and land-application fields (6,288 acres) (see Chapter 3).

Figure 2-11: Cape Fear River Basin Turbidity Exceedance Rate by Station

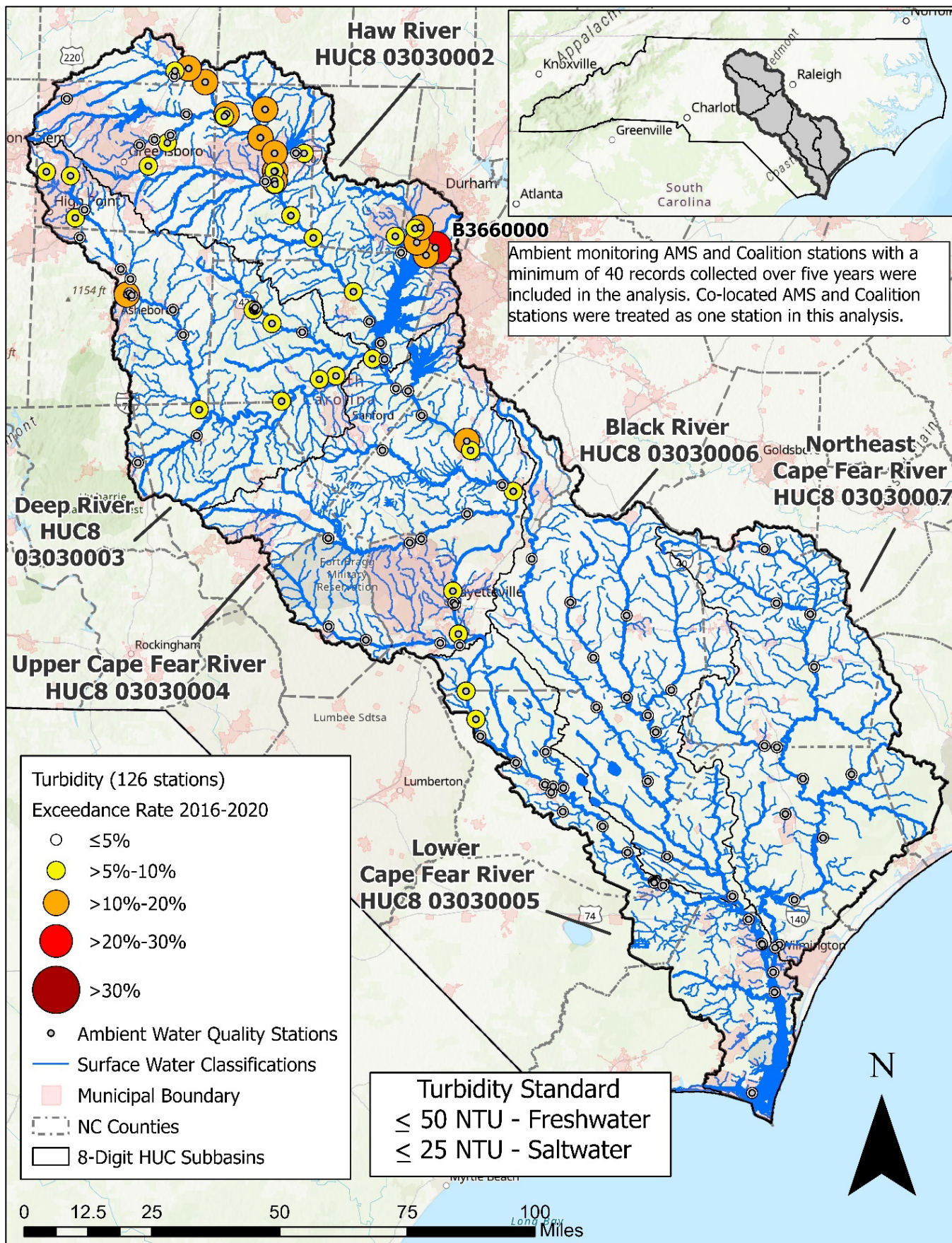


Figure 2-12: Cape Fear River Basin HUC8 Subbasin Annual Mean Turbidity

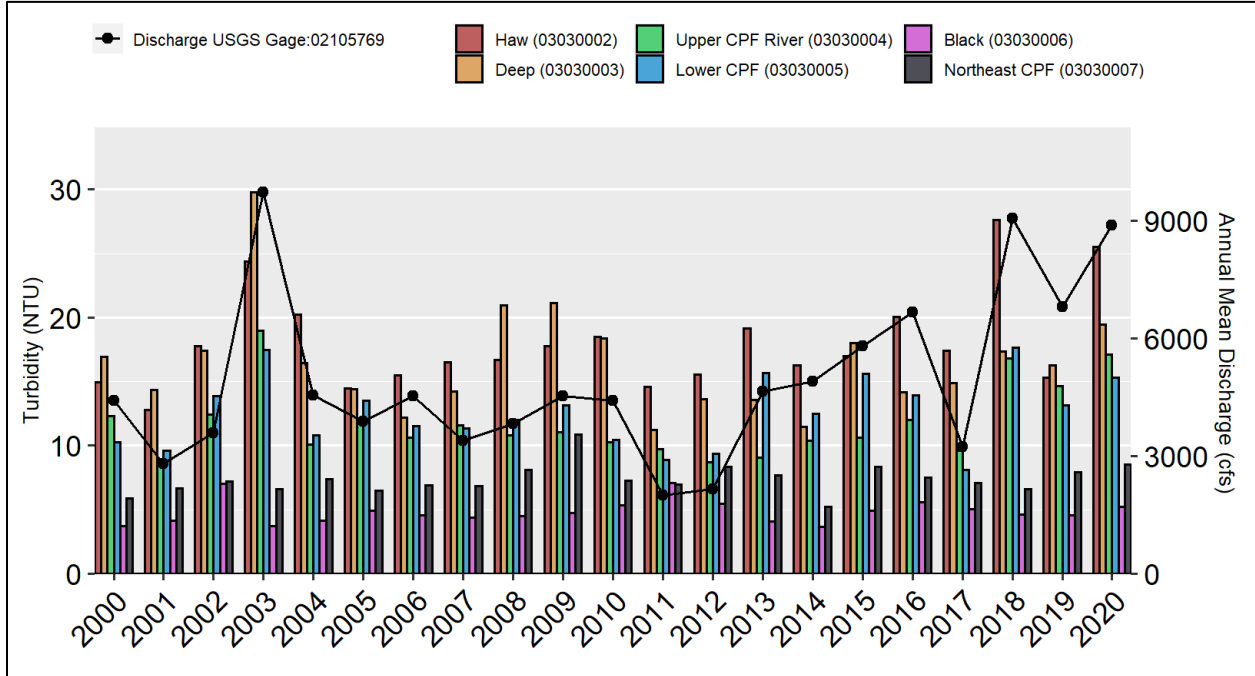
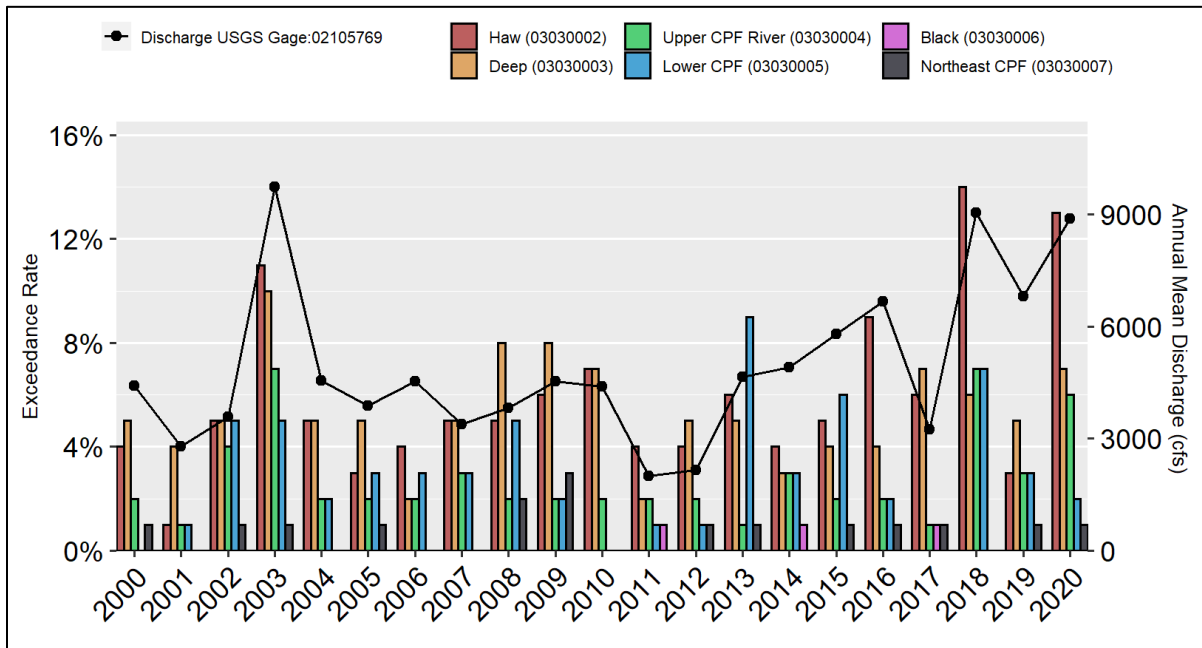


Figure 2-13: Cape Fear Basin HUC8 Subbasins Sample Percentages that Exceed the Water Quality Standard for Turbidity



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 220 freshwater and 7 saltwater stations used in the mean and exceedance analyses from 2000 to 2020. Station number and records per station vary from year to year. The turbidity standard is ≤ 50 NTU for freshwater, ≤ 25 NTU for saltwater.

2.5.2 pH

Potential of hydrogen (pH) is the measure of hydrogen ion concentration in water expressed on a scale from 0 to 14 to determine whether a solution is acidic, neutral, or alkaline (basic). Low values (< 6.0) can be found in waters rich in dissolved organic matter, such as swamp waters. High values (> 9.0) may be found in sea water and in water experiencing an algal bloom. Lower values can have chronic effects on the community structure of macroinvertebrates, fish, and phytoplankton. Changes in the pH of surface waters can occur during algal events, acidic rain and snow melt, changes in temperature, stormwater runoff, mining operations, point source discharges, geologic conditions, and accidental chemical spills. Class C freshwaters shall have a pH between 6.0 and 9.0, (15A NCAC 02B .0211). Class SC tidal saltwaters, shall have a pH between 6.8 and 8.5 (15A NCAC 02B 0.220). Class C or Class SC waters with the supplemental classification of Sw (swamp) may have a pH as low as 4.3 if due to natural conditions. In 2022, there were 14.9 FW miles, 3,552.1 FW acres, and 743.7 SW acres impaired for pH ([Table 2-6](#)), in all subbasins but the Deep. Impairments and monitoring for FW acre lakes and reservoirs within the Cape Fear River Basin is covered in Section 2.6, Lake Monitoring Data. The Northeast Cape Fear subbasin had half the FW mile impairments, 7.4 FW miles exceeded the 4.3 standard, other FW mile impairments occurred in the Upper Cape Fear River subbasin (1.9 miles exceeded the 6.0 standard) and Lower Cape Fear River subbasin (5.6 miles exceeded the 4.3 Sw standard). The Haw River subbasin had the most FW acre impairments, 2,716.9 FW acres exceeding the 9.0 standard and the Lower Cape Fear River subbasin had all of the SW acre impairments, 743.7 acres exceeding the 6.8 standard. There was an error identified during the development of the basin plan that found an additional 4,281.8 SW acres should have been on the 2022 IR due to low pH levels (<6.8) 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 ([Table 2-5](#), [Table 2-6](#) and [Table 2-10](#)). The standard applied was < 4.3 instead of < 6.8. These sections of the Cape Fear River will be added as a correction on the 2024IR as long as the instream value remains low. This low pH coincides with the same area of low dissolved oxygen and the SC to swamp waters declassification area (see Section 2.5.3 for more detail).

Several water quality stations in the lower two-thirds of the basin in the Upper and Lower Cape Fear River subbasins violated the low pH standard, by >20-30% and >30%, during the 2016 to 2020 timeframe ([Figure 2-15](#)). In the Upper Cape Fear River subbasin, these high number of exceedances occurred along two tributaries located to the north and south of Fayetteville, Lower Little River (stations B7280000 and B7300000) and Rockfish Creek (stations B7679300, B7700000, B8224000, B8230000). In the Lower Cape Fear, high exceedance rates occurred along the Turnbull Creek tributary (B8321000) located to north of Elizabethtown, and at several lower Cape Fear River mainstem saltwater stations near Wilmington ([Table 2-10](#)). There was also one Sw classified station on Colly Creek (B8981000), in the Black River subbasin, that had >30% exceedance of the 4.3 standard ([Figure 2-15](#)); however, this was determined to be due to natural conditions based on an assessment completed in 2014 ([link](#)). The other FW stations were not classified as Sw stations, so the standard was 6.0-9.0, all being too acidic and not meeting the lower end of the standard. The acidic conditions along the lower Cape Fear River are likely affected by the presence of wetlands, particularly, the stations near Wilmington which receives 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. The Colly Creek station (B8981000) in the Black River subbasin and Turnbull Creek tributary station (B8321000) in the Lower Cape Fear River subbasin are also located in

watersheds with extensive wetland coverage that may be affecting acidity levels (62% coverage for the Colly Creek station and 47% coverage for the Turnbull Creek tributary station). The exact cause and source of these lower pH values in the Lower Little River and Rockfish Creek is unclear; however, it has been noted that the low buffering capacity of sandy soils and the potential influence of conifer trees could exert an influence on flow-through pH in these waterways although this is an active area of research and other factors (acidic soils, sulfur-bearing minerals, human influence, or other) may have an influence on lower the pH of these waterways. Currently there are no North Carolina Sandhills specific studies, or conflicting information, to definitively support these two phenomena, although they could exist. Further investigation is needed to verify whether there are any other non-natural anthropogenic pollutants that may be affecting pH levels. The Turnbull Creek station (B8321000) and some of lower Cape Fear River stations have had DO issues (see the next section) and the Colly Creek station (B8981000) has had organic nutrient issues (see Section 2.5.7).

Table 2-10: Lower Cape Fear River Estuarine Stations with Percentage of Samples Not Meeting Water Quality Standards for pH and Dissolved Oxygen (DO) for 2022IR Period (2016-2020).

Cape Fear River Estuary	Assessment Unit #	Stream Class	Area Miles (Mi) or Acres (A)	Station #	~ # of samples	% DO < 4 mg/L* or < 5mg/L	% pH < 4.3 ^ or < 6.8 s.u.
Cape Fear River	18-(63)b	C; Sw	18.5 Mi	B9030000	71	9.6*	0^
Brunswick River	18-77a & 18-77b	SC	743.7 A	B9790000	57	28.1	26.3
Cape Fear River	18-(71)a1	SC	+10.6 A	B9050000	35	28.6	60.6
Cape Fear River	18-(71)a2a	SC	+290 A	B9050025	70	40.0	57.1
Cape Fear River	18-(71)a2b	SC	+149.8 A	B9050100	70	38.6	42.9
Cape Fear River	18-(71)a3	SC	+1,274.9 A	B9800000	104	36.5	26.9
Cape Fear River	18-(71)a4	SC	+372.9 A	B9820000	34	24.2	35.3
Cape Fear River	18-(71)a5	SC	+2,183.7 A	B9795000	71	26.8	12.7
Cape Fear River	18-(71)a6	SC	1,394 A	NA			
Cape Fear River	18-(71)b	SC	7,855.1 A	B9850100	71	8.5	7

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

^pH standard not less than 4.3 s.u. (standard units) in class Sw waters.

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

Note: Saltwater SC DO standard in not less than 5 mg/L and pH standard not less than 6.8 s.u.

Figure 2-14: Cape Fear River Basin pH Exceedance Rate by Station

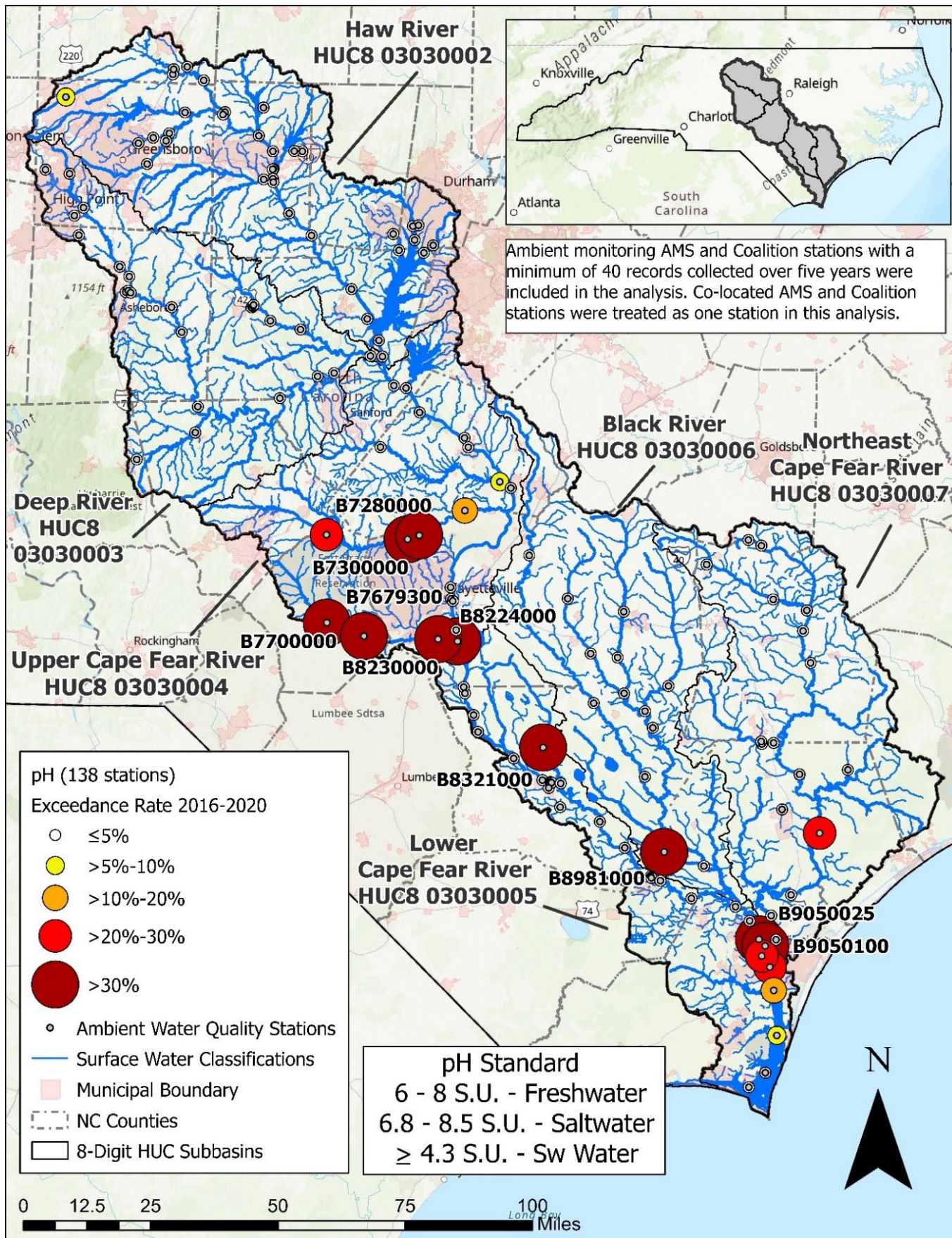


Figure 2-15: Cape Fear River Basin HUC8 Subbasins Annual Mean pH

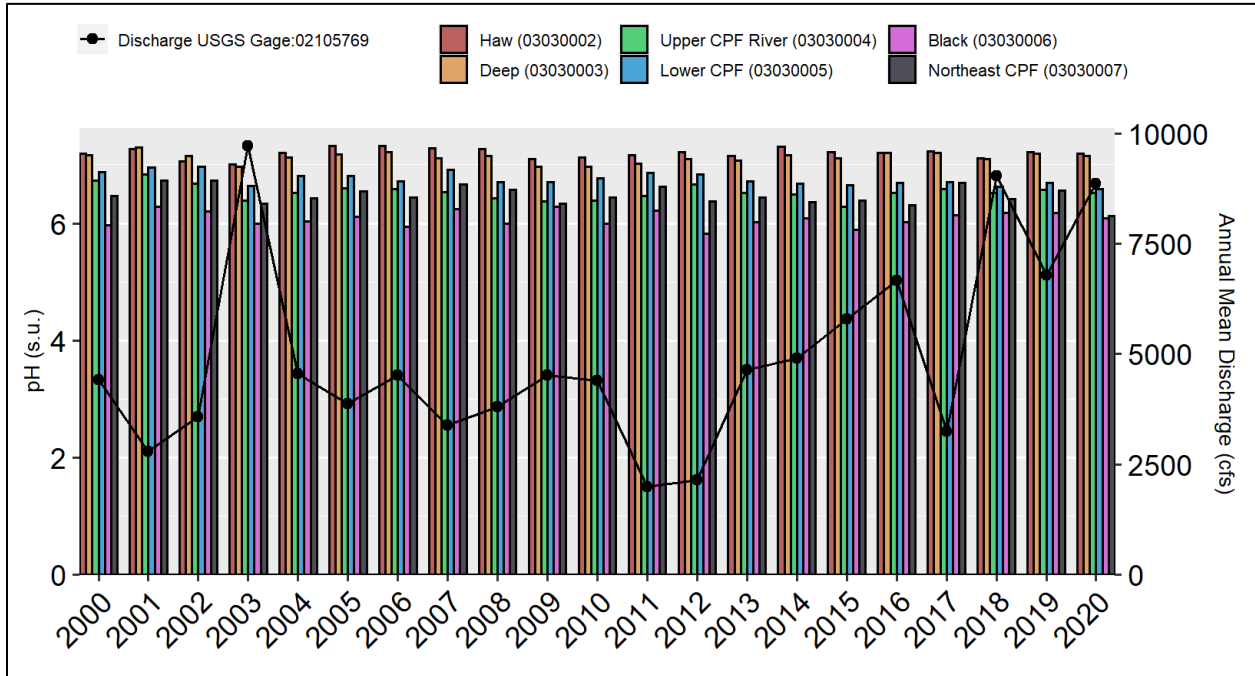
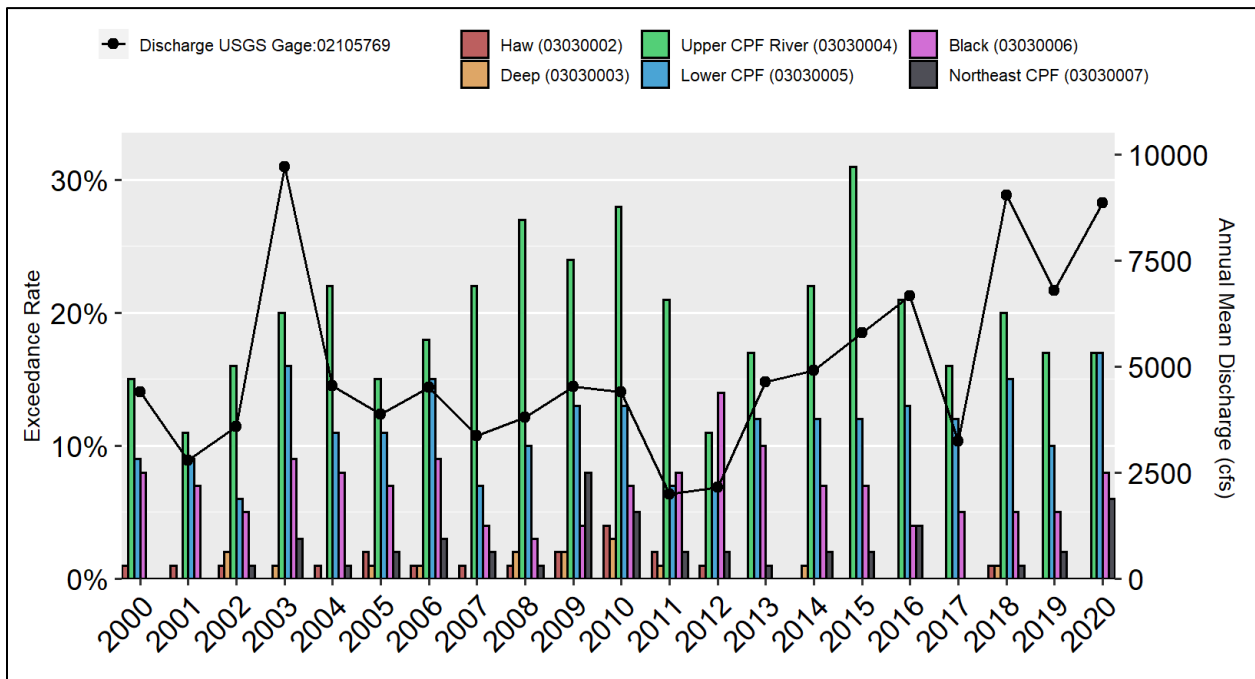


Figure 2-16: Cape Fear Basin HUC8 Subbasins Sample Percentages that Exceeded the Water Quality Standard for pH



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 170 freshwater, 64 freshwater swamp, 13 saltwater, and one saltwater swamp stations used in the mean and exceedance analyses from 2000-2020. Station number and records per station vary from year to year. The pH standard is 6 to 9 S.U. for freshwater, and 6.8 to 8.5 S.U. for saltwater, and >4.3 S.U. for freshwater or saltwater designated as swamp water.

HUC 8 subbasins annual means were fairly consistent from year to year and indicate the lower two thirds of the basin is more acidic (*Figure 2-15*), particularly the Black and Northeast Cape Fear River subbasins, which have many wetlands and swamp classified stations (see *Figure 2-10*). The Upper Cape Fear River subbasin followed by the Lower Cape Fear River subbasin, had the highest percent yearly exceedance of the pH standard from 2000 to 2020 (*Figure 2-16*). Not shown on these maps and graphs are lakes related water quality data. Much of Jordan Lake is impaired due to elevated pH levels as result of eutrophic conditions and excess biological productivity. See the watershed chapters 6 for more details.

2.5.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO) levels are often the product of wind or wave action mixing air into the water. It is also produced through aquatic plant photosynthesis. During the day, DO levels are higher when photosynthesis occurs and drop at night when respiration occurs by aquatic organisms. High DO levels are found mostly in cool, swift moving waters, and low levels are found in warm, slow-moving waters. In slow-moving waters, such as lakes and reservoirs, depth is also a factor. Wind action and plants can cause these waters to have a higher DO concentration near the surface, while biochemical reactions lower in the water column may result in concentrations as low as zero at the bottom.

The DO in Class C freshwaters shall 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). In 2022, there were 24.4 FW miles and 5,025.6 SW acres impaired for DO (*Table 2-6*). Impairments to FW miles occurred in the Haw River (7.0 FW miles), Deep River (5.2 FW miles), and Upper Cape Fear River (12.2 FW miles) subbasins, all impairments to SW acres were in the Lower Cape Fear River subbasin (5,025.6 SW acres) (*Figure 2-17*).

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 2-10* and *Figure 2-17*). 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 at the Cape Fear River estuarine station B9820000, located at channel marker 56 near Barnards Creek, south of Wilmington, NC are extensive (*Table 2-11*). The drainage area at station B9820000 is estimated to be about 8,865 square miles with the whole basin being 9,164 square miles. These stations exceeded the 5 mg/L DO saltwater standard between 24 and 40% of the time (*Table 2-10*).

The Lower Cape Fear Turnbull Creek station (B83210000), which had pH exceedances >30%, also exceeded the 4 mg/L DO freshwater standard by >10-20% (11.3%) as did one station in the Haw River subbasin located in the headwaters of Jordan Lake along New Hope Creek (B3020000; 16.7%). Both Turnbull Creek and New Hope Creek are likely influenced by wetlands along with other nonpoint sources in their watersheds.

Annual mean DO levels were higher in the upper half of the basin from 2000 to 2020, with the Haw, Deep, and Upper Cape Fear River subbasins ranging from 7.5 to 8.7 mg/L most years (*Figure 2-18*). The DO concentrations in the lower subbasins, the Lower Cape Fear, Black, and Northeast Cape Fear River, generally ranged from 6 to 7.5 mg/L. Annual exceedance rates at the HUC8 scale were highest in the Lower Cape Fear River subbasin, ranging from 6 to 14%. The other subbasins had few exceedances (*Figure 2-19*).

Table 2-11: 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-Build 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 ¹	Deemed permitted only	76 million head, 2,464 operations ³
Poultry Production Contracts ²	Deemed permitted only	332.2 million head, 687 operations ³
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 %	

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

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

³Poultry head count and operations estimation for inventory and poultry production is based on 15 counties that had >45% land area within the Cape Fear River Subbasin. See Chapter 1 for more information.

Figure 2-17: Cape Fear River Basin Dissolved Oxygen Exceedance Rate by Station

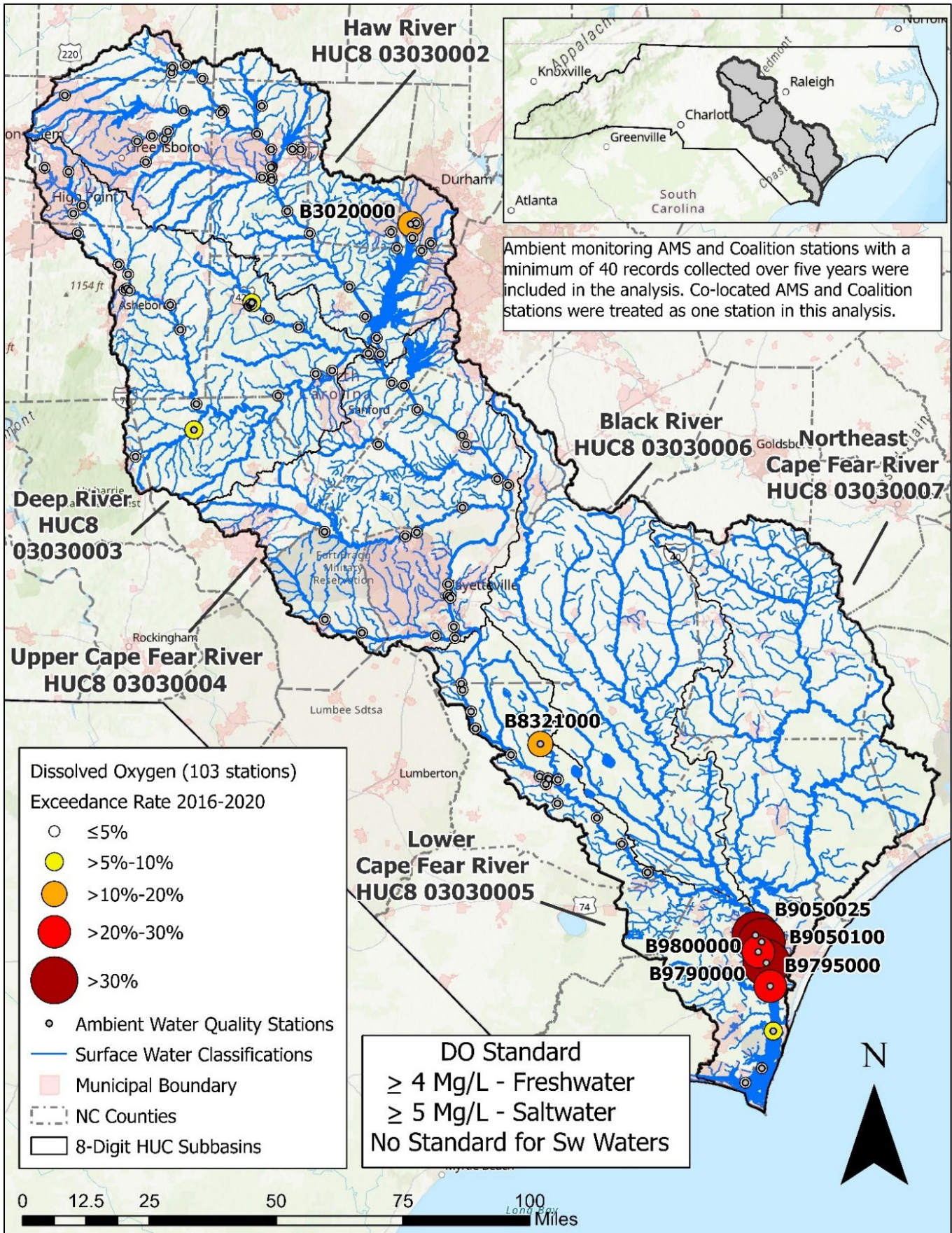


Figure 2-18: Cape Fear River Basin HUC8 Subbasins Annual Mean Dissolved Oxygen

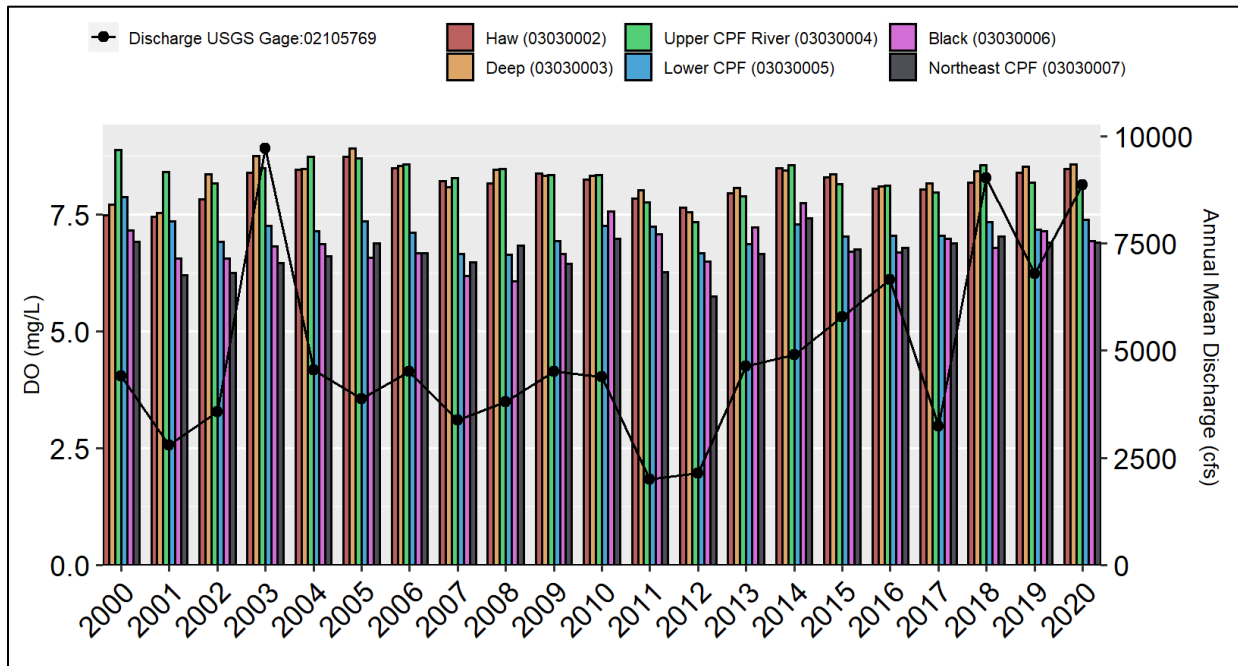
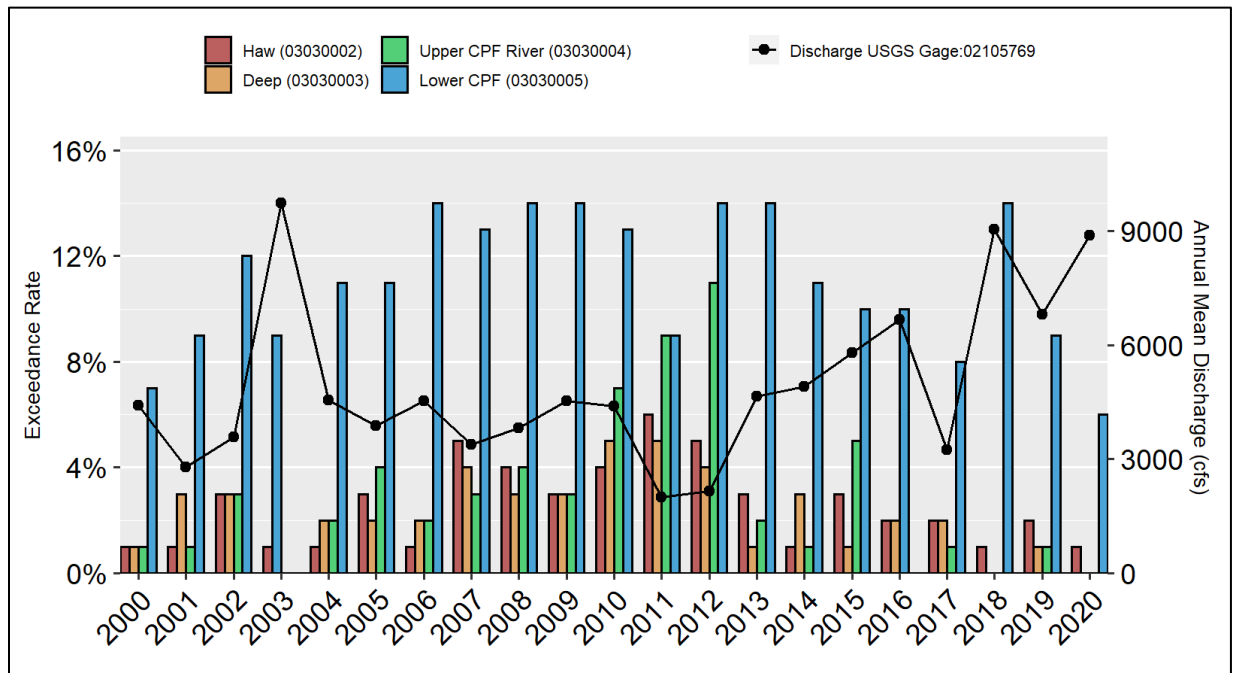


Figure 2-19: Cape Fear HUC8 Subbasins Sample Percentages that Exceeded the Dissolved Oxygen Water Quality Standard



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 170 freshwater, 64 freshwater swamp, 13 saltwater, and one saltwater swamp stations used in the mean and exceedance analyses. Station number and records per station vary from year to year. The dissolved oxygen standard is ≥ 4 mg/L for freshwater, ≥ 5 mg/L for saltwater, and there is no standard for freshwater or saltwater designated as swamp water.

2.5.4 Fecal Coliform Bacteria and Enterococci Bacteria

Fecal coliform bacteria (FCB) and enterococci bacteria in aquatic environments indicate that the waterbody has been exposed to fecal material from humans or other warm-blooded animals. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to the water. Bacteria and viruses can occur in ambient water as a result of the overflow of domestic sewage or runoff from nonpoint sources of human and animal waste.

Class C and Class B freshwaters shall not exceed a fecal coliform bacteria geometric mean of 200 colonies/100 mL or 400 colonies/100 mL in 20% of the samples where five samples have been taken in a 30- day period (5-in-30). Class SC tidal waters shall not exceed a geometric mean of 35 enterococci/100 mL (5-in-30). Only results from a 5-in-30 study are used to determine if the stream is impaired (exceeding criteria) or supporting (meeting criteria). Class B or SB (primary recreation) waters will receive priority for 5-in-30 studies. Other waterbodies will be studied as resources permit. In 2022, there were 107.5 FW miles impaired for fecal coliform bacteria (*Table 2-6*). Over half the impairments to FW miles occurred in the Haw (56.1 FW miles) with the rest occurring in the Deep (20.6 FW miles), and Northeast Cape Fear River (30.8 FW miles) subbasins.

Most water quality monitoring results for fecal coliform are qualified due to the time required to transport the samples for analysis, which is greater than the hold time, these qualified results are considered to be screening level indicators. Although just 107.5 miles were impaired for fecal coliform in the Cape Fear River Basin, screening level monitoring data indicates many stations throughout the entire basin had exceedances over the 400 colonies/100 mL standards during the 2016 to 2020 timeframe and it is highly likely other waterbodies have fecal coliform impairments. There were 14 stations with greater than >30-40% exceedance and five stations with greater than 40% exceedance (*Figure 2-20*). These stations were generally located on tributaries closer to headwater areas that drained smaller watersheds, typically <40 Mi² that included urban area drainage. DWR has information on some permits in these locations, other potential sources such as poultry farms or straight pipes is more limited. Further discussion on fecal coliform issues is included in the subbasin chapters. The following provides location, permitting, watershed size, and land cover information for stations identified on the map figure (*Figure 2-20*).

- The **Haw River subbasin (HUC8 03030002)** has six stations with >30%-40% exceedances draining urban areas. These stations are located on North Buffalo Creek (B0480050) and South Buffalo Creek (B0670000) draining Greensboro, Big Alamance Creek (B1940000) and Town Branch south of Burlington (B1260000), Moadams Creek draining Mebane (B1350000), and Northeast Creek in the headwaters of Jordan Lake (B3660000).
- The **Deep River subbasin (HUC8 03030003)** has four stations with >30%-40% exceedances and two stations with >40% exceedance. For the >30%-40% range, three stations drain High Point and nearby communities on East Fork Deep River (B4240000), Richland Creek (B4380000), and Muddy Creek (B46210000) and one station drains Asheboro on Haskett Creek (B4890000). For the >40% exceedance range, there is one station located higher up on Haskett Creek (B4870000) that has 52% exceedance and another station (B5390800) located on Cotton Creek with 68% exceedance. The Haskett creek station is a small 11.8 Mi² watershed with 62% development, while the Cotton

Creek station has a very tiny 2.2 Mi² watershed with 27% development that receives direct drainage from the community of Star. The Cotton Creek station (B5390800) is also below the Town of Star WWTP (NC0058548) with a permitted 0.6 MGD as-built flow. Additionally, there were 34 acres of solid waste land application fields permitted for Town of Star (WQ0003945) that were active through March 2021. Several NPDES stormwater permits are in both the Haskett Creek and Cotton creek drainage areas.

- The **Upper Cape Fear River subbasin (HUC8 03030004)** has one station (B7590000) with >30-40% exceedances located below Fayetteville on Cross Creek.
- The **Lower Cape Fear River subbasin (HUC8 03030005)** has one station with >30-40% exceedance on Hammond Creek (B8340200) and one station with 44% exceedance (B8340050) on Browns Creek in Elizabethtown. The Browns Creek station has a 16.7 Mi² watershed with 21% development and a couple of NPDES stormwater permits, 18.2 acres of solid waste land application fields permitted for the Town of Elizabeth (WQ0004038), and two swine Animal Feeding Operations (AFOs, AWS090156 and AWS090022) permitted for 1.469 million lb. allowable weight combined.
- The **Northeast Cape Fear River subbasin (HUC8 03030007)** has two stations with >30-40% exceedances and two stations with >40% exceedances. The stations in the >30-40% range are both located near the community of Wallace on Rockfish (B9430000) and Little Rockfish (B9460000) creeks. The stations in the >40% exceedance range include B9130000 with 41% exceedance on Panther Creek and B9520000 on Burgaw Creek with 42% exceedance. The Panther Creek station has a 6.8 Mi² watershed with 14% development that drains the community of Faison and the Burgaw Creek station has an 8.1 Mi² watershed with 19% development that drains the community of Burgaw. The Panther Creek/Branch station (B9130000) has had more incidences of extreme levels of fecal coliform (20,000 to 60,000 colonies/100 mL) than any other station in the basin. This station is below one NPDES discharge permit (NC0001970, Meal Preparation Inc an Industrial Process & Commercial wastewater discharge permit), and one NPDES stormwater permit. While determining the nonpoint sources of pollution to Panther Creek will require additional investigation, this report will note that it is unlikely that these high fecal coliform bacteria concentrations are from the only permitted NPDES industrial wastewater discharger (Bay Valley Foods Inc.) as they do not treat domestic wastewater. On January 20, 2021, a nearby swine AFO (AWS820352) underwent a Structure Evaluation inspection site visit which documented waste was flowing from one of the hog houses at the foundation to a storm water drain system which discharges to a ditch which flows to another ditch on the adjoining property. The adjoining ditch is an unnamed tributary to Panther Creek/Branch. Six water quality samples collected in 2021 show no fecal coliform bacteria levels reaching the concentration of 60,000 colonies/100 mL, the values ranged from 5 to 1,400 colonies/100 mL. The Burgaw Creek station (B9520000) watershed has just one non-contact Cooling Boiler Blowdown permit, NCG500270 with no permitted discharged flow. Aerial photography also indicates there are poultry farms in both the Panther Creek and Burgaw Creek station watersheds.

Figure 2-20: Cape Fear River Basin Fecal Coliform Exceedance Rate by Station

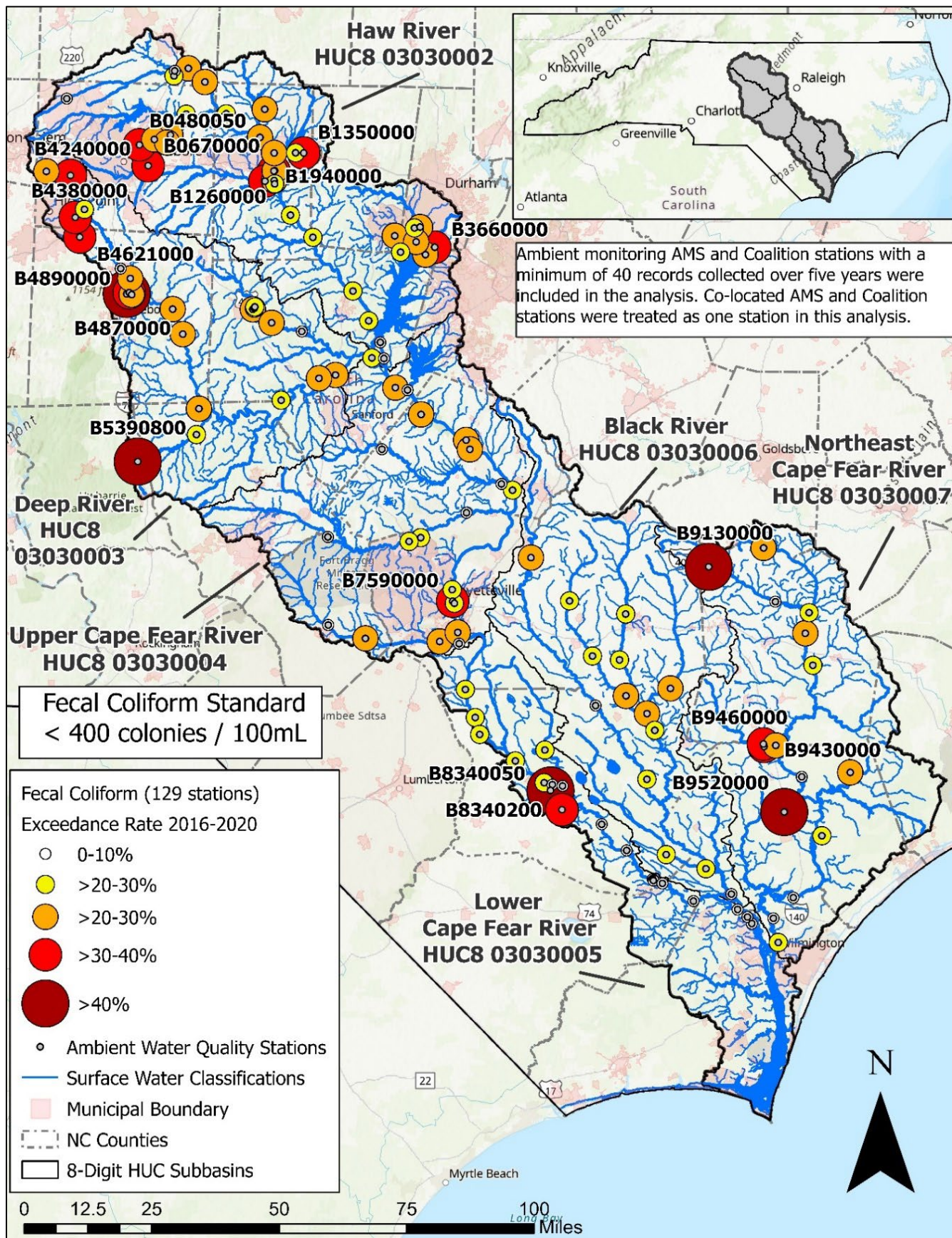


Figure 2-21: Cape Fear River Basin HUC8 Subbasin Annual Mean FCB

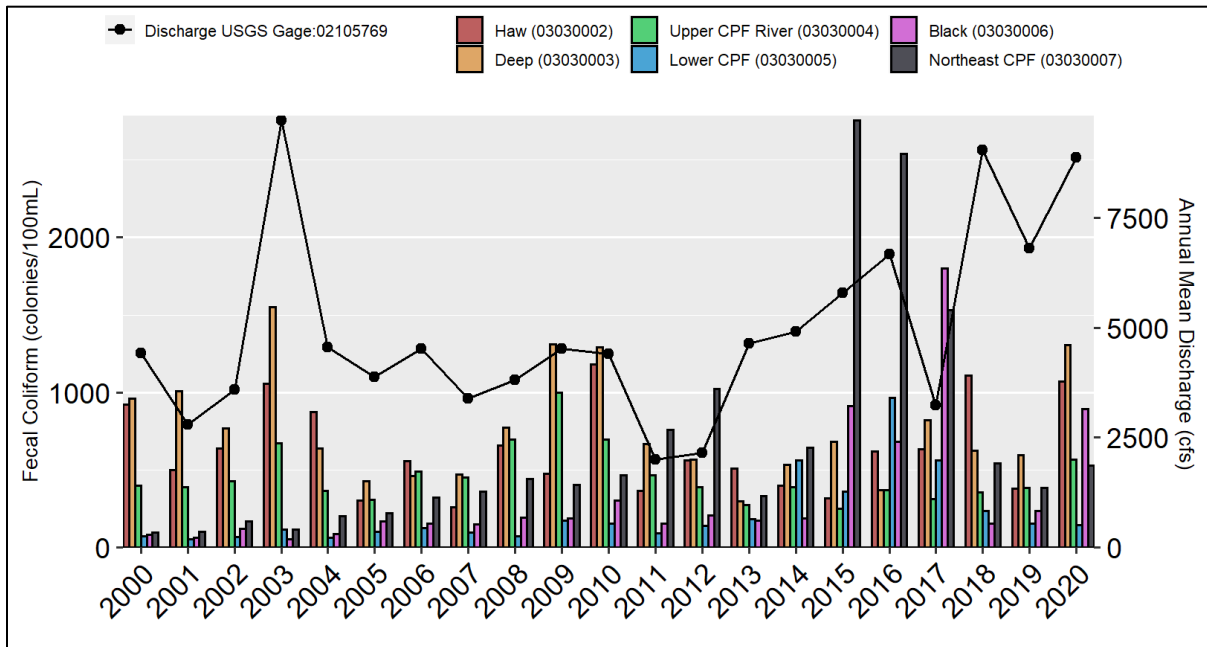
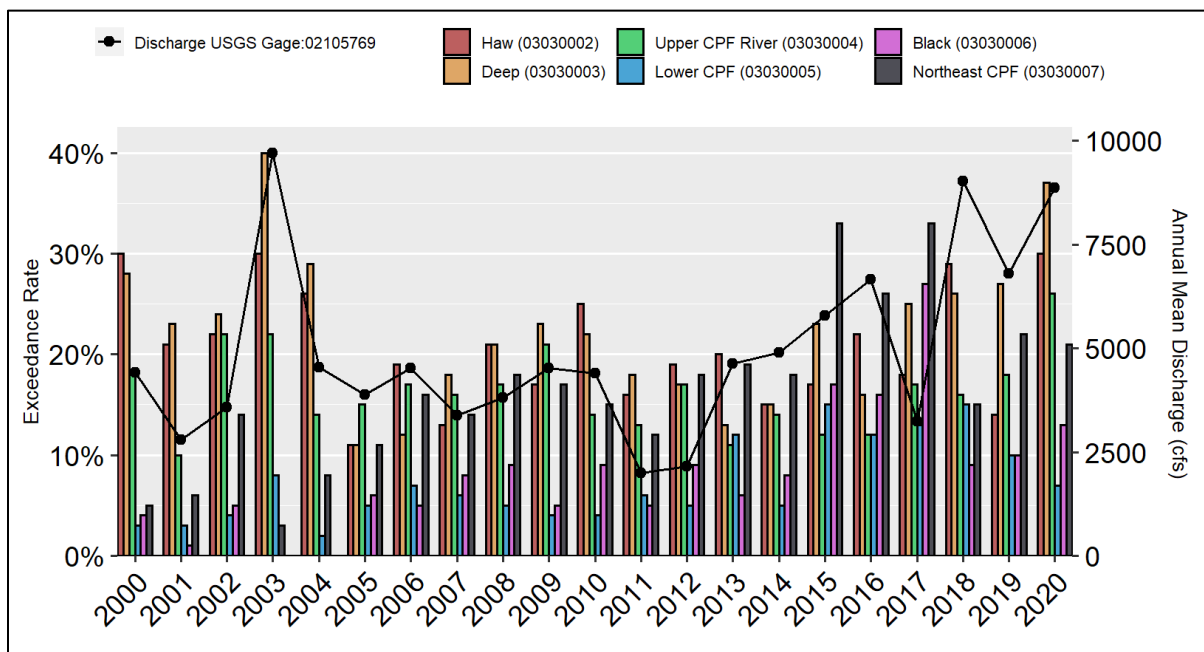


Figure 2-22: CPF River Basin HUC8 Subbasins Sample Percentages that Exceeded the 400 colonies/100 ml Standard for FCB



All AMS, RAMS, and Coalition were included in the above graphs. There were 186 freshwater and 14 saltwater stations used in the mean and exceedance analyses from 2000 to 2020. Station number and records per station vary from year to year. The fecal coliform bacteria standard is ≤ 400 colonies/100 mL.

The HUC8 subbasin annual data from 2000 to 2020 suggests fecal coliform levels are stormwater driven with higher levels generally occurring during higher flow years (*Figure 2-21* and *Figure 2-22*). The Deep and Haw River subbasins had the highest fecal coliform mean levels and exceedances most years with 2015 to 2017 being the exception (*Figure 2-21* and *Figure 2-22*). The Haw and Deep River subbasin yearly means ranged from 300 to 1,300 colonies/100 mL and 10% to 30% exceedance. The Northeast Cape Fear River has been extremely variable, ranging from yearly means of <100 to 2,750 colonies/100 mL and exceedances of < 5% to >30% (*Figure 2-21* and *Figure 2-22*). The highest means and exceedances occurred from 2015 to 2017 when several stations had extreme outliers ranging 10,000 to 60,000 colonies/100 mL.

The Black River subbasin had means ranging from 50 to 1,800 and exceedances below 10% prior to 2015 and usually above 10% after 2015 (*Figure 2-21* and *Figure 2-22*). The data suggest the Northeast Cape Fear and Black River subbasins have increasing fecal coliform levels (*Figure 2-21* and *Figure 2-22*). The Upper Cape Fear River subbasin ranged from 250 to 1,000 colonies per 100 mL and ranged from 10% to 20% exceedance most years (*Figure 2-21* and *Figure 2-22*). Yearly mean fecal coliform levels were lowest in the Lower Cape Fear River subbasin, ranging from 50 to 230 colonies per 100 mL with most years below 10 % exceedance (*Figure 2-21* and *Figure 2-22*).

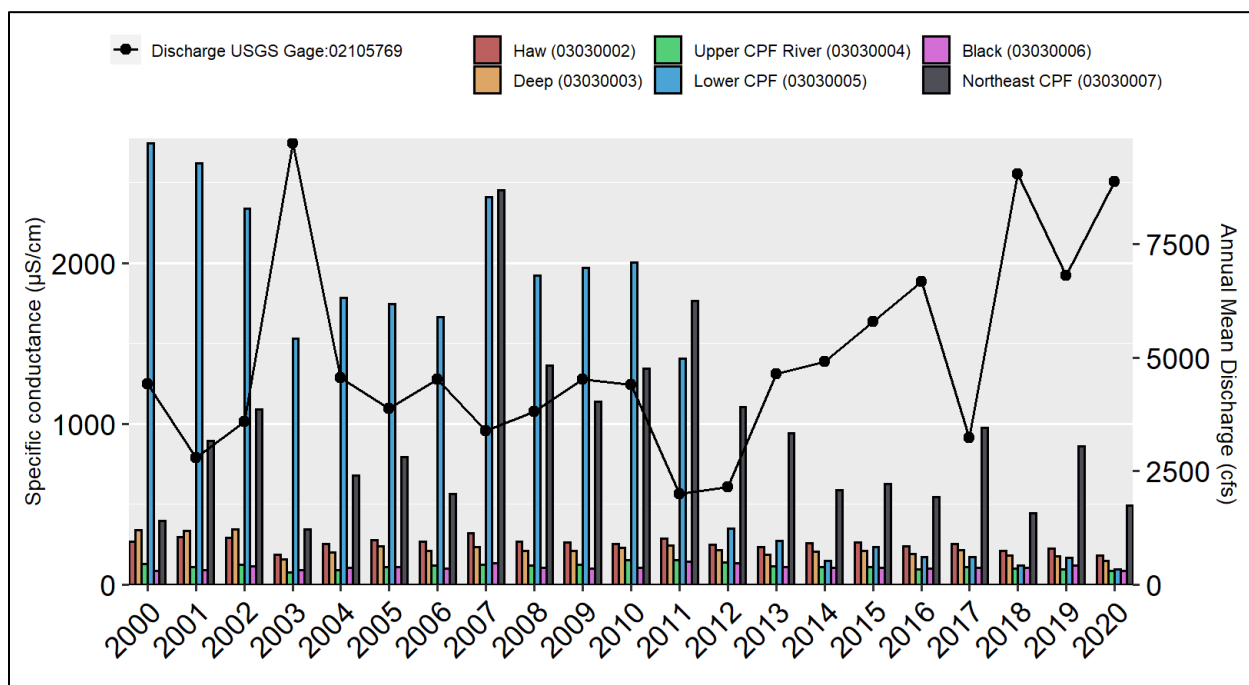
2.5.5 Specific Conductance

Specific conductance, also referred to as conductivity, is a measure of the ability of water to pass an electrical current. Conductivity measures the amount of dissolved ions present in surface water and serves as an indicator of water quality in freshwater systems. Relatively low conductivity can be found in streams with little to no impact from point and nonpoint sources of pollution. Higher conductivity values are found in estuaries where water is influenced by the mixing of sea water with freshwater rivers. Outside the coastal plain, higher conductivity can be an indicator of pollutants associated with the application of road salts during winter months and the discharge or runoff of chlorides, phosphates, nitrates, and other inorganic dissolved solids. North Carolina does not have a water quality standard for conductivity. Instead, conductivity is often used as an indicator of pollution and is used to identify changes in water quality over time. Changes in conductivity can impact aquatic communities and potentially impact their overall productivity. Conductivity is also affected by temperature, so conductivity is always reported as conductivity at 25 degrees Celsius.

Specific conductance levels from 2000 to 2020 were relatively highest in the Lower Cape Fear River subbasin prior to 2012, ranging from 1,400 to 2,750, after 2012 mean levels ranged from <100 to 350 (*Figure 2-23*). Higher specific conductance levels also occurred in the Northeast Cape Fear River, particularly between 2007 and 2012 when mean levels ranged from 1,100 to 2,450 (*Figure 2-23*). The HUC8 mean yearly levels in both subbasins have been skewed by stations that are influenced by saltwater. The Lower Cape Fear River had two saltwater stations that were sampled in the past, B9980000, located along the Intracoastal Waterway near Southport sampled until 2011 and I9380000, located at Beaverdam Creek near Long Beach, until 2002, both of these stations usually had yearly mean values over 4,000 $\mu\text{S}/\text{cm}$. The Northeast Cape Fear River has two stations that currently receive some saltwater influence, B9670000 a saltwater station on the Northeast Cape Fear River mainstem near Wilmington and B9720000, a freshwater station, located just upstream along the Smith Creek tributary. Both stations are typically

over 1,000 $\mu\text{S}/\text{cm}$ and have been over 4,000 and 5,000 $\mu\text{S}/\text{cm}$ for several years. The influence of saltwater has a stronger effect during lower flow years, 2007 to 2012 (*Figure 2-23*), as freshwater discharge is replaced by saltwater tides that reach higher up in the river system, even as high as Lock and Dam #1 during drought years. Sea-level rise and dredging in the lower part of the Cape Fear River Basin near Wilmington has also increased saltwater intrusion (see Chapter 1). Additionally, two waterways (Panther Creek/Branch) and the headwaters of the Northeast Cape Fear receive discharge from NPDES permitted facilities that have variances from the water quality standard for chloride concentrations resulting in elevated specific conductivity. The Haw River subbasin had the highest conductivity (222 $\mu\text{S}/\text{cm}$) in the basin not impacted by the estuary or permit variances (*Table 2-9*). The elevated specific conductance is mainly due to the large amount of point source discharge into the Haw River subbasin (146.8 MGD permitted As-built flow; see section 3.2.1 details).

Figure 2-23: Cape Fear River Basin HUC8 Subbasins Annual Mean Specific Conductance



All AMS, RAMS, Coalition, and special study stations were included in the above graph. There were 234 freshwater and 3 saltwater stations used in the mean analysis. Station number and records per station vary from year to year.

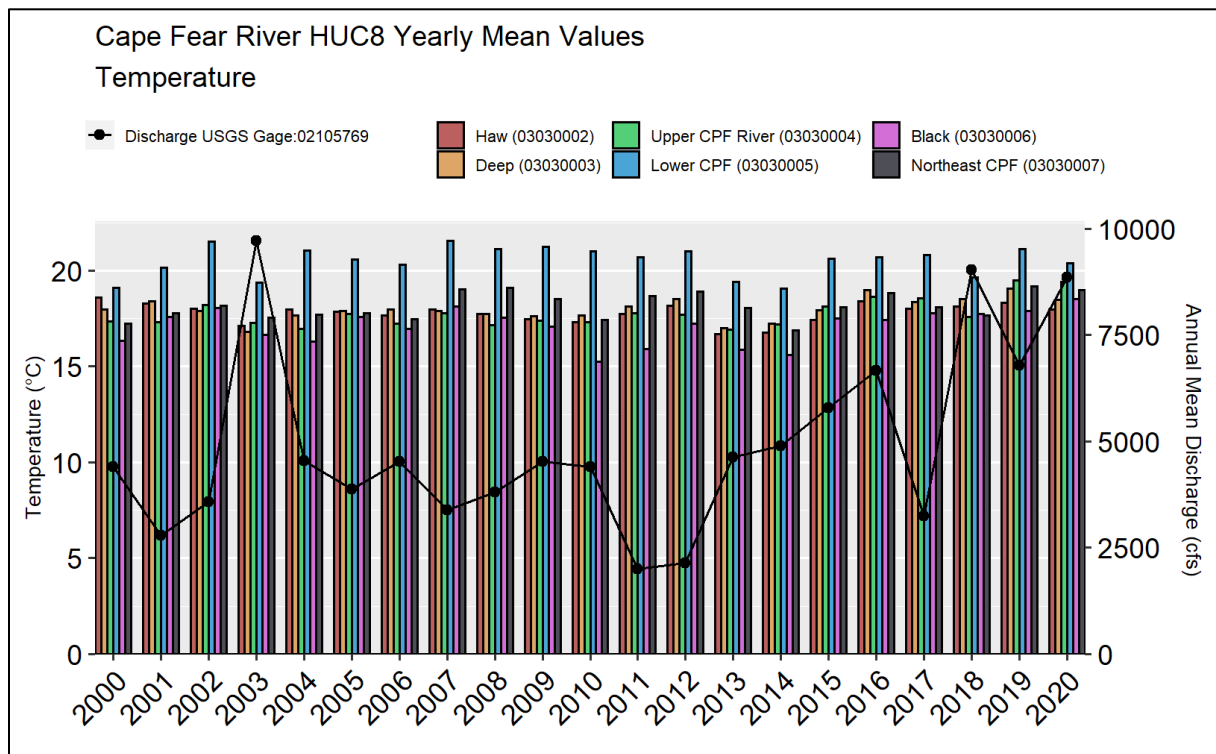
2.5.6 Temperature

All aquatic species require specific temperature ranges in order to be healthy and reproduce. An aquatic species becomes stressed when water temperatures exceed their preferred temperature range, often making them more susceptible to injury and disease. Trout, for example, prefer temperatures below 20°C (68°F) and cannot survive in the water reservoirs of the piedmont and coastal plain where temperatures

can exceed 30°C (86°F). Changes to natural conditions or weather patterns can often change the ambient water temperature. For example, higher ambient water temperatures are expected during years with severe drought in areas where there is little shade. Higher ambient water temperatures can also be expected when air temperatures are high during summer months. Climatic conditions should also be taken into account and include extreme drought, hurricanes, flooding, and/or dams.

North Carolina water quality standards state that discharge from permitted facilities should not exceed the natural temperature of the receiving waterbody by more than 2.8°C (5.04°F) and that waters should never exceed 29°C (84.2°F) for the mountain or upper piedmont regions and 32°C (89.6°F) for lower piedmont and coastal plain. In saltwater, the temperature (1) shall not be increased above the natural water temperature by more than 0.8°C (1.44°F) during the months of June, July and August; (2) shall not be increased by more than 2.2°C (3.96°F) during other months of the year; and (3) shall in no case exceed 32°C (89.6°F) due to the discharge of heated liquids ([15ANCAC 02B.0220](#)). When assessing temperature, climatic conditions are also taken into account. When climatic conditions result in the temperature standard being exceeded, the stream is identified as Data Inconclusive or Not Rated in the IR. There were no impairments due to temperature in the Cape Fear River Basin in 2022. Water quality data and graphical representation suggests there have been slightly higher temperatures in recent years. Changes in temperature could be influenced by the amount of data or lack of data collected in a given year as well as due to changes in monitoring equipment or techniques such as time of day or depth.

Figure 2-24: Cape Fear River Basin HUC8 Subbasins Annual Mean Temperature



2.5.7 Nutrients (Nitrogen and Phosphorus)

Collectively referred to as nutrients, nitrogen and phosphorus are major components of living organisms and are essential to maintain life. Nitrogen can occur in water in the form of nitrite (NO_2^-), nitrate (NO_3^-), ammonia ($\text{NH}_3 + \text{NH}_4^+$), and organic nitrogen (dissolved and particulate). The combined sum of these forms of nitrogen is referred to as total nitrogen (TN). Total Kjeldahl Nitrogen (TKN) is the total concentration of organic nitrogen and ammonia. Dissolved and particulate phosphorus is reported as total phosphorus (TP). When nutrients are introduced to an aquatic ecosystem from municipal and industrial treatment processes or runoff from urban or agricultural land, the growth of algae and other plants may be accelerated as a result of nutrient over-enrichment (eutrophication). In addition to the possibility of causing algal blooms, elevated ammonia (NH_3) concentrations can be toxic to fish and other aquatic organisms especially in areas with high pH and temperature conditions. North Carolina does not have water quality standards for nitrogen or phosphorus.

Each water quality station's 75th percentile for ammonia, TKN, nitrite-nitrate (NOx), total nitrogen (TN), and total phosphorus (TP) was mapped using 2016-2020 data (*Figure 2-25, Figure 2-28, Figure 2-31, Figure 2-34, and Figure 2-37*). The HUC8 subbasin annual mean and 75th percentiles concentrations for each nutrient from 2002 to 2020 are also displayed in graphs for comparison (*Figure 2-26, Figure 2-27, Figure 2-29, Figure 2-30, Figure 2-32, Figure 2-33, Figure 2-35, Figure 2-36, Figure 2-38, and Figure 2-39*). Stations with more concentrated levels of nutrients are identified on the map figures. Additional information on permitting, land cover, watershed size, and station location is provided below for reference in this section. Several of the stations had issues with multiple nutrient types.

Haw River (HUC8 03030002)

- B0540000 (Ammonia, NOx, TN) - Located on **North Buffalo Creek** with a 37 Mi² watershed that drains part of Greensboro and is highly developed (86%). Permitted facilities include a few minor dischargers with no permitted-as-built flow and several NPDES stormwater permits. The North Buffalo Creek WWTP (NC 0024352), permitted for 16 MGD as-built, ceased discharging into North Buffalo Creek on October 6, 2017.
- B0540050 (NOx, TN) – Located on **North Buffalo Creek** below B0540000 near the confluence with Buffalo Creek. The North Buffalo Creek WWTP (NC 0024352), permitted for 16 MGD as-built, ceased discharging into North Buffalo Creek on October 6, 2017.
- B0750000 (TKN, NOx, TN, TP) – Located on **South Buffalo Creek** in a 43 Mi² watershed with 76% development. Permitted facilities include City of Greensboro's T.Z. Osborne WWTP (NC0047384), with 56 MGD as-built flow located 2.6 miles upstream, three minor NPDES dischargers, several NPDES stormwater facilities, and one AFO with 130,500 lb. allowable weight.
- B1380000 (Ammonia) – Located on **Moadams Creek** in a 3.2 Mi² watershed with 64% development that drains the town of Mebane. This station is a mile and a half below Mebane's WWTP (NC0021474), a major discharger permitted for 2.5 MGD as-built flow.
- B0840000 (NOx) – Located on **Reedy Fork** near the community of Ossipee below the Buffalo Creek confluence in a 255 Mi² watershed with 47% development. Permits include 13 NPDES dischargers, including the Greensboro's T.Z. Osborne WWTP (NC0047384), permitted for 56 MGD as-built and

located 20.2 miles upstream, 12 minor NPDES dischargers, 14 acres of non-discharge fields, and four AFOs with 858,500 lb. allowable weight. The concentration at this location reflects high concentrations from Greensboro's WWTPs.

- B3040000 (NOx, TN) – Located on in the headwaters of Jordan Lake on **New Hope Creek** in a 76 Mi² watershed that drains Durham and is 44% developed. There are 33 permitted NPDES facilities (many single family) including the City of Durham (South Durham WRF, NC0047597) located 2.3 miles upstream and permitted for 20 MGD as-built.
- B3900000 (NOx, TN) – Located on the headwaters of Jordan Lake on **Morgan Creek** in a 46 Mi² watershed that drains Chapel Hill and is 26% developed. Permitted facilities include the Orange County Water and Sewer Authority (NC0025241) located 3.9 miles upstream, permitted for 14.5 MGD as-built, 44 minor NPDES dischargers (many single family), 23.8 non-discharge fields and one Animal Feeding operation with no allowable weight.

Deep River (HUC8 03030003)

- B4890000 (NOx, TN) – Located on **Haskett Creek** in a 12.2 Mi² that drains Asheboro and is 60% developed. Permitted facilities include the Asheboro WWTP (NC0023123), located 0.5 miles upstream permitted for 9 MGD as-built, multiple NPDES stormwater facilities, and one AFO with 200,000 lb. allowable weight.
- B5920000 (NOx, TN) – Located on **Loves Creek** in an 8.3 Mi² watershed that drains Siler City and is 43% developed. Permitted facilities include the Siler City WWTP (NC0026441) permitted for 4 MGD as-built and located 0.3 miles upstream, two minor NPDES dischargers, 60.4 acres of residual land application fields for Siler City (WQ0003226), and several NPDES stormwater permits.
- B5390800 (NOx, TN, TP) – Located on **Cotton Creek** in a 2.2 Mi² watershed that drains the community of Star and is 25% developed. Permitted facilities include one minor WWTP for the Town of Star (NC0058548), permitted for 0.6 MGD as-built and located 2.3 miles upstream, 34 acres residual land application fields for the Town of Star (WQ0003945) that were active through March 2021, and several NPDES stormwater permits. Station B5390800 also had issues with fecal coliform (see section 2.5.4).

Black River (HUC8 03030006)

- B8604000 (TP) – Located on **Great Coharie Creek** in a 180 Mi² rural watershed with 46% agriculture, 10% development, 20% wetland, and 19% forest coverage. Permitted facilities include the City of Clinton's WWTP (NC0020117) permitted for 5 MGD as-built and located 8.6 miles upstream, one minor NPDES discharger, 77 acres of non-discharge wastewater and residual solid application fields, several NPDES stormwater permits, and 81 AFOs with a total permitted allowable weight of 46.6 million lbs. Since the year 2000, elevated and increasing total phosphorus concentrations have been observed in the downstream section of Great Coharie Creek.
- B8981000 (Ammonia, TKN) – Located on **Colly Creek** in a 101 rural Mi² watershed with 62% wetland, 18% forest, and 8% agriculture coverage. Permitted facilities include one minor discharger for the Town of White Lake (NC0023353) permitted for 0.8 MGD as-built and located 18.8 miles upstream, four AFOs with 1.2 million lb. allowable weight and six lagoons, and five acres of wastewater irrigation fields located much higher up in the watershed. Ammonia

concentrations in Colly Creek tend to be elevated in the spring, summer, and early fall seasons with lower concentrations observed in the winter. Elevated total Kjeldahl nitrogen concentration may be the result from the breakdown of organic material in this waterway and/or leaking sewer systems. See Chapter 10 for more details on Colly Creek.

Northeast Cape Fear River (HUC8 03030007)

- B9430000 (TKN, TP) - Located on **Rockfish Creek** in a 161 Mi² watershed that drains parts of the nearby community of Wallace, and has 32% agriculture, 6% development, 32% forest, and 22% wetland coverage. Permitted facilities include three minor NPDES dischargers, including the Wallace Chicken Processing Plant, an Industrial Process and Commercial Wastewater Discharger (NC0003344) located 8.3 miles upstream with a permitted as-built discharge of 1.5 MGD (also see Chapter 11). This plant is likely a large source of nitrogen in this watershed. The permit fact sheet indicates that this plant discharged an average TN concentration of 77.5 mg/L and TP concentration of 12.1 mg/L (based on effluent data Jan. 2017 through Jan. 2021). Unfortunately, the permit does not require the reporting of the separate species of nitrogen with the exception of ammonia which on average was very low (0.6 mg/L summer and 0.3 mg/L winter) ([link to factsheet](#)). It is important to note, the permittee meets all EPA effluent requirements for this type of industrial processing. In addition to discharge from the Wallace Chicken Processing Plant, the Wallace Regional WWTP (NC0003450) discharges between stations B9430000 and B9470000. The Lower Cape Fear River Program has commented that when low flow periods occur in Rockfish Creek the discharge from the Wallace Regional WWTP (NC0003450) outfall can flow upstream to the sampling site (Mallin et al., 2022). Other possible sources include several NPDES stormwater facilities, close to 50 acres of wastewater irrigation fields, and 67 AFOs with 54.5 million lbs. allowable weight and 135 lagoons/wastewater ponds. This station also had issues with fecal coliform (see Section 2.5.4).
- B9470000 (TP) - Located on **Rockfish Creek** ~ 3.25 miles downstream of B9430000 in a 176 Mi² watershed that drains the nearby community of Wallace, and has 32% agriculture, 7% development, 31% forest, and 22% wetland coverage. Permitted facilities include the Town of Wallace WWTP (NC0003450) with a permitted discharge of 5.42 MGD and located 3.4 miles upstream, three minor dischargers including the Wallace Chicken Processing Plant located 11.3 miles upstream, several NPDES stormwater facilities, close to 50 acres of wastewater irrigation fields, and 70 AFOs with 54.9 million lbs. allowable weight and 138 lagoons/wastewater ponds.
- B9490000 (TKN, TP) - Located on **Angola Creek** in a 40 Mi² that drains the parts of the Angola Bay Game Land and has 16% agriculture, 24% forest, and 53% wetland coverage. Permitted facilities include 18 AFO facilities with 11.9 million lbs. of permitted live weight and 28 lagoons/waste ponds and several stormwater facilities. The organic fraction of the total Kjeldahl nitrogen concentrations were attributed to flows through forested wetlands, which dominate the Angola Creek drainage area, suggesting that forested wetlands are comparatively critical to produce organic nitrogen based on the Soil and Water Assessment Tool (SWAT) model analysis (NCDENR, 2008). Total phosphorus concentrations in this watershed were also exceptionally high, especially in the year 2020, with concentrations greater than considered normal for minimally impacted streams (See Chapter 11). The SWAT model again attributed much of the total phosphorus loads

to passive transportation into streams through forested wetlands not designed to trap nutrients loading coming from adjoining lands (NCDER, 2008).

- B9520000 (NO_x, TN, not labeled on map) - Located on **Burgaw Creek** in an 8.1 Mi² watershed that drains the community of Burgaw and has 19% development, 35% agriculture, 28% forest, and 9% wetland. Currently there is one AFO and one NPDES stormwater permit in this watershed. The 0.75 MGD as-built Burgaw WWTP (NC0021113) was active in this watershed until August 9, 2012. While it appears overall water quality has improved, the addition of inorganic nitrogen from nonpoint sources contributes to elevating total nitrogen concentrations in Burgaw Creek.

2.5.7.1 Total Kjeldahl Nitrogen (TKN)

The Total Kjeldahl Nitrogen (TKN) map (*Figure 2-25*) indicates stations with more concentrated TKN 75th percentile levels during the 2016 to 2020 timeframe, >0.98 mg/L, occurred throughout the basin but are most prevalent in the Northeast Cape Fear and Haw, and to a lesser degree, the Black and Deep subbasins. The Upper Cape Fear River subbasin had the fewest stations with elevated TKN levels. There are many stations throughout the basin with TKN instream concentrations ranging from approximately 1.0 to 1.3 mg/L, and four stations in the >1.3 to 1.8 mg/L range, B0750000 located on South Buffalo Creek in the Haw River subbasin, B8981000 on Colly Creek in the Black River subbasin, and B9430000 on Rock Fish Creek and B9490000 on Angola Creek in the Northeast Cape Fear River subbasin (*Figure 2-25*, also see station descriptions above). The Haw River Subbasins South Buffalo Creek station (B0750000) had the highest five-year TKN 75th percentile in the basin, 1.8 mg/L, likely due to the nearby upstream discharge from the City of Greensboro's T.Z. Osborne WWTP, which also has the highest permitted discharge (56 MGD as-built) in the basin. The Black River subbasins Colly Creek station's (B8981000) five-year TKN 75th percentile was nearly as high as the Haw River station, at 1.75 mg/L, although, there are no nearby permitted facilities located in this station's large rural watershed. This station also has high ammonia levels contributing to the TKN concentrations (see the next section).

The high organic nitrogen levels (TKN minus ammonia) may be partially related to the number of wetlands, many of which are bays with organic soil, including several nearby that have been ditched and converted to agriculture. The organic nutrients at the Colly Creek station may also be related to failing septic systems and groundwater seepage identified as an issue in the Town of White Lake's watershed. The TKN five-year 75th percentile levels at the Northeast Cape Fear stations are comparatively lower, 1.45 mg/L at the Rockfish Creek station (B9430000) and 1.6 mg/L at the Angola Creek station (B9490000). Aerial photography indicates poultry farms exist in the watersheds for stations, especially the Rockfish Creek station (B9430000). The Rock Fish Creek station (B9430000) also has an industrial poultry processing located plant 8.3 miles upstream. The Angola Creek station receives some drainage from the Angola Creek Bay Lands, a pocosin wetland with deep organic soils that may also be contributing to the TKN levels. Water quality data indicates TKN levels increased in the 2014 to 2015 timeframe at both the Northeast Cape Fear (B9430000 and B9490000) stations and the Black River station (B89810000) which suggests there have also been anthropogenic-related watershed changes.

Figure 2-25: Cape Fear River Basin TKN mg/L 75th Percentile by Station

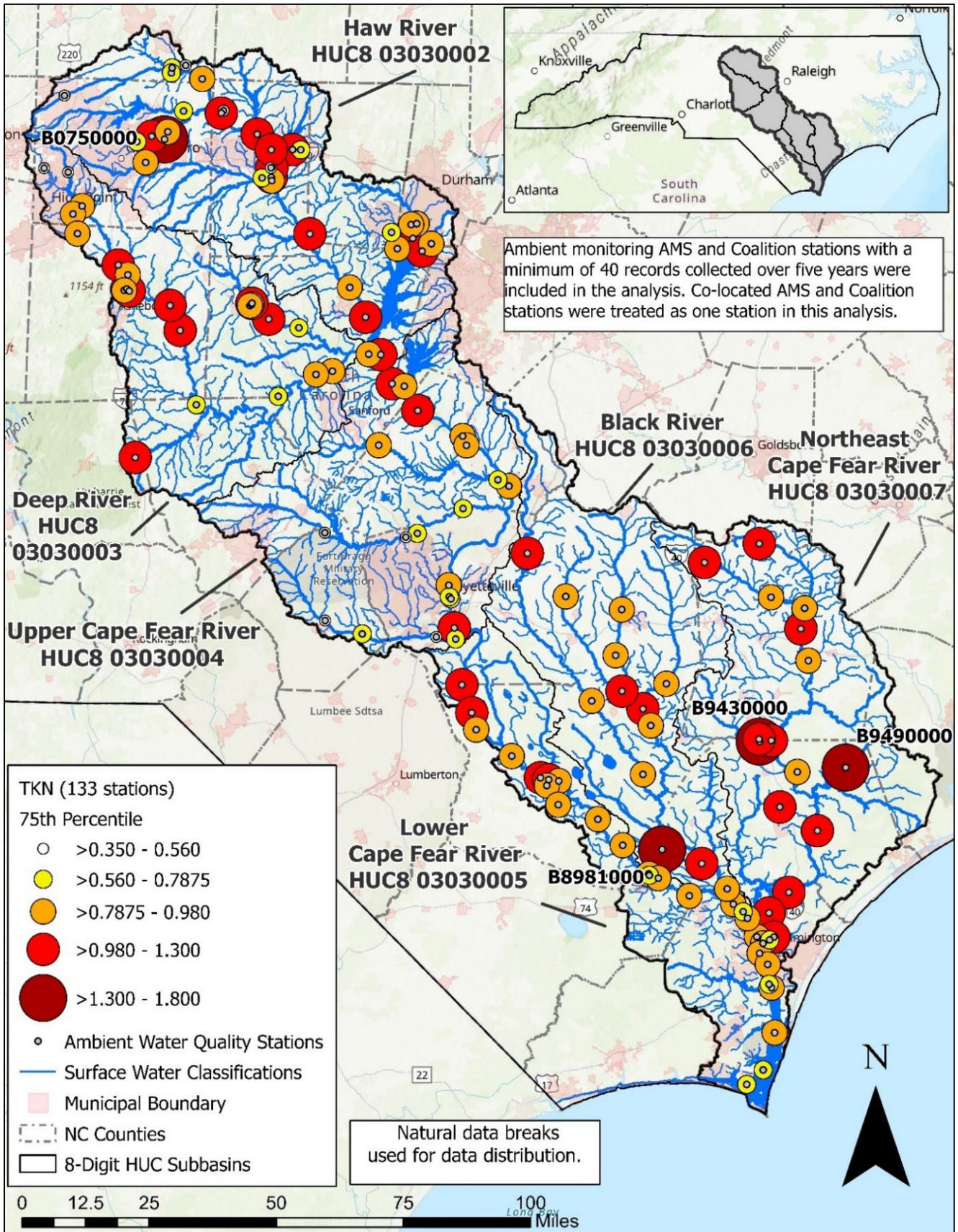


Figure 2-26: Cape Fear River Basin HUC8 Subbasin Annual Mean TKN

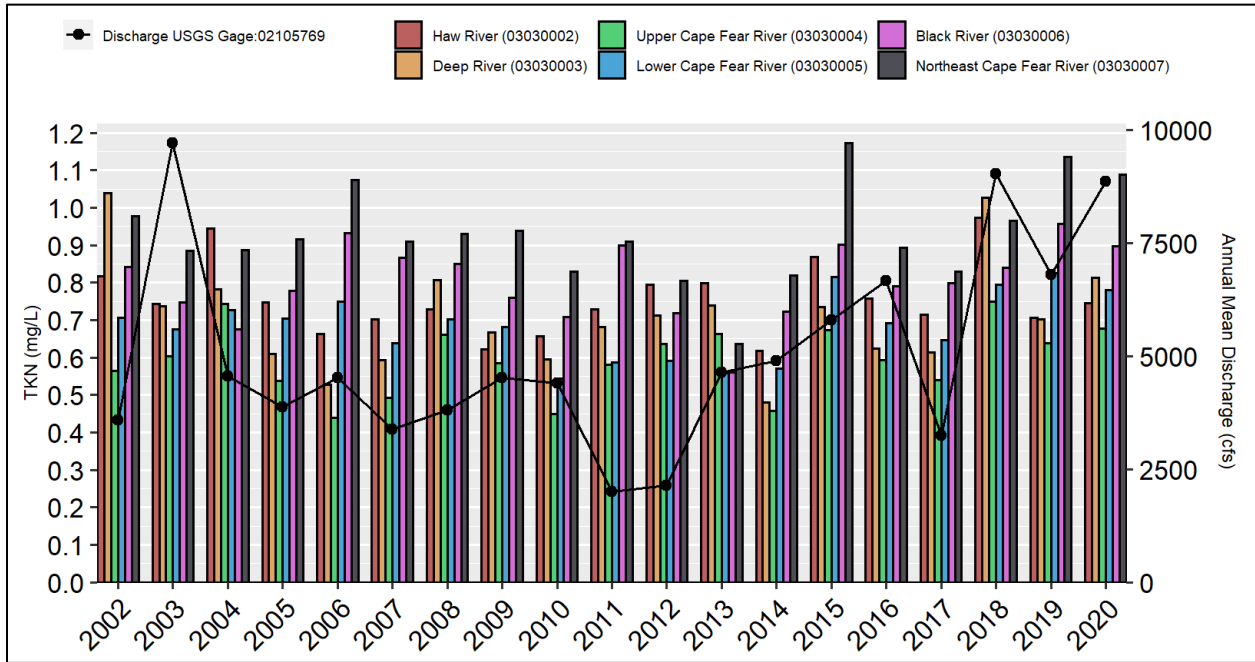
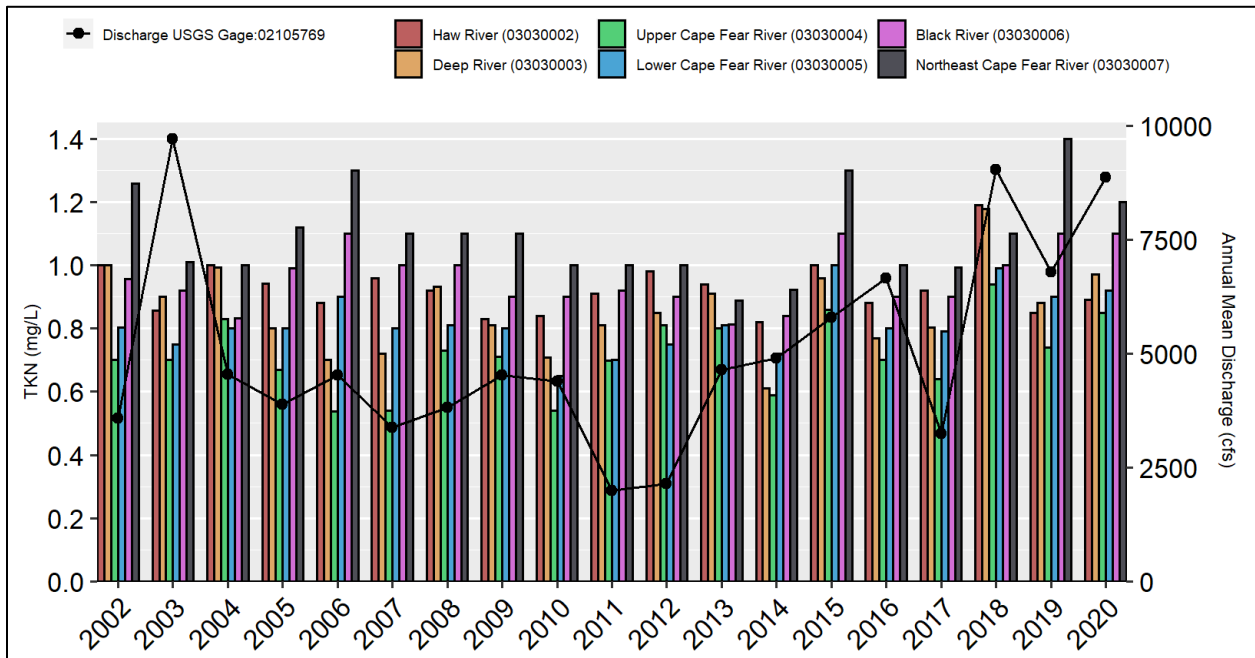


Figure 2-27: Cape Fear River Basin HUC8 Subbasin Annual 75th Percentile TKN



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 144 freshwater, 59 freshwater swamp, 12 saltwater, and one saltwater swamp stations used in the nutrient mean analyses. Station number and records per station vary from year to year.

At the HUC8 level, the Northeast Cape Fear River subbasin followed by the Black, generally had the highest mean and 75th annual concentrations for TKN from 2002 to 2020 (*Figure 2-26*). The annual mean and 75th percentile graph results had similar relative results. The Haw River and Deep River subbasins were comparable to the Northeast Cape Fear River subbasin for a few years and were higher in 2018. The Upper Cape Fear River subbasin had relatively lower annual mean and 75th concentrations than the other subbasins almost every year. TKN yearly mean concentrations ranged from 0.7 to 1.2 mg/L in the Northeast Cape Fear and 0.6 to 1.0 mg/L in the Black while the 75th percentiles ranged from 0.8 to 1.4 mg/L and 0.8 to 1.1 mg/L respectively. TKN levels in the Northeast Cape Fear River subbasin spiked during several recent years 2015, 2019, and 2020 (*Figure 2-27*). USDA census data in 2022 indicated Duplin County, located almost completely in the Northeast Cape Fear River subbasin, had the most inventory and production contracts for poultry in the basin and in the entire state, 22 million for inventory and 96 million for contract production (chickens only). Duplin also has the highest concentration of swine in inventory (1.88 million) and production (6.5 million). Sampson County, located in the Black River subbasin, is the second most concentrated county in the basin with a poultry inventory of 19.2 million and contracts for 76.8 million chickens. Sampson County is also the second highest concentration of swine inventory (1.85 million) and production (5.2 million). Together Duplin and Sampson counties house 76% of the basins swine inventory and 47% of the NC statewide inventory totals (See chapter 1 for agricultural totals). Both counties individually had over 17,000 acres treated with manure in 2022.

The DWR Modeling and Assessment Branch conducted screening-level seasonal Mann-Kendall trend tests at 95% confidence using Cape Fear River station TKN data for the 2010 to 2019 timeframe. Many of the stations along the Cape Fear River mainstem and some in the Deep, Haw, and Northeast Cape Fear River subbasins have significantly increasing TKN concentrations, including the Colly Creek station in the Black and the Rockfish and Angola creek stations in the Northeast Cape Fear River subbasins, however, the South Buffalo Creek station in the Haw River subbasin was not significantly increasing.

2.5.7.2 Ammonia (NH₃)

The ammonia map figure (*Figure 2-28*) for 2016-2020 station data shows there are the several stations with higher 75th percentile levels of ammonia, >0.11 mg/L, scattered throughout the basin, while stations in the mid-range, >0.7-0.11 mg/L, were concentrated in the lower third of the basin in the Lower Cape Fear River, Black River, and Northeast Cape Fear River subbasins. There were three stations in the highest 75th percentile range, >0.19 mg/L, B0540000 on North Buffalo Creek and B1380000 on Moadams Creek, in the Haw River subbasin, and B8981000 on Colly Creek in the Black River subbasin (also see the station descriptions at the beginning of Section 2.5.7). The Colly Creek station (B8981000) (Black River subbasin) had the highest five-year 75th percentile concentration of ammonia, 0.315 mg/L, and also has high TKN levels. As was discussed in the previous section, this may be related to failing septic systems and groundwater seepage in and around the town of White Lake. Ammonia levels, like TKN, started increasing in the 2015 timeframe. Further investigation is needed to verify what is causing the ammonia and TKN problems at this station. Additional monitoring of the White Lake WWTP effluent and downstream of their discharge would help DWR to understand if the treatment plant is a potential source of elevated ammonia in Colly Creek.

Figure 2-28: 22: Cape Fear River Basin Ammonia mg/L 75th Percentile by Station

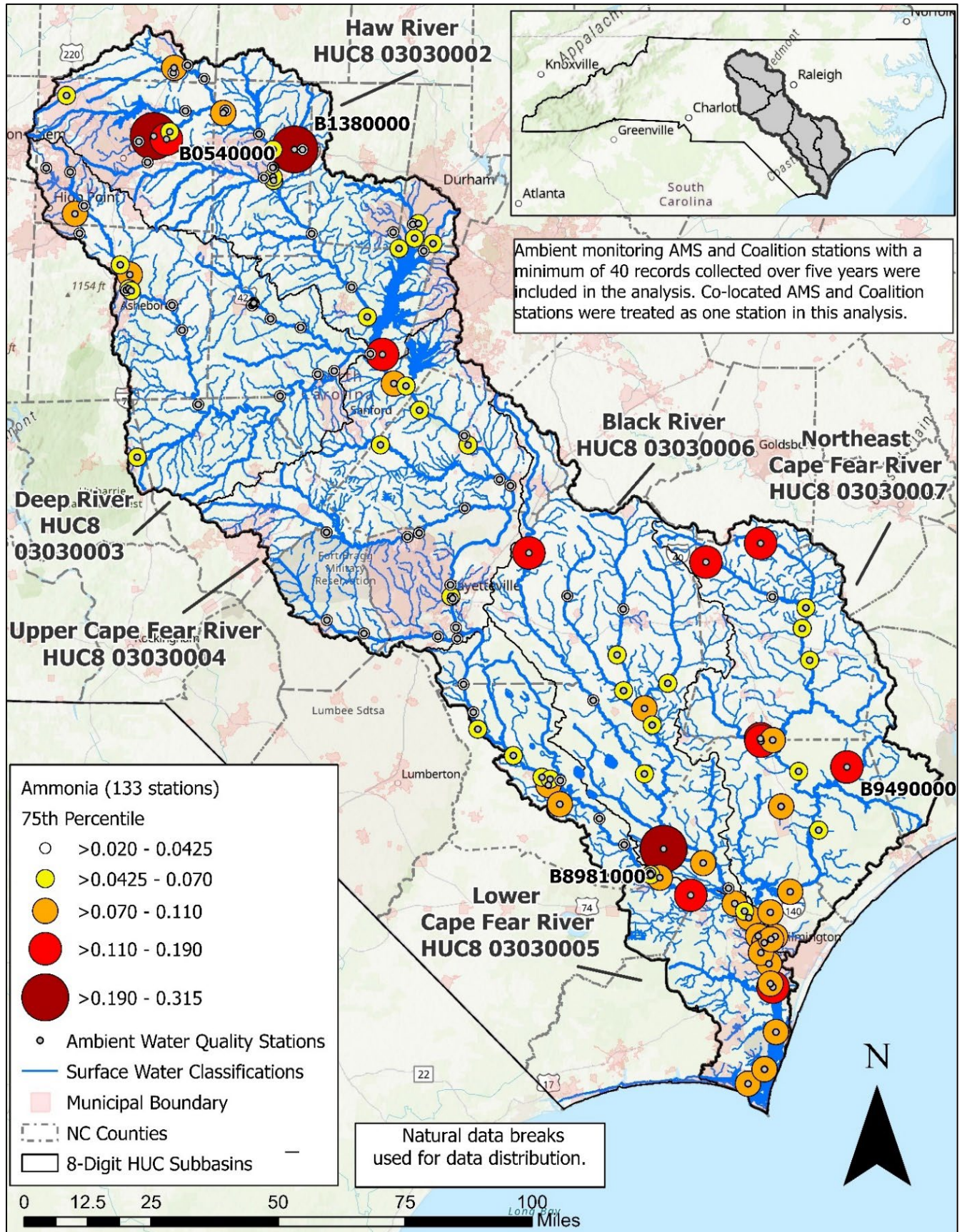


Figure 2-29: Cape Fear River Basin HUC8 Subbasin Annual Mean Ammonia

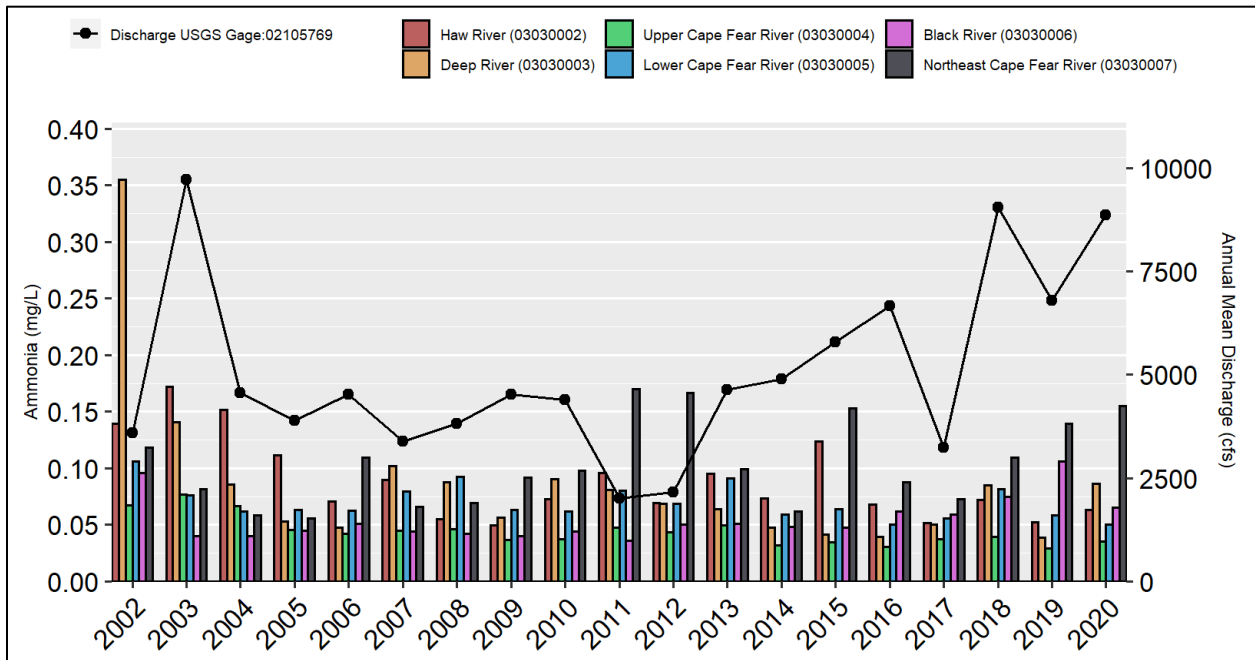
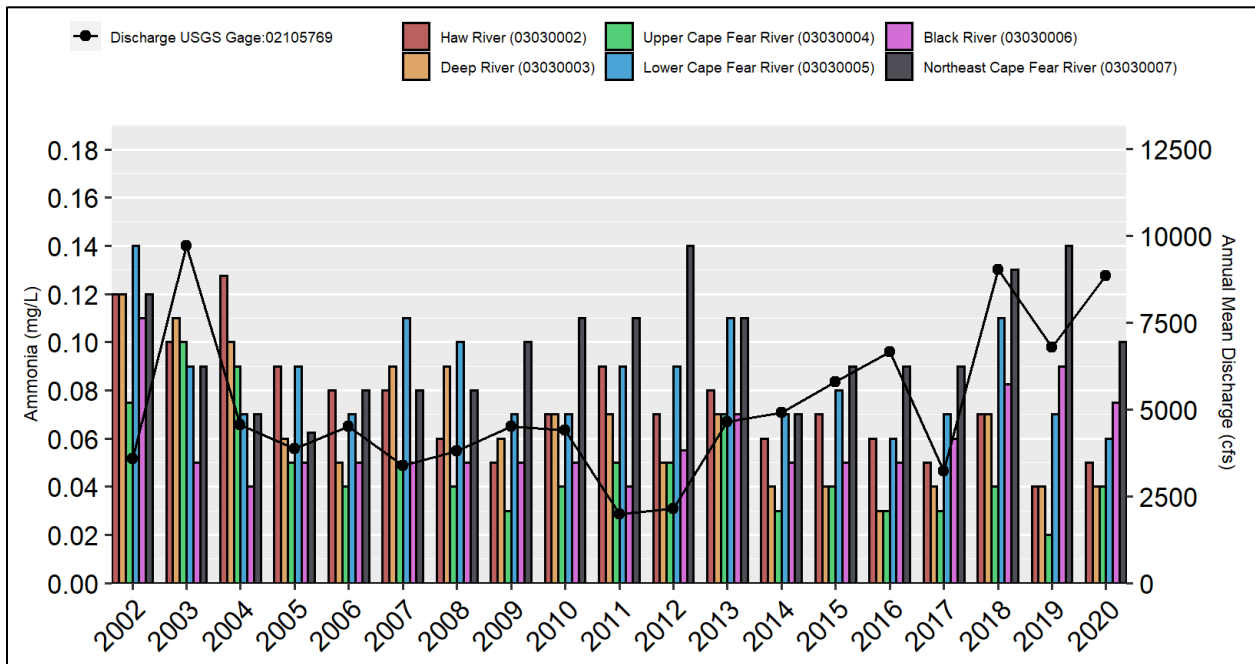


Figure 2-30: Cape Fear River Basin HUC8 Subbasin Annual 75th Percentile Ammonia



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 144 freshwater, 59 freshwater swamp, 12 saltwater, and one saltwater swamp stations used in the nutrient mean analyses. Station number and records per station vary from year to year.

The Haw River subbasin stations had comparatively lower five-year 75th percentile levels, 0.22 mg/L for North Buffalo Creek station (B0540000) and 0.21 mg/L for the Moadams Creek station (B1380000). The North Buffalo Creek station's ammonia levels declined notably in 2017 when the North Buffalo Creek WWTP (NC 0024352) closed. The small watershed and the station's close proximity to the Mebane WWTP is likely affecting ammonia levels. Ammonia levels were comparably lower at the station located above the WWTP. The Moadams Creek station data does suggest levels are trending upward.

At the HUC8 level, yearly means for ammonia from 2002 to 2008 indicate the Northeast Cape Fear River subbasin has had relatively higher concentrations of ammonia most years since 2008 ranging from 0.1 to 0.15 mg/L (*Figure 2-29*). The Deep and the Haw River subbasins had relatively higher concentrations during the first several years with annual means declining notably from 2002 to 2006. HUC8 levels for yearly 75th percentiles also show that the Northeast Cape Fear River subbasins has relatively higher concentrations than the other subbasins most years after 2008 (*Figure 2-30*). However, the 75th percentile graph also shows the Lower Cape Fear River subbasin had relatively higher levels of ammonia that were more comparable to the Northeast Cape Fear River for several years. The 75th percentile graph also shows TKN concentrations were more concentrated in Lower Cape Fear River subbasins during low flow years indicating there may be more of a point source influence leading to higher instream productivity as seen by the increased algal production during low flow years in this subbasin (*Figure 2-30*).

2.5.7.3 Nitrite-Nitrate (NO_x)

Higher instream concentrations of nitrite-nitrate (NO_x) occurred in the upper part of the basin in the Haw and Deep River subbasins (*Figure 2-31*). There were six stations that ranged from >3.2 to 5.9 mg/L and three stations that were in the >5.9 mg/L range for the 75th percentile concentration during the 2016 to 2020 timeframe (see the station descriptions at the beginning of Section 2.5.7).

The Haw River subbasin had five stations in the >3.2 to 5.9 mg/L range, two located in the headwaters of Jordan Lake on New Hope Creek (B3040000) and on Morgan Creek (B3900000), one on Reedy Fork near the community of Ossipee (B0840000) below the Buffalo Creek confluence, and two stations on North Buffalo Creek, one near the confluence with Buffalo Creek (B0540050) and the other further upstream (B0540000) (*Figure 2-31*). There is also one station on South Buffalo Creek, B0750000, with a 75th percentile instream five-year concentration of 9.5 mg/L (*Figure 2-31*). All of these stations are located in watersheds with over 25% development, the Reedy Fork station is close to 50% development and the North and South Buffalo Creek stations have 75% or more development. All of these stations are also located downstream of a major NPDES discharger as well as other permitted facilities. The North Buffalo Creek stations (B0540000 and B0540050) received discharge from the 16 MGD North Buffalo Creek WWTP (NC0024352) until October 2, 2017. All of the City of Greensboro wastewater is now treated at the T.Z. Osborne WWTP (NC0047384) located on South Buffalo Creek. Permitted discharge at T.Z. Osborne WWTP was increased from 40 MGD to 56 MGD, the highest in the basin (see Chapter 6 for more information). Station B0750000 is 2.6 miles downstream of T.Z. Osborne WWTP and the Reedy Fork station (B0840000) is also 20.2 miles downstream of this same major discharger.

The Deep River subbasin had several stations also located in small, developed watersheds with higher instream NO_x 75th percentile concentrations for data collected from 2016 to 2020 (*Figure 2-31*). There was one station in the >3.2 to 5.9 mg/L range located on Cotton Creek near the community of Star (B5390800). This is a small 2.2 Mi² watershed with one minor WWTP permitted for 0.6 MGD as-built for the Town of Star (NC0058548) as well as 34 acres residual land application fields for the Town of Star (WQ0003945) and several NPDES stormwater permits. The Deep River subbasin also has two stations in the >5.9 mg/L range for NO_x, B4890000 on Haskett Creek below Asheboro's WWTP with a five-year 75th percentile of 9.9 mg/L and B5920000 on Loves Creek below Siler City's WWTP with the highest five-year 75th percentile in the basin, 15.2 mg/L (*Figure 2-31*). Both the Haskett Creek and Loves Creek stations have major NPDES WWTP located less than a mile upstream as well as other permitted facilities in their watersheds (see station descriptions, Section 2.5.7). Water quality data for these three stations indicates NO_x levels were more concentrated during low flow years which suggests a primary point source influence.

The HUC8 level yearly mean and 75th percentile for NO_x from 2002 to 2020 is shown in *Figure 2-32* and *Figure 2-33*. Yearly means were highest in the Haw and Deep River subbasins most years (*Figure 2-32*) except for 2007 to 2011 and 2019 when the Northeast Cape Fear River subbasin was comparable. Overall, mean concentrations in the Deep and Haw River subbasins have been decreasing, generally ranging from 1.7 to 2.7 mg/L prior to 2013 and 0.7 to 1.8 mg/L from 2013 to 2020. In Northeast Cape Fear River subbasin, NO_x mean concentrations from 2007 to 2011 and in 2019, ranged from 1.4 to 2.4 mg/L, other years the range was 0.5 mg/L to 1.1 mg/L. The yearly 75th percentile graph (*Figure 2-33*) shows the Haw River subbasins was relatively much higher than the other subbasins from 2005 to 2017 ranging from 1.8 to 3.6 mg/L. Similar to the mean graph, yearly 75th percentile concentrations in the Haw River have had a decreasing trend (Section 2.5.7). The differences between the two graphs suggests the Deep and Northeast Cape Fear River subbasins have a few outlier stations that are skewing the yearly mean results and that overall, at the HUC8 level, the Haw River subbasin has had the most notable issues with NO_x concentrations.

The high levels in 2007 to 2011 in the Northeast Cape Fear River subbasin were mainly due to one outlier station, B9520000 located on Burgaw Creek near the Town of Burgaw, which had more records >15 mg/L than any other station in the basin between 2002 to 2020. The Burgaw Creek station (B9520000) has an 8.1 Mi² watershed with just one minor discharger currently, a non-contact Cooling, Boiler Blowdown Wastewater industrial facility with no permitted discharge. However, historically the Town of Burgaw had a minor WWTP (NCG500270) permitted for 0.75 MGD as-built that was active until August 2012. Water quality data for this station shows NO_x was most concentrated during low flow years, 2007 to 2011, and that concentrations dramatically decreased to near zero in 2012 when the WWTP closed. Additional water quality stations were added for a special study that increased the NO_x concentrations in 2019 for the Northeast Cape Fear River subbasin. The special study was conducted in Stocking Head Creek, Maxwell Creek, and two unnamed tributaries in 2018 and 2019; with a permanent ambient water quality monitoring station established to continue to monitor Stocking Head Creek. See Chapter 11 on the Northeast Cape Fear River subbasin for the mapped locations of the stations, discussion monitoring results, and acknowledgement of next steps.

Figure 2-31: Cape Fear River Basin Nitrite-Nitrate (NOx) mg/L 75th Percentile by Station

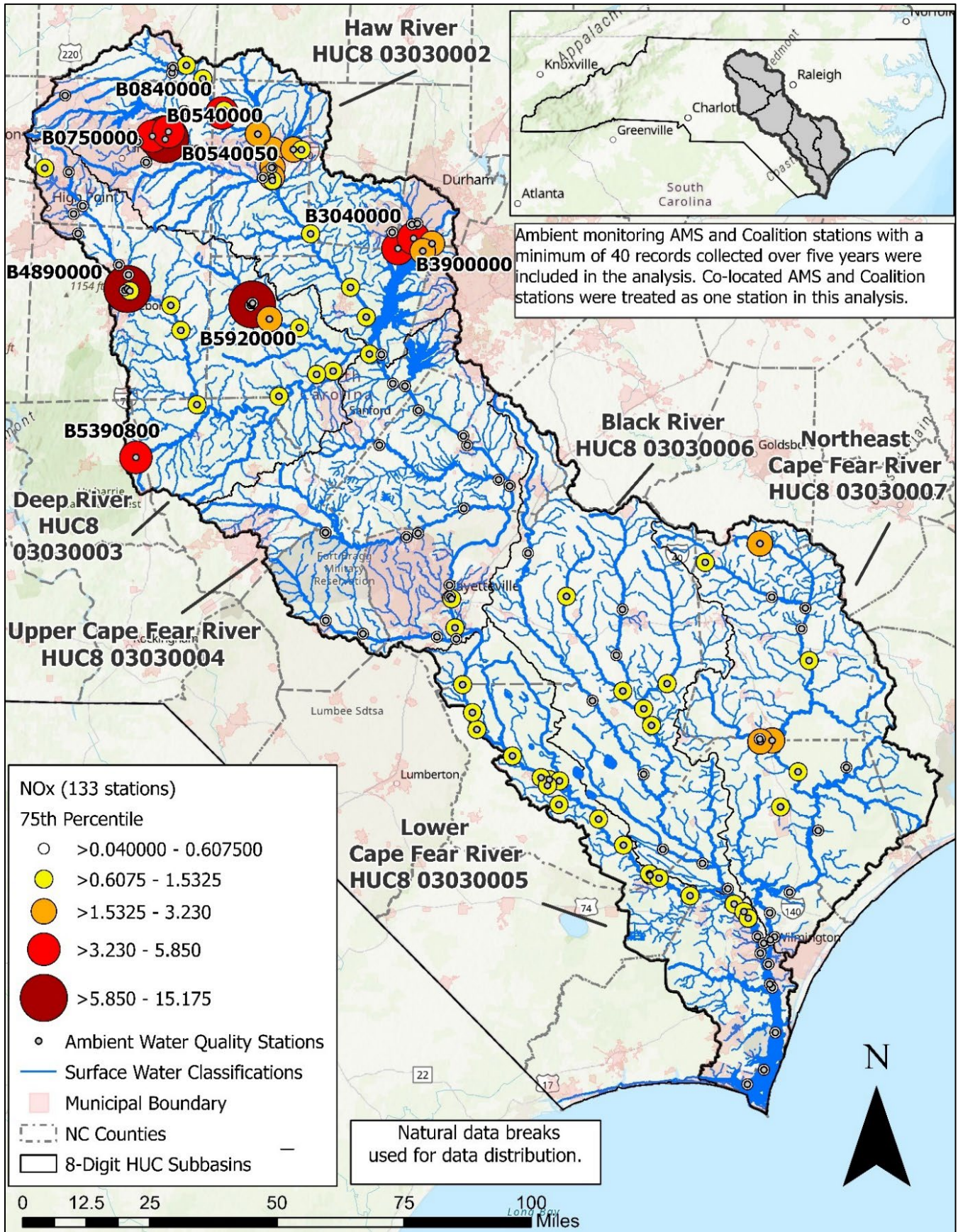


Figure 2-32: Cape Fear River HUC8 Subbasins Annual Mean for Nitrite-Nitrates

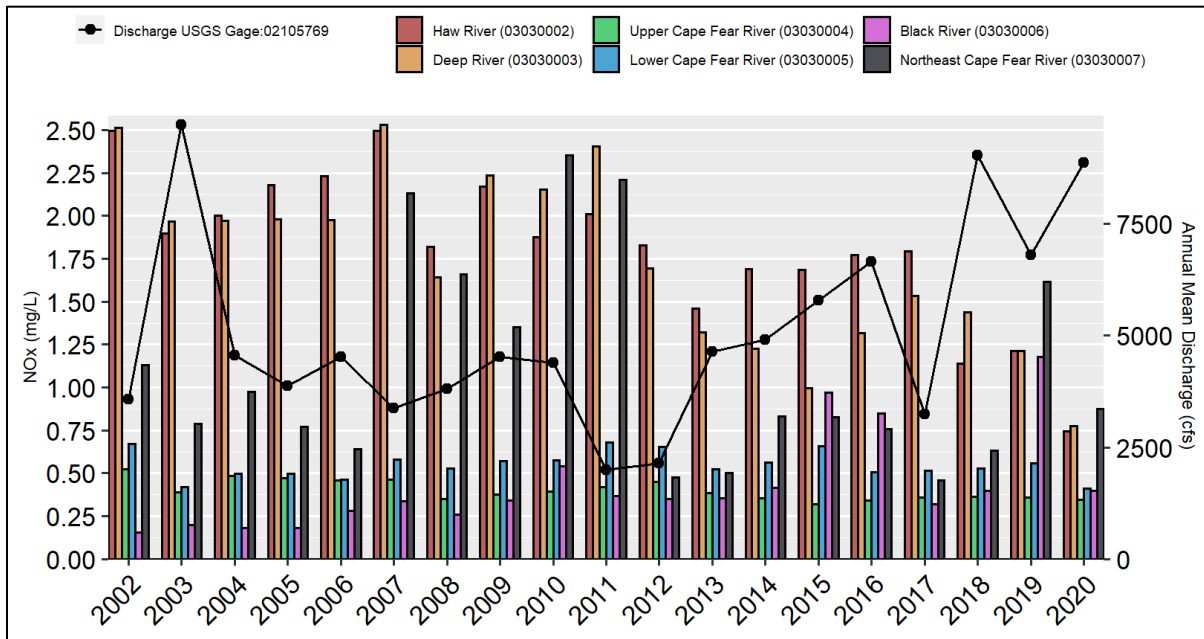
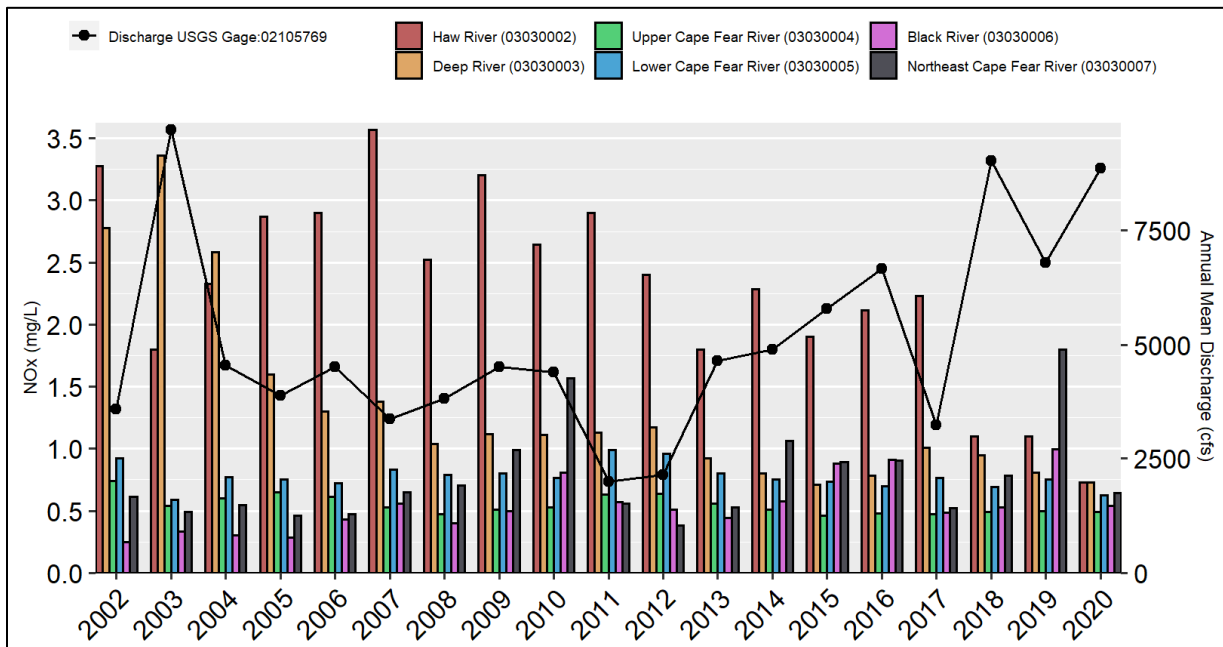


Figure 2-33: Cape Fear River HUC8 Subbasins Annual 75th Percentile for Nitrite-Nitrates



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 144 freshwater, 59 freshwater swamp, 12 saltwater, and one saltwater swamp stations used in the nutrient mean analyses. Station number and records per station vary from year to year.

2.5.7.4 Total Nitrogen (TN)

Similar to NO_x, the higher instream 75th percentile concentrations of total nitrogen (TN) occurred in the upper part of the basin in the Haw and Deep River subbasins (*Figure 2-34*). There were five stations that ranged from >4.3 to 7.5 mg/L and three stations that were >7.5 mg/L for 75th percentile concentrations during the 2016 to 2020 timeframe (see the station descriptions at the beginning of Section 2.5.7). Almost the exact same stations identified as hotspot locations for NO_x pollutants were also identified in *Figure 2-34* as hotspots for TN which indicates there is a high inorganic to organic ratio for stations with the most concentrated levels of TN in the Cape Fear River Basin.

The Haw River subbasin had four stations in the >4.3 to 7.5 mg/L range, the two located in the headwaters of Jordan Lake on New Hope Creek (B3040000) and on Morgan Creek (B3900000), the one on Reedy Fork near the community of Ossipee (B0840000) below the Buffalo Creek confluence, and just the upper station on North Buffalo Creek (B0540000), *Figure 2-34*. The South Buffalo Creek station (B0750000), was the only station in the >7.5 mg/L range with five-year 75th percentile of 11.8 mg/L.

In the Deep River subbasin, the Cotton Creek station near the community of Star (B5390800), was in the >4.3 to 7.5 mg/L range and both the Haskett Creek station below Asheboro's WWTP (B4890000), and Loves Creek station below Siler City's WWTP (B5920000), were >7.5 mg/L range (*Figure 2-34*). The Haskett Creek station had a 11.2 mg/L five-year 75th percentile and the Loves Creek station had a 15.4 mg/L five-year 75th percentile. The Siler City station had the most concentrated 75th percentile for the 2016 to 2020 timeframe in the basin, as it did for NO_x (see the previous Section 2.5.7.3).

HUC8 mean and 75th percentile graphs (*Figure 2-35* and *Figure 2-36*) were very similar to the NO_x graphs (*Figure 2-32* and *Figure 2-33*). TN mean concentrations were highest in the Haw and Deep River subbasins most years with the Northeast Cape Fear River subbasin being comparable in 2007 to 2011 and comparably higher in 2019 and 2020. Mean TN concentrations in these three subbasins generally ranged from 1.7 to 3.6 mg/L during those high-level years. Overall, TN levels also showed a decreasing trend, like NO_x, in the Haw and Deep River subbasins. The Haw River subbasin also had relatively higher TN 75th percentile concentrations most years relative to the other subbasins, ranging from 2.6 to 4.7 mg/L prior to 2018. The 75th percentile concentrations were also highest in the Northeast Cape Fear River subbasin in 2019 due to the Stocking Head Creek study (see previous section).

A comparison of the NO_x and TN graphs shows that the more concentrated TN levels in the Haw, Deep, and Northeast Cape Fear River subbasins are due to the inorganic NO_x faction. Similar to the NO_x graphs, the differences between the mean graphs and 75th percentile graphs are due to the Deep River (through 2018) and Northeast Cape Fear River (not including 2019) subbasins having a few outliers causing the more concentrated means in these subbasins. The high inorganic-to-organic nitrogen ratio and the negative correlation of TN concentrations to stream flow indicates there is point source influence in the Haw River and parts of the Deep River subbasins. The Northeast Cape Fear River subbasin had one station with a clear point source influence prior to 2012 (B5920000) but has had more of a positive correlation with discharge in recent years which suggests more of a non-point source influence.

Figure 2-34: Cape Fear River Basin Total Nitrogen mg/L 75th Percentile By Station

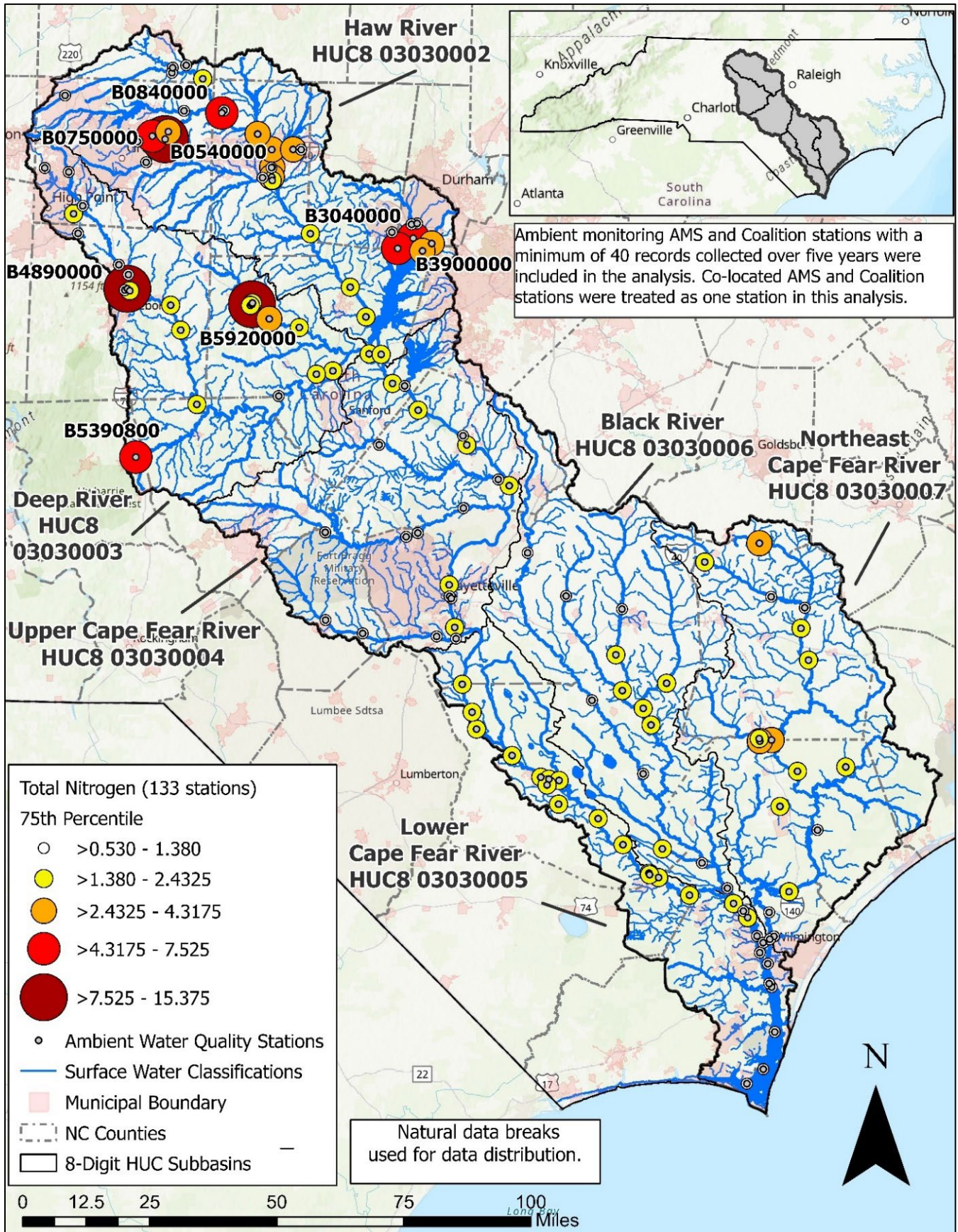


Figure 2-35: Cape Fear River Basin HUC8 Subbasins Annual Mean for Total Nitrogen

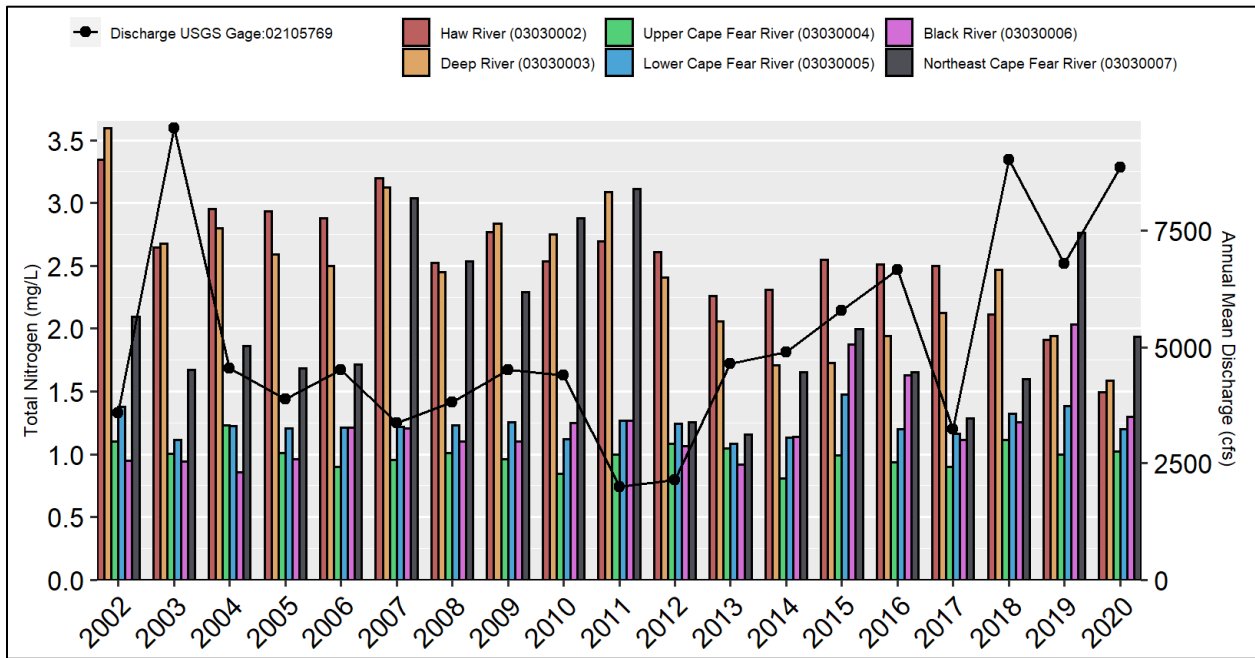
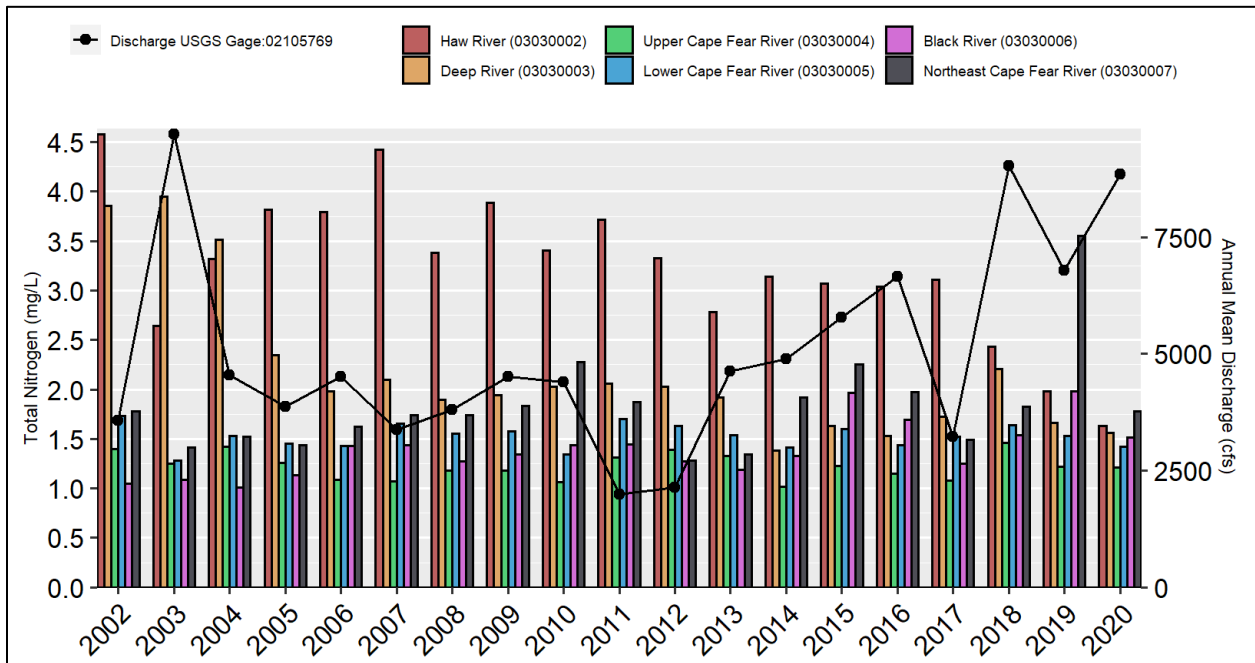


Figure 2-36: Cape Fear River Basin HUC8 Subbasins Annual 75th for Total Nitrogen



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 144 freshwater, 59 freshwater swamp, 12 saltwater, and one saltwater swamp stations used in the nutrient mean analyses. Station number and records per station vary from year to year.

2.5.7.5 Total Phosphorus (TP)

The total phosphorus (TP) map figure (*Figure 2-37*) indicates that higher 75th concentrations of TP from 2016 to 2020, >0.2 mg/L, were most prevalent in the lower part of the basin in the Northeast Cape Fear, Black, and Lower Cape Fear River subbasins. However, several stations, with higher TP concentrations occurred in the in the Haw and Deep River subbasins. There were six stations with 75th percentiles >0.33 mg/L during the 2016-2020 timeframe; the South Buffalo Creek station (B0750000) in the Haw River subbasin, the Cotton Creek station (B5390800) in the Deep River subbasin, a station on Great Coharie Creek (B8604000) in the Black River subbasin, and three stations in the Northeast Cape Fear River subbasin, the Angola Creek station (B9490000) and two Rockfish Creek stations (B9430000 and B9470000). Similar to TKN, many of the stations along the Lower Cape Fear River mainstem fell in the mid-range of >0.14 to 0.2 mg/L (*Figure 2-37*). Also see the station descriptions at the beginning of Section 2.5.7.

In the Haw River subbasin, the South Buffalo Creek station (B0750000) located below the City of Greensboro's T.Z. Osborne wastewater facility, had a 0.52 mg/L five-year 75th percentile. This station also had concentrations that were in the highest range for TKN, NO_x, and TN. Several stations located in the Jordan Lake headwaters and Haw River mainstem near Burlington were in the >0.2 to 0.33 mg/L range. The Deep River subbasin Cotton Creek station (B5390800) had a TP five-year 75th concentration of 0.67 mg/L and also had issues with high concentrations of NO_x and TN. Likely the main cause of high TP levels at these two stations was the close proximity to WWTPs.

The Great Coharie Creek station, B8604000, in the Black River subbasin had a five-year 75th percentile of 0.43 mg/L and is located in a large 180 Mi² rural watershed with one major NPDES discharger for the City of Clinton (NC0020117; 5 MGD as-built) located 8.6 miles upstream and many AFOs (81 AFO permits) contributing to the TP concentrations.

In the Northeast Cape Fear River subbasin, the Angola Creek station (B9490000), had a five-year 75th percentile of 0.39 mg/L, in this rural 40 Mi² watershed, permitted AFOs, stormwater facilities, and poultry operations are likely contributing to elevated TP concentrations. The Rockfish Creek stations are in large rural watersheds with over 30% agriculture that includes poultry operations and permitted AFOs that may be contributing to TP levels. The upper station, B9430000, has a 0.59 mg/L 75th five-year percentile and the lower station, B9470000, has a 0.54 mg/L 75th five-year percentile concentration. Both stations receive discharge from the Wallace Chicken Processing Plant (NC00003344), and the lower station also receives discharge from the Town of Wallace WWTP (NC0003450). These WWTPs are likely contributing to the elevated TP levels. Prior to 2019, the lower station (B9470000) had slightly higher TP concentrations than the upper station (B9430000), however the upper station (B9430000) spiked in 2019 which suggests the main issues with TP are now originating higher in the watershed.

Figure 2-37: Cape Fear River Basin Total Phosphorous mg/L 75th Percentile by Station

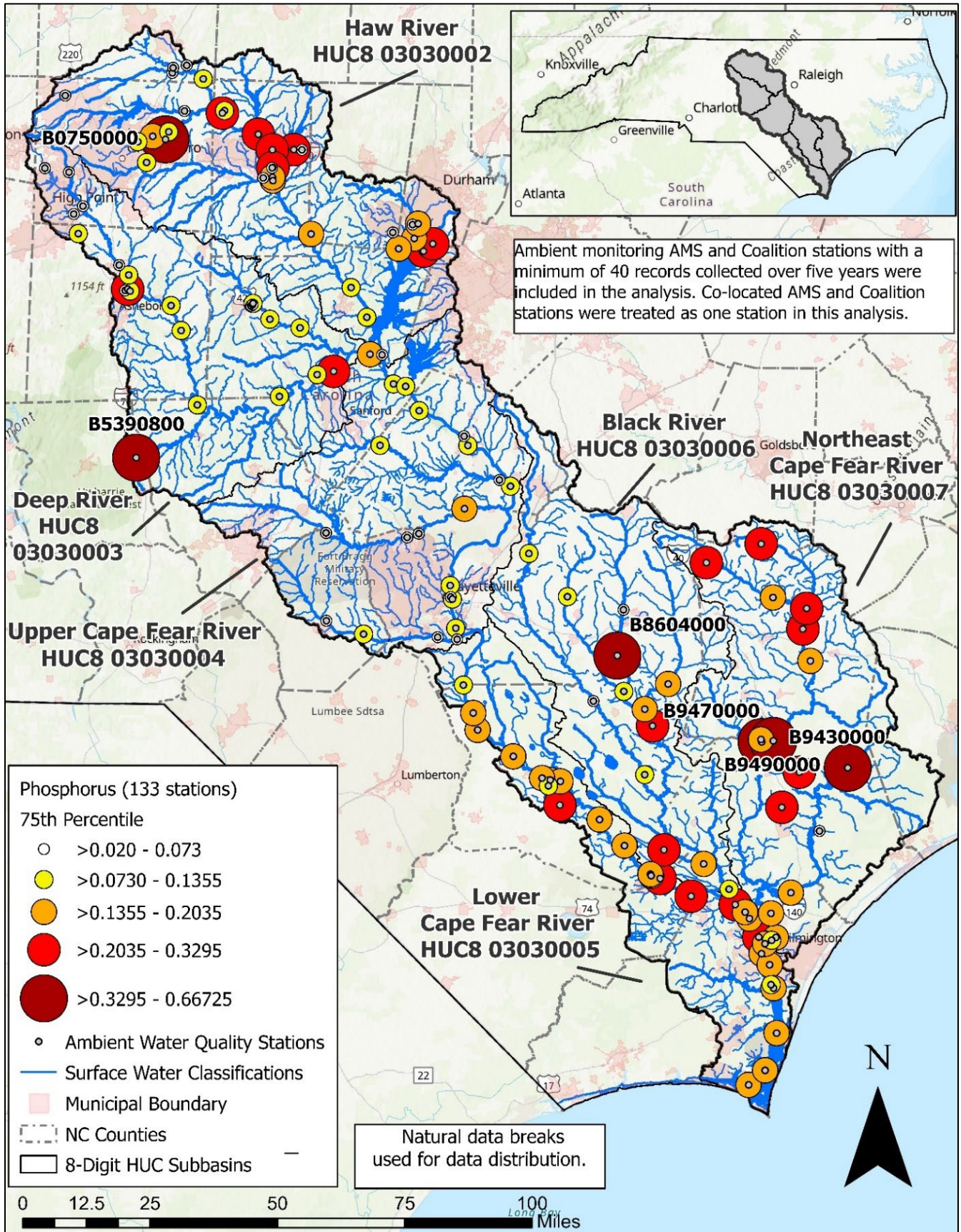


Figure 2-38: Cape Fear River Basin HUC8 Subbasins Annual Mean for Phosphorus

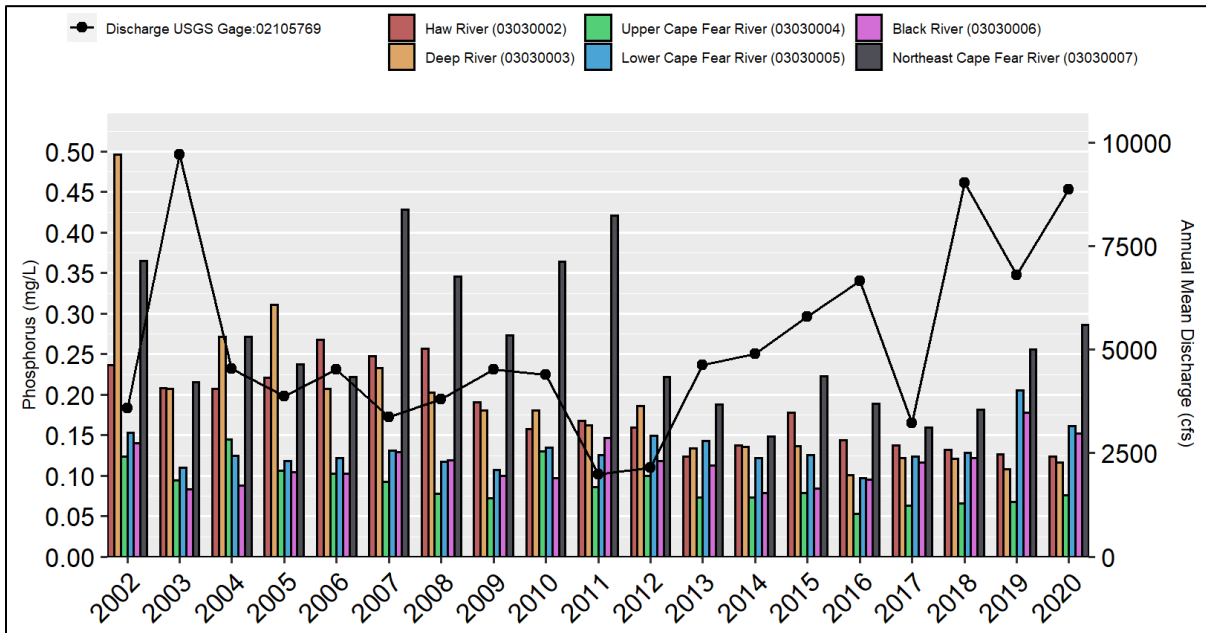
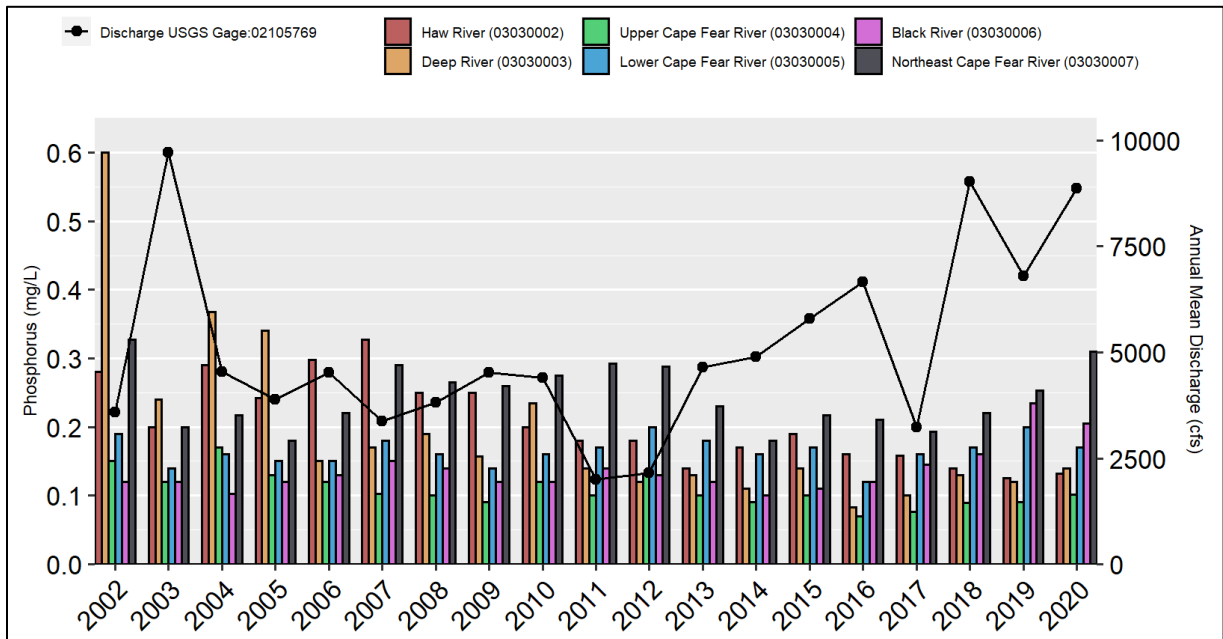


Figure 2-39: Cape Fear River Basin HUC8 Subbasins Annual 75th Percentile for Phosphorus



All AMS, RAMS, and Coalition stations were included in the above graphs. There were 144 freshwater, 59 freshwater swamp, 12 saltwater, and one saltwater swamp stations used in the nutrient mean analyses. Station number and records per station vary from year to year.

At the HUC8 level, annual TP mean and 75th percentile concentrations (*Figure 2-38* and *Figure 2-39*) were relatively higher in the Haw and Deep River subbasins during the earlier years. TP levels in the Haw and Deep River subbasins decreased from 2002 to 2010 then leveled out. The Northeast Cape Fear River subbasin annual mean and 75th percentiles have been more variable. Annual means were more comparable to the Haw and Deep River subbasins prior to 2007 but were relatively higher than the other subbasins the rest of the years, especially from 2007 to 2011 due to the Burgaw Creek station, B9520000, which received discharge from the Town of Burgaw WWTP until 2012 when it closed. The 75th percentile graph showed the Northeast Cape Fear River subbasin concentrations were relatively lower than the Haw and Deep River subbasins prior to 2007, similar from 2007 to 2009, and relatively higher for the last eleven years. The graphs also indicate TP levels have been increasing in the Northeast Cape Fear River subbasin for the last few years. TP levels in the Black River and Lower Cape Fear River subbasins were also higher for the last couple years. The correlation with discharge indicates the main drivers for most stations (other than the Burgaw Creek station, B9520000) in the Northeast Cape Fear subbasin are non-point source related.

2.5.7.6 TNC Cape Fear River Basin SWAT Model Nutrient Summary

The Nature Conservancy (TNC) developed the first Soil and Water Assessment Tool (SWAT) model for both water quality and quantity for the entirety of the Cape Fear River Basin, in collaboration with the US Geological Survey and Arizona State University. In 2023, TNC completed and published results from a [Cape Fear River SWAT](#) model to assist with understanding sources and location of nutrient loading with the goal of optimizing the type and location of conservation practices to reduce nutrient loading to the lower Cape Fear River ([Schaffer-Smith et al. 2023](#)). They also developed a water quality risk index (WQRI) that highlights places where watershed scale interventions can best improve water quality across the different climate conditions occurring in the basin. The SWAT model was developed for conditions representing land use, soil and slope, and historical weather conditions from 1979-2019 and contributions of flow, sediment, nitrogen and phosphorus from wastewater treatment plants and other permitted facilities using measured data 1994-2019 and monthly averages for the period preceding recordkeeping. Model calibration and validation were done using observed streamflow and water quality monitoring records for the 2000-2019 period. For model specific information, model results and associated maps, see the [2023 Schaffer-Smith et al. publication](#) and [supporting information document](#).

Results from the model using the best available data and specific assumptions identified in the paper include:

- Typically, predicted higher pollutant loads from 1982-2019 for large streams and rivers with higher daily average flow.
- Jordan Lake and the mainstem Cape Fear River had high daily average loads for sediment, TN and TP.
- Other sediment hot spots included stream segments draining urban centers in the Triangle and Triad, the Little River below Fort Liberty, the Black River below Six Runs Creek, and in the Northeast Cape Fear River above and below Chinquapin.
- Other TN loads were notably high in the Haw River at and below Burlington, the Deep River below Asheboro, South River below Garland, Black River downstream from Great Coharie Creek and Six Runs Creek as well as the Northeast Cape Fear River downstream from Bear Swamp.

- Other TP loads were high in the Haw River below Greensboro, the Deep River below Franklinville and below. The highest TP loads were predicted for the Black River below Six Runs Creek and the Northeast Cape Fear River below Grove Creek.

Key takeaways from the model and the development of a Water Quality Risk Index (WQRI) include:

- During normal and flooding flow rates, nonpoint sources account for approximately 90% of the pollution going into the Cape Fear River system.
- During drought years, point sources contribute the majority of the instream nutrient pollution, such as in 2011, point sources contributed approximately 70% of the nutrient pollution to the system.
- The landscape consistently contributed large amounts of contaminants, but 16% of the watershed contributed the most pollutants across all flow/weather conditions (extremely dry, normal and extremely wet conditions). *These areas should be a priority for implementation measures in order to have the largest effect to alleviate water quality impacts.*
- TNC developed a Water Quality Risk Index (WQRI) using the average and variability of loads predicted by SWAT across normal, dry and wet conditions from 1982-2019. High WQRI regions track with known surface water quality impairments as well as high groundwater nitrate levels and provide water quality information for many poorly monitored parts of the basin.
- High WQRI watersheds tend to have a high degree of urban and agricultural land use, while Low WQRI watersheds tend to have relatively intact natural land uses (see figure 6 in the Schaffer-Smith et al. 2023 <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022EF003137?af=R> publication).
- High WQRI regions merit further attention for monitoring and actions to improve water quality and watershed condition.
- Low WQRI regions represent key conservation opportunities.
- Taking a long history of weather variability into account can help highlight priority areas to improve the resilience of watersheds in terms of both water quantity and quality.

This tool can help identify areas where restoration can help reduce pollution into the river as well as reduce or slow flooding. TNC's approach can easily be adapted for locally specific water quality concerns and tailored to unique event thresholds. Contact TNC for additional information (<https://www.nature.org/en-us/about-us/where-we-work/united-states/north-carolina/>).

DWR has identified several portions of the Cape Fear River Basin as nutrient enriched or nutrient sensitive. In 2019, DWR began an intensive monitoring study to gather additional information to support dissolved oxygen and nutrient modeling efforts in the central portion of the Cape Fear River Basin. EPA Region IV's modeling team is collaborating with DWR's modeling staff to develop both watershed and receiving water models for the areas of interest. These models are needed to support permitting in the basin, inform the development of management strategies for impaired waters, provide information on conditions associated with algal bloom frequency and duration, and provide information on the sources of nutrients and biological oxygen demand (BOD)-loading to the lower Cape Fear River. As currently designed, the modeling will support permitting below Randleman and Jordan Lakes down to Lock and Dam #1. See section 2.14 below for more information on the DWR modeling efforts and the Nutrient Criteria Development Plan to address nutrient issues in the Cape Fear River.

2.5.8 Chlorophyll *a*

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. Algae is the base of the food chain and is a required component of a healthy aquatic ecosystem. However, nutrient over-enrichment can lead to over production of algae (eutrophication), resulting in the formation of algal blooms with elevated chlorophyll *a* concentrations. As part of the algal bloom development and photosynthetic process, the uptake of carbon dioxide results in a corresponding increase in surface water pH levels. This corresponding shift in the ambient pH is often used to indicate the presence of an algal bloom at an ambient monitoring station. North Carolina has a chlorophyll *a* water quality standard of 40 µg/L (micrograms per liter) for lakes, reservoirs, and other waters subject to macroscopic or microscopic vegetation not designated as trout (Tr) waters.

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. We have found that once climate conditions are optimal (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 stream 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 result in large segments of impounded river acting more like slow moving lakes rather than swift moving rivers. The slow movement in the backwaters behind the dams are perfect for the development of algal blooms when conditions are right (temperature, nutrients, and clarity). 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 shallow, well-lit upper layer provides enough light to support algal growth (Hall, 2021).

2.5.8.1 Current 2022 IR conditions

In 2022, there were 34 FW miles and 11,723.6 FW acres impaired for chlorophyll *a* ([Table 2-6](#) and [Table 2-12](#)). Impairments to FW miles occurred in the Haw River (11.3 FW miles) and Deep River (22.7 FW miles) subbasins while the majority of the chlorophyll *a* FW acres impairments were primarily in the lakes and reservoirs in the Haw River subbasin (11,460.5 FW acres) and Deep River subbasin (65.9 FW acres) ([Table 2-12](#)). There was a single impairment on the mainstem Cape Fear River behind Buckhorn dam in the Upper Cape Fear River subbasin (121.9 FW acres), and Greenfield Lake in the Lower Cape Fear River subbasin (75.3 FW acres). All but two of the chlorophyll *a* impairments occur in drinking water supply streams and reservoirs which are mainly monitored by the Ambient Lakes Monitoring Program (ALMP).

The Deep River [AU#17-10.5)d1] just below the confluence with Haskett Creek is one of the two non-water supply chlorophyll *a* impairments identified. This is a historical impairment that is carried forward due to lack of new data collected for chlorophyll *a* at station B4920000. This segment of the Deep River is likely impacted by the high nutrient concentrations from the Asheboro WWTP discharging to Haskett Creek and due to the dam at Cox Lake, slowing the flow of the Deep River and allowing algal blooms to develop. The UCFRBA monitoring coalition continues to monitor this segment for many other water quality parameters (station B4920000). At a point where there is improved treatment at the Asheboro

WWTP and/or other actions in the Haskett Creek watershed resulting in lower instream nutrient concentrations, this segment of the Deep River should be monitored for chlorophyll *a* to determine if the Deep River can once again meet surface water quality standards. The other non-water supply water impairment is Greenfield Lake in the Lower Cape Fear River subbasin which receives urban stormwater runoff from the city of Wilmington which surrounds the lake.

Table 2-12: Cape Fear River Basin 2022 IR Chlorophyll *a* Impaired Waterbodies.

AU #	Waterbody	Area	Area Type	Classification	IR Cat
Haw River Subbasin (HUC 03030002)					
16-(37.5)a1	Haw River (Jordan Lake below normal pool elevation)	694.5	FW Acres	WS-IV,B;NSW,CA	4i
16-(37.5)a2	Haw River (Jordan Lake below normal pool elevation)	651.5	FW Acres	WS-IV,B;NSW,CA	4i
16-(37.5)b	Haw River (Robeson Creek Arm of Jordan Lake below normal pool elev.)	46.6	FW Acres	WS-IV,B;NSW,CA	4i
16-14-(5.5)a	Stony Creek (Stony Creek Reservoir)	84.6	FW Acres	WS-II;HQW, NSW, CA	5
16-18-(1.5)a1	Back Creek (Graham-Mebane Reservoir)	146.4	FW Acres	WS-II;HQW, NSW, CA	4i
16-18-(1.5)a2a	Back Creek (Graham-Mebane Reservoir)	355.1	FW Acres	WS-II;HQW, NSW,CA	4i
16-18-(1.5)a2b	Back Creek (Graham-Mebane Reservoir)	84.6	FW Acres	WS-II;HQW, NSW,CA	4i
16-18-(1.5)b	Back Creek (Graham-Mebane Reservoir)	107.2	FW Acres	WS-II;HQW, NSW,CA	4i
16-19-8-3	Rock Creek	11.3	FW Miles	WS-V;NSW	5
16-41-(0.5)	New Hope River Arm of Jordan Lake (below normal pool elevation)	1200	FW Acres	WS-IV,B;NSW,CA	4i
16-41-(3.5)a1	New Hope River Arm of Jordan Lake (below normal pool elev.)	2235.1	FW Acres	WS-IV,B;NSW,CA	4i
16-41-(3.5)a2	New Hope River Arm of Jordan Lake (below normal pool elev.)	337.3	FW Acres	WS-IV,B;NSW,CA	4i
16-41-(3.5)a3	New Hope River Arm of Jordan Lake (below normal pool elev.)	3102	FW Acres	WS-IV,B;NSW,CA	4i
16-41-1-(14)	New Hope Creek (including New Hope Creek Arm of New Hope River Arm of Jordan Lake)	1415.9	FW Acres	WS-IV;NSW,CA	4i
16-41-2-(1.5)	Morgan Creek (University Lake)	163.2	FW Acres	WS-II; HQW, NSW, CA	4i

AU #	Waterbody	Area	Area Type	Classification	IR Cat
16-41-2-(9.5)	Morgan Creek (Morgan Creek Arm of New Hope River Arm of Jordan Lake)	836.3	FW Acres	WS-IV;NSW,CA	4i
Haw River Subbasin - Total Freshwater Acres		11,460 acres			
Haw River Subbasin - Total Freshwater Miles		11.3 miles			
Deep River Subbasin (HUC 03030003)					
17-(10.5)d1	DEEP RIVER – (from Haskett Creek to Gabriels Creek)	2.7	FW Miles	C	5
17-16-(1)a	Sandy Creek	16.1	FW Miles	WS-III	5
17-16-(1)b	Sandy Creek	19.3	FW Acres	WS-III	5
17-16-(3.5)	Sandy Creek (Ramseur water supply)	4.6	FW Acres	WS-III;CA	5
17-43-(1)b	Rocky River (Upper Reservoir)	3.9	FW Miles	WS-III	5
17-43-(5.5)a	Rocky River (Turner Reservoir)	15	FW Acres	WS-III;CA	5
17-43-(5.5)b	Rocky River (Turner Reservoir)	27	FW Acres	WS-III;CA	5
Deep River Subbasin - Total Freshwater Acres		65.9 acres			
Deep River Subbasin - Total Freshwater Miles		22.7 miles			
Upper Cape Fear River Subbasin (HUC 03030004)					
18-(5.5)a	Cape Fear River - Behind Buckhorn Dam (NC 42 to Dam)	121.9	FW Acres	WS-V	5
Lower Cape Fear River Subbasin (HUC 03030005)					
18-76-1	Greenfield Lake	75.3	FW Acres	C;Sw	5
Cape Fear River Basin - Total Freshwater Acres		11,723.6 acres			
Cape Fear River Basin - Total Freshwater Miles		34.0 miles			

Figure 2-40: Cape Fear River Basin Chlorophyll a Exceedance Rate by Station (Lakes Stations Not Included)

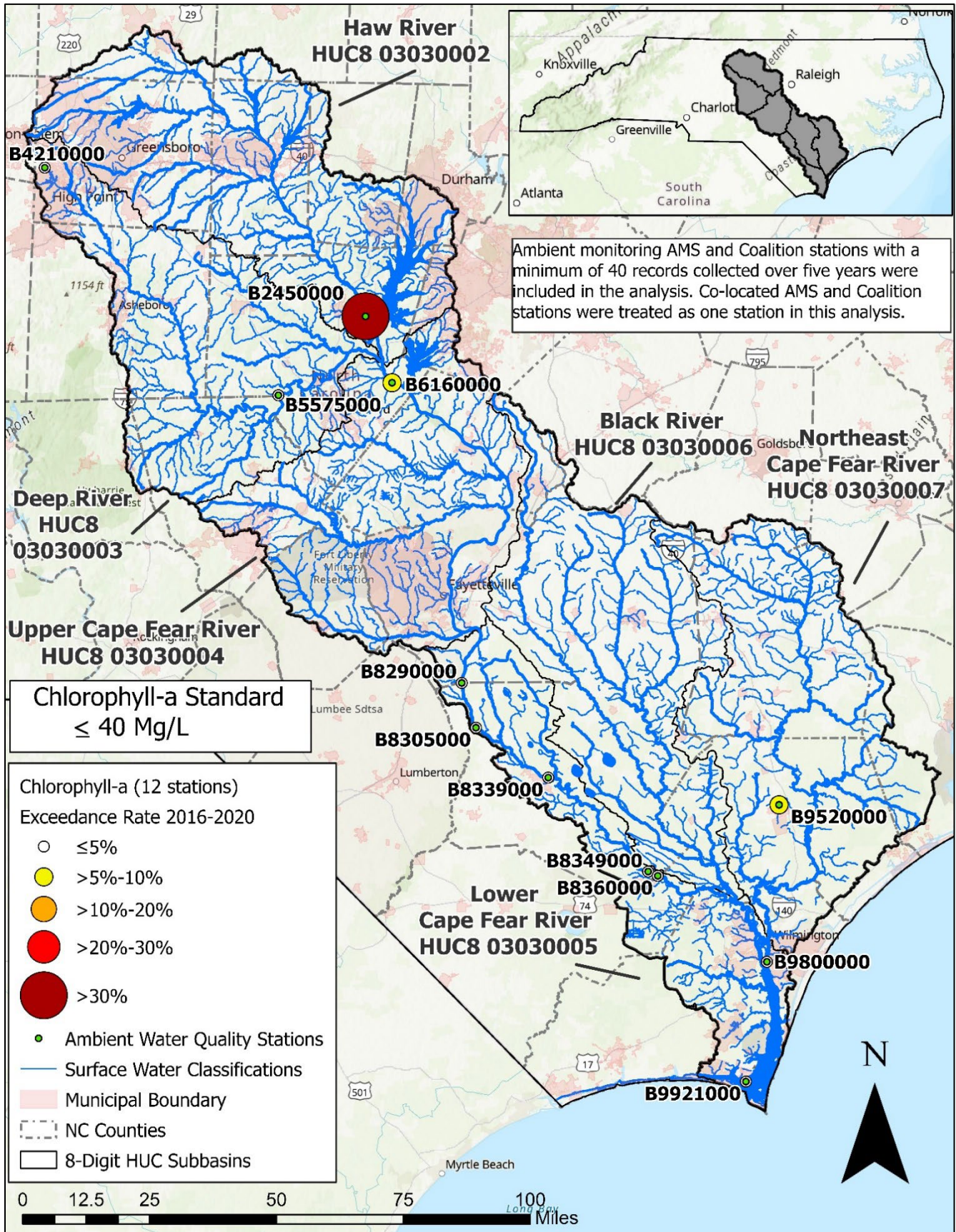
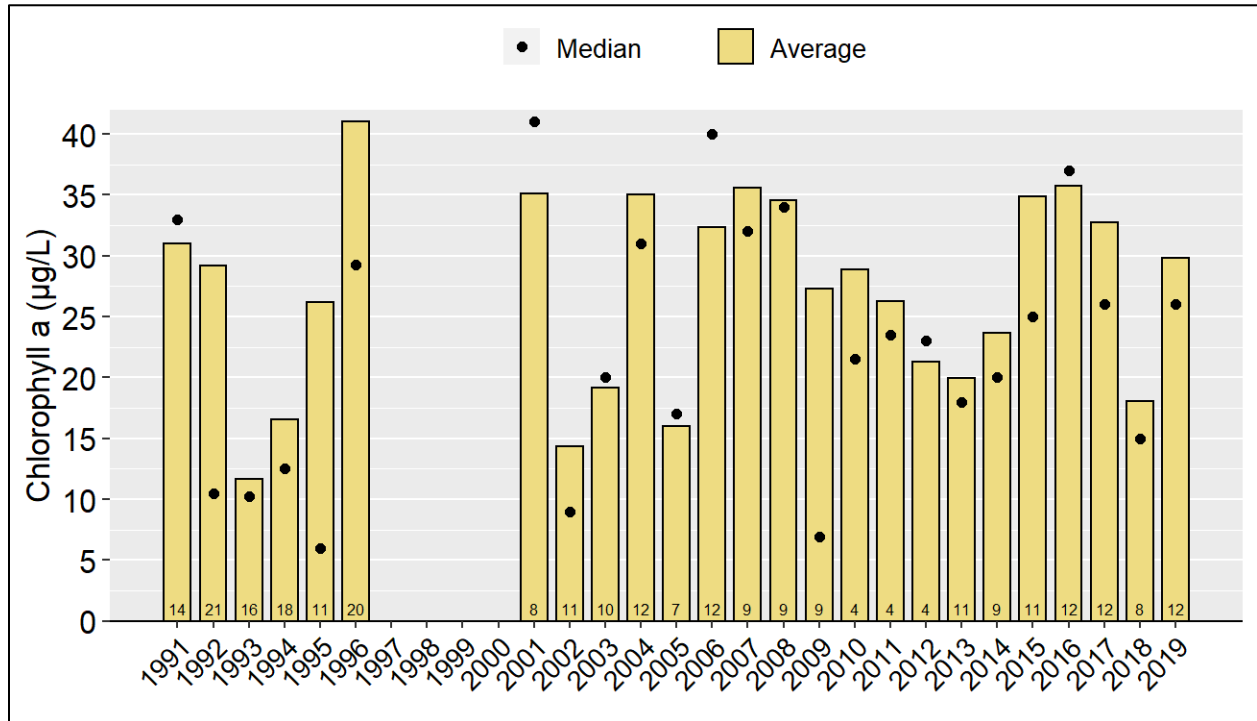


Figure 2-41: Chlorophyll *a* Mean Concentration for Station B2450000 on Robeson Creek Arm of Jordan Lake



The DWR AMS program and the monitoring coalitions collect monthly chlorophyll *a* samples at only 12 ambient water quality stations across the basin (Figure 2-40). There were exceedances at two stations that ranged between >5-10% (B6160000, Cape Fear River and B9520000, Burgaw Creek) and one station at >30%, B2450000, a station located on the Robeson Creek arm of Jordan Lake. The Robeson Creek station has a 28 square mile watershed that is nearly 75% forested and just 8% developed. There is one minor NPDES discharger for the Town of Pittsboro/Chatham Park Water Recovery Center permitted for 0.75 MGD located 3.3 miles upstream and about 50 acres of Residual Land Application and wastewater irrigation fields in the watershed above B2450000. Mean and median chlorophyll *a* levels from 1991 to 2019 have varied (Figure 2-41). There is a lot of new development beginning to occur in this watershed that will need to control runoff and limit nutrients from making their way to Robeson Creek. There are two EPA approved TMDLs in place to address excess nitrogen and phosphorus draining to this segment of the stream/lake. See the subbasin chapters for more information on the watershed issues impacting the elevated chlorophyll *a* concentration identified above.

2.5.8.2 *Historical Chlorophyll a Conditions*

The collection of chlorophyll *a* data has changed over the years and could impact the interpretation of how conditions in the Cape Fear River system have changed over time. DWR does not regularly collect chlorophyll *a* samples at most of the ambient monitoring stations in flowing river and streams because most algal species generally do not bloom in fast flowing river systems, even if sufficient nutrient concentrations are available. Up until the early 2000s, DWR generally used a grab sampling technique to assess chlorophyll *a* at most riverine stations (not including lakes and estuaries), especially when samples were taken from bridges or road crossings. A grab sample collection method generally requires the sample bottle to be filled about 0.15 meters below the water surface. When the Cape Fear River Basin coalitions formed in 1998, the sampling protocol for chlorophyll *a* required sampling only during the critical summer growing season and use of the grab sampling technique. This new coalition chlorophyll *a* data for several sections on the mainstem Cape Fear River, showed that algal blooms were forming in the surface waters during the critical growing season. The data was used for the 303(d) assessment which resulted in several mainstem segments of the Cape Fear River to be listed as impaired (exceeding the 40 µg/L chlorophyll *a* standard) due to high levels of chlorophyll *a* concentrations (*Table 2-13*). In November 2004, the coalition modified their memorandum of agreement (MOA) to allow for monthly year-round and depth integrated photic zone sampling. Depth integrated or photic zone composite samples are collected throughout the photic zone which is twice the Secchi depth.

Table 2-13: Historical Water Quality Impairment Status at Three Segments of the Cape Fear River

Integrated Report (IR) Year	Cape Fear River AU# 18-(4.5)	Cape Fear River AU# 18-(5.5)a	Cape Fear River AU# 18-(26.25)b [^]	IR Data Assessment Years
	B6160000*	CPFBDL2 [#]	B8290000 ⁺	
2006	Impaired	No Data	Impaired	2005 Basin Plan (9/1/98-8/31/2003)
2008	Impaired	No Data	Impaired	2002-2006 ¹
2010	Impaired	No Data	Supporting	2004-2008 ¹
2012	Impaired	Data Inconclusive	Supporting	2006-2010 ¹
2014 ²	Supporting	Data Inconclusive	Supporting	2008-2012
2016	Supporting	Impaired	Supporting	2010-2014
2018	Supporting	Impaired	Supporting	2012-2016
2020	Supporting	Impaired	Supporting	2014-2018
2022	Supporting	Impaired	Supporting	2016-2020

[^] Previously AU# was 18-(26)c;

* Middle Cape Fear River Basin Association Cape Fear River station B6160000 located at NC 42 near Corinth, upstream of Buckhorn Dam;

[#] DWR-Intensive Survey Branch, Lakes Ambient Monitoring Program station CFRBDL2 located in the Buckhorn Dam Lake upstream of dam;

⁺ Middle Cape Fear River Basin Association Cape Fear River station B8290000 located at Dupont water intake, upstream of LD3;

¹ No data available between June 2004 and April 2007.

² [New 2014 IR assessment method](#), added the use of 90% Statistical Confidence

At this same time, the analytical laboratories for several of the coalitions had analytical problems with the EPA approved chlorophyll *a* method, which was not discovered until mid-2007. As a result, data from June 2004 to April 2007 was considered highly suspect and not usable for use support purposes. Once the changes in monitoring frequency and sample depth took effect (also coincided with changes in the 2014 303(d) assessment method), several of the Cape Fear River segments were delisted (meeting criteria) (*Table 2-13*).

As discussed above, there are several factors in play that impact the overall chlorophyll *a* concentrations. Understanding the changes in the mainstem Cape Fear River algal bloom development using chlorophyll *a* concentrations as a surrogate is challenging due to the changes in sampling methods as well as due to the extreme climate variability over the last several decades. Ambient monitoring data, special studies and research study results presented below are beginning to provide some initial understanding of the different controlling factors influencing the algal responses throughout the Cape Fear River.

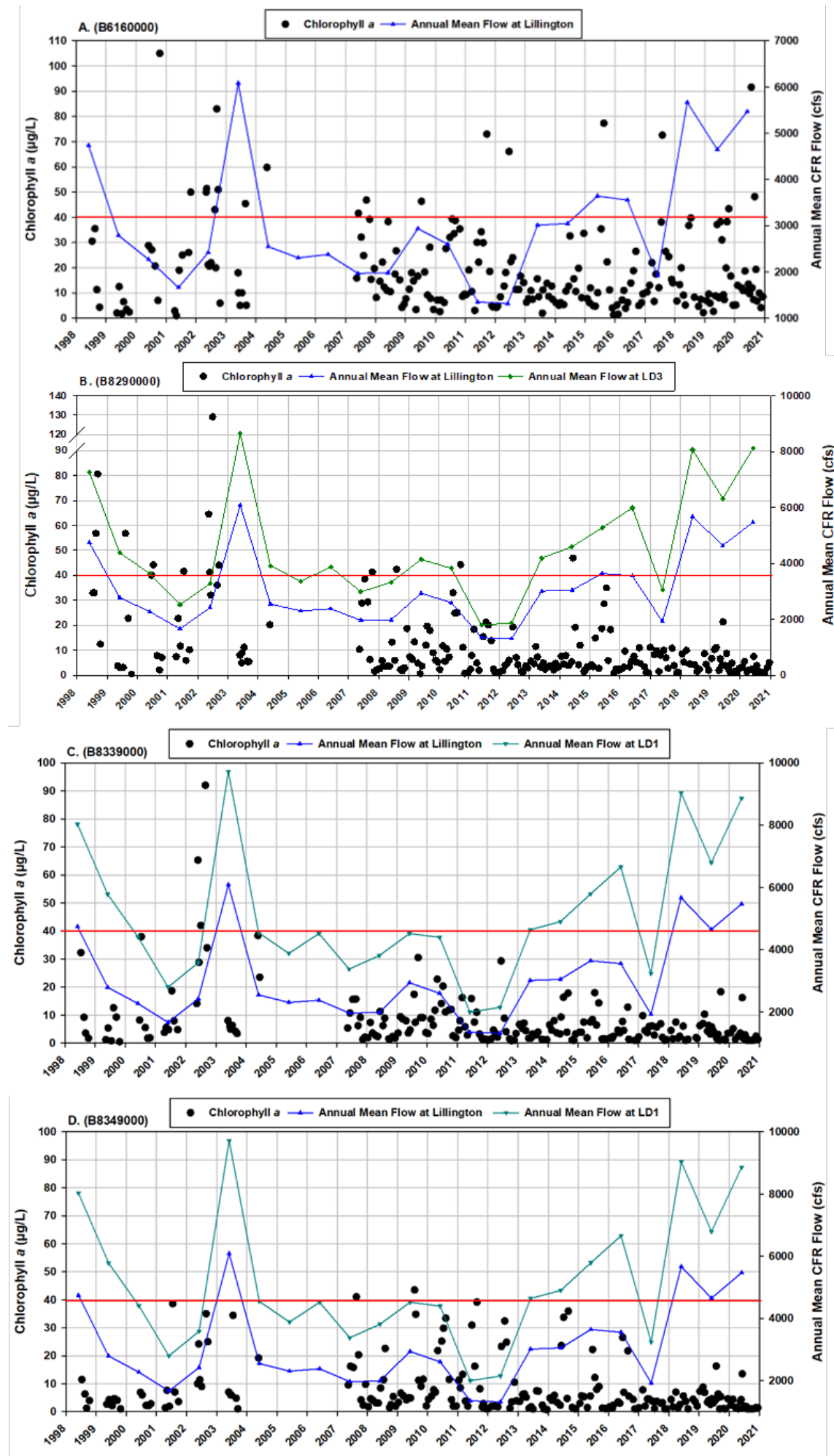
Four stations located in backwaters behind dams on the mainstem Cape Fear River are presented here for comparing concentrations over time (*Figure 2-42*).

- A. Upstream Cape Fear River station B6160000, located upstream of the Buckhorn Dam at NC 42 near Corinth [AU# 18-(4.5)],
- B. Middle Cape Fear River station B8290000, located upstream of LD3 at the Dupont water intake [AU# 18-(26.25)b,
- C. Middle Cape Fear River station B8339000, located upstream of LD2 near Elizabethtown [AU# 18-(26.75)b], and
- D. Lower freshwater portion of the Cape Fear River station B8349000, located upstream of LD1 near East Arcadia [AU# 18-(58.5)].

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 2-42*). The upper portion of the river is likely influenced by releases from Jordan Lake dam. This includes contributing nutrients, 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). The instream chlorophyll *a* concentrations often do not reflect the actual bloom conditions in the riverine system. The large blue-green algal blooms identified throughout much of the Cape Fear River mainstem in 2009-2012 are not captured by the chlorophyll *a* data collected as part of the routine ambient monitoring programs or even as part of the algal bloom responses. See details in the special study section below.

Figure 2-42 Chlorophyll a Concentration at Four Cape Fear River Mainstem Stations with Corresponding USGS Flow.

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.



This leads to several possible actions that may be needed in the Cape Fear River Basin including:

- Modification of the sampling techniques to capture actual instream conditions.
- Additional monitoring (parameters, frequency, spatial extent, large streams, small streams, bloom events, etc.).
- Instream nutrient criteria (nitrogen and phosphorus) as directed by EPA.
- Modification of the chlorophyll *a* criteria to better protect flowing riverine systems.
- Nutrient management strategy to reduce loading from all sources.
- Additional research on conditions influencing algal productivity and nutrient source identification.
- Support the TNC/ACOE 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.).

2.5.8.3 Special studies regarding algal bloom development in the Mainstem Cape Fear River

Since 2009, the area of the Cape Fear River from above Lock and Dam #3 (LD3) to Riegelwood, below Lock and Dam # 1 (LD1) has experienced potentially harmful blue-green (cyanobacteria) algal blooms consisting mainly of *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. The Department of Environmental Quality has published several press releases since 2009 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.

Several studies by university researchers and DWR have occurred in an attempt to understand the driving forces behind bloom development in this complex riverine system. Algal blooms were very persistent between 2009 and 2012, at one point impacting 75 miles of the Cape Fear River mainstem (7/22/2011 - 2012 Algal Summary Report in Chapter 2 Appendix). These Harmful Algal Blooms (HABs) have continued off and on when conditions allow. An algal bloom specific information will be provided in the Algal Bloom section of this chapter (see Section 2.7).

Prior to the unprecedented 2009 bloom, Whalen and Dubbs (2005) from UNC Chapel Hill studied the middle Cape Fear River (CFR) to understand phytoplankton ecosystem-level response to changes in nutrients and light. Their study utilized algal bioassays and reported several outcomes, including:

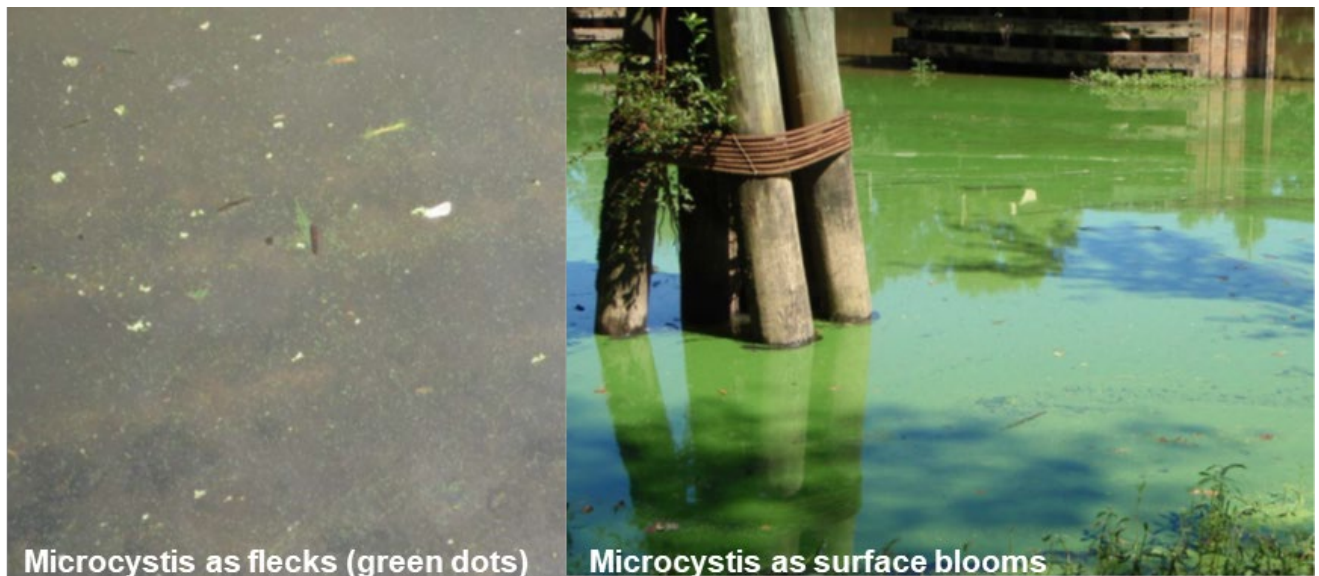
1. Dilution of *in situ* (instream) nutrient concentrations of up to 45% did not elicit any phytoplankton growth response in the middle CFR water under predominant environmental conditions, indicating that *in situ* nutrients are well in excess of phytoplankton growth requirements (nutrient-replete).
2. When the amount of light was increased above the average level normally experienced in the mixed water column of the middle CFR by a factor of four, nutrient assimilation and

phytoplankton productivity and biomass increased. Indicating that amount of light available is a controlling factor in phytoplankton productivity in the middle CFR system.

3. Water quality management decisions that may increase water clarity in the middle CFR should coincide with reductions in nitrogen loading to avoid exceeding chlorophyll *a* standards. Otherwise, decomposition of the increased phytoplankton biomass may reduce dissolved oxygen levels, which has been a cause for concern in the middle CFR in the past.

(Note: Study utilized water collected eight times between June 2002 and November 2003 from the middle Cape Fear River at two stations between LD2 and LD3 (Whalen and Dubbs, 2005).)

As a result of the severe *Microcystis* bloom which started in 2009 as surface flecks above LD1 and expanded to form an intensive surface bloom from above LD3 to below LD1 on the mainstem Cape Fear River, the Division conducted a special study in 2010 at 21 sites between July and October with the goal of understanding bloom development in this system, including species composition, magnitude, duration, and spatial extent (NCDENR, 2011). *Microcystis* surface blooms did occur in 2010 but not to the extent of those observed in 2009. The study documented algal blooms at 36 of the 97 site visits with blooms occurring in two main stretches of the river: 1) from the lower Haw River (below Jordan Lake dam) down to Buckhorn Dam and 2) from Fayetteville (above LD3) down to LD1 (near Riegelwood). The various hydrologic characteristics of the Cape Fear River appeared to be the predominate deterministic factors influencing the overall algal species composition and density patterns seen in 2010, primarily with high algal densities (blooms) forming in the impounded areas behind the dams and low algal densities in the free-flowing stretches of the river. Detailed results from this study will be discussed in the algal bloom section of this chapter (NCDENR, 2011).



Microcystis as flecks (green dots)

Microcystis as surface blooms

In the 2010 study, only the stations upstream of Buckhorn dam exceeded the chlorophyll *a* standard even though algal counts were categorized as severe or extreme. The highest recorded chlorophyll reading between LD3 and LD1 was 39 µg/L with an algal bloom count of 95,800 cells/mL of *Staurosira* (diatom; on 9/23/10).

The report concluded that “although the exact environmental cue(s) that triggered the *Microcystis aeruginosa* surface blooms in 2009 were not determined, the optimal environmental conditions and nutrient rich warm waters were likely contributing factors.”

The 2010 study collected ambient water quality data on the Cape Fear River from behind Buckhorn dam and found that three of the five samples collected were above the 40 µg/L standard with an overall average concentration of 41.8 µg/L (*Table 2-14*). Due to the high chlorophyll *a* concentrations found in 2010, this section of the Cape Fear River was added to the Ambient Lakes Monitoring Program assessment in 2013 and 2018 (*Table 2-14*).

Table 2-14: Chlorophyll a Concentrations at Station CPFBDL2 on the Cape Fear River Behind Buckhorn Dam with Corresponding 1-Day and 7-Day Average Flow at Lillington USGS Gage 02102500.

Sample Date	Chlorophyll <i>a</i> (µg/L)	1-Day Average Flow (cfs)*	7-Day Average Flow (cfs)^
7/19/2010	32	691	673
8/12/2010	48	596	594
8/30/2010	45	628	908
9/23/2010	46	502	548
10/21/2010	38	621	597
5/22/2013	4	6,000	2,324
6/24/2013	22	1,480	3,014
7/22/2013	11	1,920	5,183
8/27/2013	14	996	4,042
9/30/2013	48	564	608
5/1/2018	5	6,180	8,911
6/11/2018	20	872	869
7/16/2018	20	561	597
8/28/2018	12	967	4,469

*Corresponding daily average USGS flow at Lillington USGS gage 0210500

^ Corresponding previous 7-day average USGS flow at Lillington USGS gage 0210500 (average of the 7 individual daily averages).

The additional data collected in 2013 resulted in Cape Fear River behind Buckhorn Dam [AU# 18-(5.5)a] being added to the 2016 303(d) list of impaired waters (*Table 2-13*). Forty percent of the samples exceeded the standard, and the two-year chlorophyll *a* average was 30.8 µg/L. The three-year dataset showed a fairly clear pattern: when the flow of the Cape Fear River drops below about 900 cfs at the Lillington USGS flow gage for an extended period of time, algae will likely bloom if the other environmental controlling factors are suitable (such as temperature, light and nutrients). It is important to understand that the non-drought period low flow target at Lillington is 600 cfs (± 50 cfs). The flow target at Lillington is met from flows out of the Deep River and releases from Jordan Lake by the USACE.

A 2016 DWR assessment looked at how chlorophyll *a* concentration corresponded to river flows at two mainstem Cape Fear River locations behind LD1 (B8349000; USGS gage 02105769) and LD3 (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 (*Table 2-15*). 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 has changed over the years). The flow statistics for this assessment were based on USGS flow gage records for 1/1/1983-8/7/2016.

Elevated chlorophyll *a* concentrations generally occur during lower-flow conditions at these two stations on the Cape Fear River (*Table 2-16* and *Figure 2-43*). At LD3 in the middle portion of the Cape Fear River above Tar Heel, NC, corresponding chlorophyll *a* and flow data show that algal productivity resulting in a chlorophyll *a* concentration of 20 µg/L or greater can develop at flows less than about 2,300 cfs, which occurred about 51% of the time (*Table 2-16* and *Figure 2-43*). Chlorophyll *a* concentration of 30 µg/L or greater occurred at flows below 1,900 cfs with the majority of the elevated chlorophyll *a* concentrations occurring historically at stream flows below 1,450 cfs, occurring about 34% of the time (*Table 2-16* and *Figure 2-43*).

At LD1 (near Riegelwood, NC), river flow below 1,650 cfs, which occurred 35% of the time can result in chlorophyll *a* concentrations of 20 µg/L or more and river flow below 1,250 cfs, which occurred 21% of the time, can result in chlorophyll *a* concentrations of 30 µg/L or more (*Table 2-16* and *Figure 2-43*).

The physical river conditions in the Cape Fear River near Lillington, NC (flowing river/lotic ecosystem) generally do not allow for the development of significant algal growth unlike the more lake-like (lentic) conditions behind the locks and dams. The ambient monitoring programs do not collect chlorophyll *a* at most free-flowing riverine stations throughout the state due to the limited ability of planktonic (free floating) algal growth due to physical constraints on the ability to grow and concentrate overtime, even at flows similar to the areas behind the dams (*Table 2-15*). In many of these systems, periphyton growth is common. Periphyton is a complex community of algae, bacteria, fungi, and detritus that is attached to submerged surfaces. This submerged ecosystem is essential to support a viable aquatic habitat, however like algae, periphyton can also grow out of control when the system is out of balance. The result is often overgrowth due to outside influences like excess nutrients and changes in the physical conditions like a

dam or reservoir. DWR does not currently monitor or have an instream standard for periphytic growth. Excess algal growth whether planktonic or attached to subsurface structures has been identified as an issue in the Cape Fear River Basin, particularly in the upper and middle portions of the Cape Fear River Basin. Due to these concerns and the increasing watershed development pressures which will continue to impact the water quality, the Cape Fear River was chosen as the flowing river/streams pilot watershed to develop instream nutrient criteria as part of the EPA required Nutrient Criteria Development Plan (NCDP) process. For more information on the NCDP see section 2.13 below.

Table 2-15: Streamflow Statistics for Three Mainstem Cape Fear River USGS Stations.

USGS Flow Gage #	Flow Gage Location	Water Quality Station* #	Low Flows (cfs)	Mid Flows (cfs)	High Flows (cfs)	Lowest Flow (cfs) Date	Highest Flow (cfs) Date	Climate Year 7Q10+ (cfs)
02102500	Lillington	B6370000	< 663	663-3,490	>3490	155 8/6/2002	41,400 9/6/1996	342
02105500	L&D 3/ Tarheel	B8290000	<1,210	1,210-5,210	>5,210	154 8/13/1999	79,400 12/25/2015	520
02105769	L&D 1/ Kelly	B8349000	<1,360	1,360-6,360	>6,360	31 11/4/2012	47,600 9/11/1996	324

Flow statistic for 1/1/1983-8/7/2016;

*All three stations are in WS-IV classified waters (Water Supply-IV) and collected by the Middle Cape Fear Basin Association monitoring coalition; Station B6370000 co-located with DWR ambient monitoring program. Flow statistics was done using DWR-WRISAR database. Stream flow was separated into three categories 1.) Low-flows, the bottom 25th percentile flows; 2.) Mid-flows based on flows between the 25th and 75th percentile; and 3.) High-flows based on greater than the 75th percentile of river flow between 1/1/1983 (post Jordan Lake impoundment) through 8/7/2016 (time of assessment).

+ 7Q10 calculation is based on Climate Year 1983 – 2016 (April – March).

cfs = cubic feet per second.

Table 2-16: Historical Cape Fear River Streamflows Which Limit Algal Productivity Behind Lock and Dam #1 and #3 (LD1 & LD3) 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.

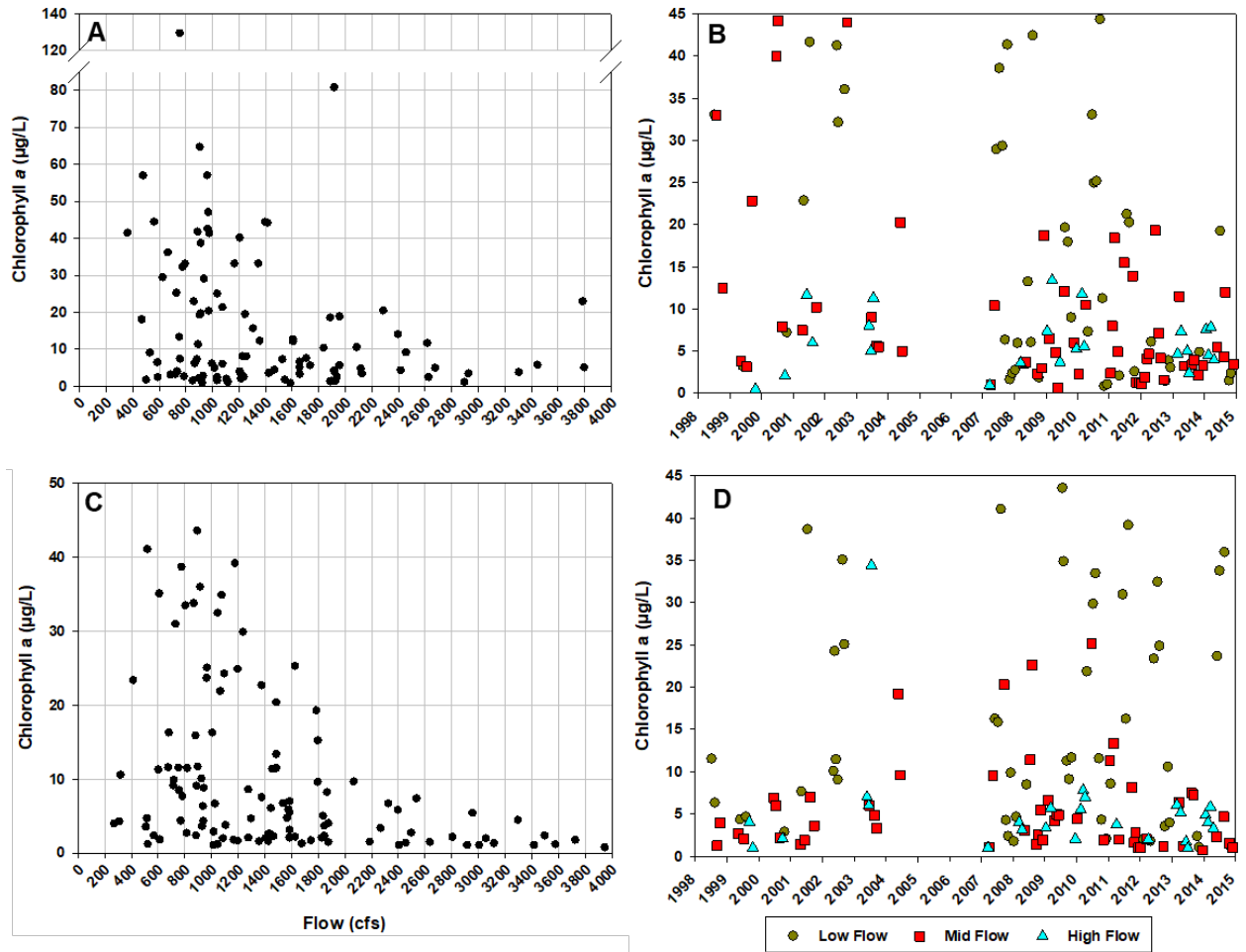
Dr. Nathan Hall from UNC Institute of Marine Science (IMS) has been working with The Nature Conservancy (TNC) and other university researchers over the past several years to understand how the Cape Fear River flow is influencing algal bloom formation. It has been recognized that “harmful toxigenic blooms of cyanobacteria, *Microcystis sp.* have become common during summertime along the Cape Fear River from Fayetteville to LD1” (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 above study’s findings 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. It is recommended that DWR work with researchers to review current SOPs for monitoring Cape Fear River algal blooms and monthly routine monitoring. 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 is whether chlorophyll *a* is 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?

Over the last twenty plus 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. We continue to work with researchers and stakeholders to understand this system and will work with the NCDP Science Advisory Council to develop instream criteria that makes it possible to accurately assess the health of this important resource. These efforts are critical as our state continues to grow, increasing the need for more clean water for communities and industries in this basin.

Figure 2-43: 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) (LD1).



Note: Flow statistics was done using DWR-WRISAR database. Stream flow was separated into three categories: 1.) Low-flows, the bottom 25th percentile flows; 2.) Mid-flows based on flows between the 25th and 75th percentile; and 3.) High-flows based on greater than the 75th 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.

2.5.9 Metals

Some metals can have a negative impact upon both human and aquatic life. Some organic metals (i.e., methylmercury) can build up (bioaccumulate) in the fatty tissue of fish by uptake through the food chain, making them potentially unsafe for human consumption. For aquatic organisms, metals in surface waters can have chronic, sublethal effects on neurological and respiratory systems. A variety of water quality characteristics including dissolved and particulate organic carbon, pH and hardness affect the availability of metals and their subsequent impacts upon aquatic life (Bergman and Dorward-King, 1997). Metals can enter surface waters through industrial and wastewater point source dischargers and atmospheric deposition.

North Carolina adopted new numerical water quality standards in 2014 for several metals including dissolved metal standards for Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Nickel, Silver, and Zinc and total metal standards for Mercury and Selenium ([15A NCAC 02B .0211](#)). These metals vary in toxicity because of their chemical form, solubility, stream characteristics and/or associated waste characteristics. Thirty AMS stations were pilot tested using the new metal standards in 2015 including eight stations in the Cape Fear River Basin, six AMS and two LCFRBA. The pilot study continued to 2018 and 29 additional stations, including five in the Cape Fear that were previously impaired for metals, were added. The reintroduction of routine metal monitoring with the new dissolved metals standard is highly important for the AMS program and will enable DWR to better understand the impact metals are having on aquatic environments.

As of 2022 there are several old total metals impairments for copper, nickel, and zinc and just two dissolved metal impairments for copper. Both are from RAMs station sampling, one in 2007-2008 along the UT to Locks Creek in Upper Cape Fear River subbasin and the other more recent one on Panther Creek from sampling in 2017-2018 in the Haw River subbasin. The UT to Locks Creek station was resampled in 2015-2016 during the dissolved metals pilot study which resulted in that waterbody remaining impaired.

2.6 Lakes Monitoring Data

Lakes are valued for the multiple benefits they provide to the public, including recreational boating, fishing, drinking water, and aesthetic enjoyment. Cape Fear lakes and reservoirs serve a variety of purposes including water supply, flood control, hydropower, cooling water source, recreation, and aquatic habitat. The WSS [Intensive Survey Branch \(ISB\)](#) collects and interprets biological, chemical, and physical data from North Carolina's lakes for the [Ambient Lakes Monitoring Program \(ALMP\)](#), lake TMDL studies, and other special studies or intensive surveys. The program monitors lakes that are greater than 10 acres, are accessible to the public, and are used for water supply and/or significant recreation, as well as other lakes that may have been requested due to certain characteristics or water quality issues. The [ALMP](#) originated under the EPA's Clean Lakes Program and was designed to identify long-term water quality trends in North Carolina's lakes and reservoirs.

The ambient monitoring data collected from lakes and reservoirs are used to calculate the state of nutrient enrichment (trophic state) and determine if the lake is meeting its designated use. The trophic state is a relative description of the biological productivity of a lake based on the calculated North Carolina Trophic State Index (NCTSI) value. The NCTSI was specifically developed for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (1982). The index accounts for nutrients along with chlorophyll *a* concentrations and Secchi depth to calculate the lake's biological productivity. Trophic states can range from extremely productive (hypereutrophic) to very low productivity (oligotrophic). Several lakes in the Cape Fear River Basin are also dystrophic, these lakes contain high amounts of humic substances and organic acids. Dystrophic lakes have characteristic tea-coloration naturally influenced by tannins. NCTSI are not generated for dystrophic lakes. Generally, lakes are monitored monthly from May through September on the same 5-year monitoring cycle as the biological sampling. The number of stations in each lake varies based on the size and characteristics of the lake and purpose of the study. In the Cape Fear River Basin 35 lakes and reservoirs were monitored between 2008 and 2018. The last basinwide assessment was in 2023 with 32 lakes monitored. The 2023 lakes data was not available at the time this plan was written. The [2023 Cape Fear River Basin Lake and Reservoir Assessment Report](#) can be found here and future report can be found on the [WSS Basinwide Assessment Reports website](#).

Table 2-17 shows the 2008, 2013, and 2018 trophic status results for the Cape Fear River Basin lakes and reservoirs and the current impairments as per the 2022 Integrated Report (also see Section 2.7 Algal Assessment Program). *Table 2-17* also shows algal bloom criteria information described in the next section. Some lakes and reservoirs were not monitored every cycle. *Figure 2-44* displays the location and current trophic status of the Cape Fear River Basin lakes and reservoirs that were monitored from 2008 to 2018. The most current trophic status for 26 of the 35 lakes and reservoirs was eutrophic, indicating elevated biological activity. Two reservoirs rated hypereutrophic due to exhibiting exceptionally elevated biological productivity, Rocky River (upper reservoir) and Charles L. Turner (formerly the Lower Rocky River Reservoir), both located in the Deep River subbasin along the Rocky River. Two other reservoirs in the Upper Cape Fear River subbasin, Kornbow and Old Town, rated mesotrophic, indicating moderate biological productivity, although Kornbow Lake has not been monitored since 2008. Several of the Cape Fear River Basin's unique bay lakes, Salters, Jones, Bay Tree, and Singletary, and Boiling Springs Lake, all

located in the lower part of the basin, are considered dystrophic and not assigned a NCTSI score. See chapter 1 for additional information on bay lakes.

In 2022, 10 lakes and reservoirs in the Cape Fear River Basin had impairments for chlorophyll *a*, turbidity, and or pH. Eight of the 10 lakes and reservoirs had chlorophyll *a* impairments, with three located in the Haw River subbasin (Jordan, Graham-Mebane, and University) and three located in the Deep River subbasin (Rocky River, Charles Turner, and Sandy Creek), including the two hypereutrophic reservoirs. Buckhorn Dam is located on the mainstem Cape Fear River in the Upper Cape Fear River Subbasin and is described in detail in section 2.5.8. Greenfield Lake in Wilmington located in the Lower Cape Fear River subbasin was also impaired for chlorophyll *a*. Two reservoirs in the Haw River subbasin had turbidity impairments, Jordan, and Graham-Mebane, and three lakes and reservoirs had pH impairments, Jordan Lake and two of the dystrophic bay lakes, Jones and Singletary.

Several of the impaired lakes and reservoirs in this basin have a TMDL (Category 4), including Jordan Lake, the only lake impaired for all three parameters. A Jordan Lake watershed-wide nutrient management strategy was developed based on reductions in both total nitrogen and total phosphorus from point and nonpoint sources. The Jordan Lake watershed encompasses 1,686 square miles and consists of two distinct arms and three distinct management areas, the Haw River arm and the Upper and Lower New Hope arms. Actions taken to improve water quality in Jordan Lake will result in improved local water quality conditions throughout the entire watershed and will address the chlorophyll *a* impairments in Graham-Mebane and University Lake as well. DWR is implementing a collaborative public involvement process to rethink and revise the nutrient management strategy for the Jordan Lake watershed. For more information on Jordan Lake, the nutrient management strategy and the rules readoption process, see Chapter 6 sections 6.6.6.8 and 6.6.6.9 or go the [NPS Jordan Lake website](#).

White Lake, the only lake in the basin that has changed from oligotrophic to eutrophic during the time-period of this plan, is of particular concern as water quality in the once crystal-clear lake has been declining. White Lake, located in the Lower Cape Fear River subbasin in Bladen County, is an unusual Carolina Bay Lake in that the water is clear, rather than tea-colored, due to numerous springs at the bottom of the lake. The clear water has made it a popular recreation and tourist destination for years and an important resource for the local economy. Monitoring data indicates the lakes pH has changed from acidic to near neutral, nutrient, turbidity, and chlorophyll *a* levels have increased, and algal communities have changed from green to blue-green dominated. 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. White Lake has also had recent fish kills (Section 2.9) and algal blooms (also see Section 2.7 and Chapter 9). See Chapter 9 for more information on White Lake.

More information the Cape Fear River Basin's lakes and reservoirs can be found in the subbasin chapters and the [2008](#), [2013](#), and [2018](#) Lake and Reservoir Assessments for the Cape Fear River Basin.

Table 2-17: Cape Fear River Basin Lake Monitoring 2008-2018 Trophic State, 2020 IR Impairments and Parameters Indicating Elevated Algal Productivity in 2018 Lakes Assessment Phytoplankton Samples

Lake / Reservoir Name	Trophic Status			2022IR Impairments (Cat 4 and 5)	2018 Algal Bloom Criteria Exceeded		
	2008	2013	2018		Chl <i>a</i>	Unit Density	Bio-Volume
Haw River (HUC8 03030002)							
B. Everett Jordan Reservoir ¹	Eutrophic	Eutrophic	Eutrophic	Turbidity Chlorophyll <i>a</i> pH	√	√	√
Buckhorn Dam Lake	X	Eutrophic	Eutrophic	Chlorophyll <i>a</i>		√	√
Cane Creek Reservoir	Eutrophic	Eutrophic	Eutrophic	X	√	√	√
Graham-Mebane Reservoir ²	Eutrophic	Eutrophic	Eutrophic	Chlorophyll <i>a</i> Turbidity	√	√	√
Lake Brandt	Eutrophic	Eutrophic	Eutrophic	X		√	
Lake Burlington (Stony Creek)	Eutrophic	Eutrophic	Eutrophic	X		√	√
Lake Higgins	Eutrophic	Eutrophic	Eutrophic	X		√	√
Lake Hunt	Eutrophic	Eutrophic	Eutrophic	X		√	√
Lake Mackintosh	Eutrophic	Eutrophic	Eutrophic	X		√	√
Lake Townsend	Eutrophic	Eutrophic	Eutrophic	X	√	√	
Reidsville Lake	Mesotrophic	Eutrophic	Eutrophic	X		√	
Stony Creek Reservoir (Stony Creek)	Eutrophic	Eutrophic	Eutrophic	X		√	√
University Lake ²	Eutrophic	Eutrophic	Eutrophic	Chlorophyll <i>a</i>	√	√	√
Deep River (HUC8 03030003)							
High Point Lake	Eutrophic	Eutrophic	Eutrophic	X	√	√	√
Oak Hollow Lake	Eutrophic	Eutrophic	Eutrophic	X	√	√	√
Randleman Lake	Eutrophic	Eutrophic	Eutrophic	X		√	√
Rocky River Reservoir	Hypertrophic	Hypertrophic	Hypertrophic	Chlorophyll <i>a</i>	√	√	√
Sandy Creek Reservoir	Eutrophic	Eutrophic	Eutrophic	Chlorophyll <i>a</i>	√	√	√
Charles L. Turner Reservoir	X	Hypertrophic	Hypertrophic	Chlorophyll <i>a</i>	√	√	√
Upper Cape Fear River (HUC8 03030004)							
Bonnie Doone Lake ³	Mesotrophic/ Eutrophic	Eutrophic	X	X	na	na	na
Carthage City Lake	X	Eutrophic	Eutrophic	X		√	
Glenville Lake	Eutrophic	Eutrophic	Eutrophic	X	√	√	√
Harris Lake	Eutrophic	Eutrophic	Eutrophic	X	√	√	√

Lake / Reservoir Name	Trophic Status			2022IR Impairments (Cat 4 and 5)	2018 Algal Bloom Criteria Exceeded		
	2008	2013	2018		Chl <i>a</i>	Unit Density	Bio-Volume
Kornbow Lake	Mesotrophic	X	X	X	na	na	na
Mintz Pond	Eutrophic	Eutrophic	X	X	na	na	na
Old Town Reservoir	Mesotrophic	Eutrophic	Mesotrophic	X		√	√
Lower Cape Fear River (HUC 03030005)							
Boiling Springs Lake	Dystrophic	Dystrophic	Dystrophic	X			
Greenfield Lake	X	Eutrophic	Eutrophic	Chlorophyll <i>a</i>	√	√	√
Jones Lake	Dystrophic	Dystrophic	Dystrophic	pH	√	√	√
Salters Lake	Dystrophic	Dystrophic	Dystrophic	X			√
Sutton Lake	X	X	Eutrophic	X		√	√
White Lake	Oligotrophic	Mesotrophic	Eutrophic	X		√	√
Black River (HUC8 03030006)							
Bay Tree Lake	Dystrophic	Dystrophic	Dystrophic	X			
Singleary Lake	Dystrophic	Dystrophic	Dystrophic	pH		√	√
Northeast Cape Fear River (HUC8 03030007)							
Cabin Lake (Limestone Lake)	Hypertrophic	Hypertrophic	Eutrophic	X	√		√

¹Jordan Lake also has a TMDL for TSS, total phosphorous and total nitrogen.

²Graham-Mebane Reservoir and University Lake also have a TMDL for total phosphorous and total nitrogen.

³Bonnie Doone Lake was only monitored for two months in 2008, rating mesotrophic in June and eutrophic in July so an overall yearly status was not assigned.

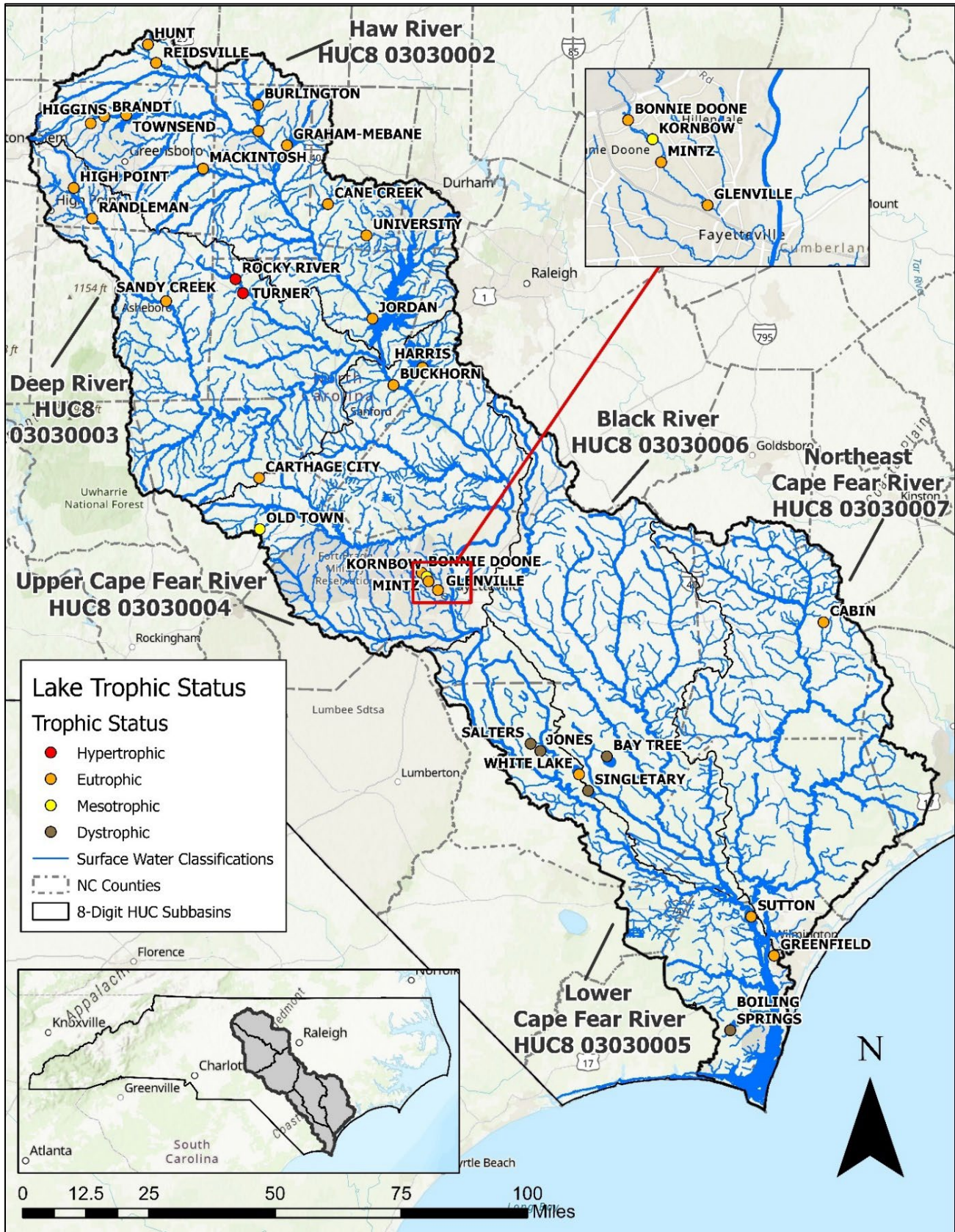
⁴Lakes and Reservoirs may be partially or entirely impaired, **Category 4** – Impairments have a TMDL; **Category 5** Impairments do not have a TMDL and are 303D listed.

√ - Parameter exceeding algal bloom productivity threshold (See Algal Assessment Program Section).

na – not available; Lake not monitored in 2018.

2023 updated/amended trophic status table can be found in the appendix.

Figure 2-44: Cape Fear River Basin Lakes and Reservoirs Trophic Status



2.7 Algal Assessment Program

The [Algal Assessment Program](#) (AAP) provides support for the Ambient Monitoring System (AMS), Ambient Lakes Monitoring System (ALMS), Planning Section, and Regional Office staff in the analysis of algal assemblages. Two types of evaluations are performed by the program: episodic and routine. Samples for episodic evaluations are collected in response to specific events such as fish kills, algal blooms, and nuisance algal growth. Routine evaluations are targeted studies of specific waterbodies of interest and are generally performed in cooperation with other DWR programs. Routine evaluations are conducted to assess changes in algal assemblages over time and are often focused on estuarine systems where there are known issues of nutrient enrichment and have had frequent algal blooms or fish kills. The AAP also supports routine algal monitoring as part of the ALMP basinwide assessment (One growing season assessment every five years) and special studies undertaken by the DWR.

Algae form the basis of most aquatic food webs and are found in all waterbodies. They range from single-celled microscopic organisms to easily visible seaweed and do not form stems, leaves, or flowers like other plant species. The “growth form” for freshwater algae are unicellular (single celled), filamentous (a chain of cells), or colonial (tight groups of cells). Algal samples are quantified by counting each individual growth form, referred to as a “unit” and expressed as “unit density” (units per volume). Algal samples are also quantified using biovolume which is expressed as the volume of the algal cells or units per volume of sample water (mm^3/m^3).

**IN NORTH CAROLINA,
THERE IS A GROWING
CONCERN ABOUT THE
NUMBER OF
CYANOBACTERIAL
BLOOMS (COMMONLY
CALLED BLUE-GREEN
ALGAE) OCCURRING
ACROSS THE STATE.**

AAP works with three main forms of algae when evaluating algal blooms: phytoplankton, filamentous, and periphyton algae. Phytoplankton are found suspended in the water column and can cause water to become discolored or create visible swirls/clumps on the surface. This type of algae is the most common cause of algal bloom investigations. Long strands of filamentous algae can be found on the bottom of the waterbody or detached and floating on the surface. Periphyton algae grow attached to hard substrates like rocks, or wood.

Algae are responsive to the physical and chemical conditions in the aquatic environment. Algal blooms occur when favorable conditions exist, such as optimal temperatures, sufficient nutrients, and static or stable waterbodies which allow for accumulation of algal biomass. The physical and chemical conditions that affect algal blooms within the Cape Fear River mainstem are discussed in detail in the chlorophyll *a* section (2.5.8) above.

In North Carolina, there is a growing concern about the number of cyanobacterial blooms (commonly called blue-green algae) occurring across the state. Under the right conditions, some species of cyanobacteria can produce toxins, which presents a potential health risk to humans and animals that come into contact with an affected waterbody. As such, blooms that are dominated by algae that can produce toxins or cause other negative water quality effects (including cyanobacteria) are designated as “potentially” harmful algal blooms (HABs). The AAP/ALMP tests water samples for microcystin, which is one of the most common and well-studied cyanotoxins. Algal blooms are of most concern in drinking

water supplies, reservoirs, impoundments, and slow-moving/flushing estuaries. Even if a bloom is caused by a non toxic-producing algae, it can cause taste and odor problems, water discoloration, form large mats which can interfere with boating, swimming, and fishing, and can be associated with fish kills and decreased biodiversity.

2.7.1 2018 Ambient Lakes Monitoring Program Algal Assessment

As part of the 2018 ALMP, monthly phytoplankton sampling was conducted at 47 ambient monitoring stations across 32 lakes between the months of May and September. To maintain a baseline dataset, at least one station on each lake monitored by the ALMP was sampled for phytoplankton. Multiple monitoring stations were selected for large reservoirs, especially those historically prone to cyanobacterial blooms. Station selection was prioritized to characterize areas at greatest risk from cyanobacterial blooms. Higher priority was given to stations with proximity to drinking water intakes, public access areas (boat ramps, beaches, marinas) and stations with historically high algal densities.

Phytoplankton were collected as depth-integrated samples within the photic zone (twice the Secchi depth). Phytoplankton samples were preserved with Lugol’s solution immediately after collection. There is no universal definition or threshold for what constitutes an algal bloom. The Algal Assessment program uses the North Carolina Trophic State Index (NCTSI) and measures of chlorophyll *a*, phytoplankton unit density and biovolume to evaluate algal productivity in a waterbody.

Parameters	Algal Bloom Criteria
Trophic State	Eutrophic/Hypereutrophic
Chlorophyll <i>a</i>	≥ 40 ug/L
Phytoplankton Unit Density	≥ 10,000 units/mL
Phytoplankton Biovolume	≥ 5,000 mm ³ /m ³

Each lake’s trophic state was calculated by averaging the NCTSI scores from all stations between the months of May and September. Chlorophyll *a* can be used to estimate the abundance of phytoplankton within the photic zone. North Carolina has set a state water quality standard of 40 ug/L for chlorophyll *a*. The AAP has also established a phytoplankton unit density ≥ 10,000 units/mL and/or biovolume ≥ 5,000 mm³/m³ as thresholds indicating elevated algal productivity. The 2018 lakes algal productivity are summarized in the previous Section 2.6, *Table 2-17*.

The majority of the 32 lakes monitored in 2018 received a trophic designation of eutrophic (75%). Of the remaining lakes, 6.3% were categorized as hypereutrophic, 3.1% as mesotrophic and 15.6% as dystrophic. The trophic status for most lakes remained unchanged between 2013 and 2018 with the exception of White Lake which increased from mesotrophic to eutrophic and Old Town Reservoir which decreased from eutrophic to mesotrophic (*Table 2-17*). Chlorophyll *a* criterion was the most conservative metric for indicating elevated algal productivity, with 15 lakes exceeding the state’s chlorophyll *a* standard on at least one occasion. Unit density and biovolume were less conservative with 28 and 27 lakes identified as exceeding each threshold respectively (*Table 2-17*).

As part of the 2018 Cape Fear River Basin lakes assessment, ALMP not only collected samples for phytoplankton speciation and bloom identification, but samples were also taken to test for the presence of microcystin, one of the most commonly found cyanotoxins. Microcystin toxin was present in the Cape Fear River during the 2009 blue-green algal blooms. The only detectable concentration of microcystin cyanotoxin taken as part of the 2018 study was found in a single sample from Oak Hollow on August 22, 2018. The concentration was found to be just above the detection limit of 0.4 µg/L. The potential toxin producing blue-green algal species identified in the sample were *Microcystis* and *Dolichospermum*. The overall algal count for this sample was 18,845 units/mL (biovolume was 4,400 mm³/m³) however, the density of the two potentially toxic blue-green species was only 63 units/mL for each species. All the other samples collected as part of the 2018 lakes assessment were below the detection limit of 0.4 µg/L. The EPA recommended microcystin human health recreational ambient water quality criteria is 8.0 µg/L (see [EPA CyanoHABs](#) website for more information).

Other finding from the 2018 assessment include:

- 30 lakes exceeded at least one of the algal bloom criteria during at least one sampling event ([Table 2-17](#)).
- 23 lakes experienced a cyanobacterial “bloom” during at least one sampling event (graph below).
- 13 lakes experienced dominance by a known toxigenic alga during at least one sampling event (graph below).
- Most common “dominant” toxigenic algal species was *Cylindrospermopsis*, typically in mid-late summer.
- Early summer toxigenic blooms were rare but were almost exclusively dominated by *Aphanizomenon* and *Dolichospermum*.

AAP produced an overall algal bloom table which provides a simple overview of the potential cyanotoxin risk associated with the blue-green/cyanobacteria species identified during the 2018 growing season. The orange blocks indicate when the algal bloom in a specific lake was dominated by cyanobacteria and the red blocks are associated with cyanobacteria species known to potentially produce cyanotoxins such as microcystin and cylindrospermopsin ([Table 2-18](#)). As stated above, only a single sample collected in August from Oak Hollow had any detectable microcystin at a very low concentration. Microcystin is the only cyanotoxin AAP is currently able to monitor for. When resources allow, AAP is hoping to expand their program to monitor for other potential cyanotoxins. Given the occurrences of cyanobacteria blooms dominated by known toxin producers, it is recommended that DWR prioritize growing this program as resources allow.

Table 2-18: Cape Fear River Basin 2018 Risk Cyanotoxin Risk Table

Waterbody	May	June	July	Aug	Sept
Baytree Lake					
Boiling Springs Lake					Black
Buckhorn Dam Lake		Yellow	Red	Orange	
Cabin Lake					Yellow
Cane Creek	Red		Red	Orange	
Carthage City		Yellow	Yellow		Black
Glenville Lake	Yellow		Orange		
Graham Mebane Reservoir	Yellow	Orange	Red	Red	Black
Greenfield Lake		Yellow	Black	Yellow	
Harris Lake	Orange	Red	Red	Red	Black
High Point Lake		Red	Orange		Yellow
Jones Lake					Yellow
Jordan Lake	Yellow	Orange	Red	Red	Black
Lake Brandt		Orange	Orange	Orange	Black
Lake Burlington	Orange	Yellow	Black	Orange	
Lake Higgins	Orange	Orange	Red	Orange	Black
Lake Hunt	Orange	Orange	Red	Red	Orange
Lake Mackintosh	Orange	Red	Orange	Red	Red
Lake Townsend		Orange	Orange	Orange	Black
Oak Hollow Lake	Yellow	Yellow	Orange	Orange	Yellow
Old Town Reservoir		Orange		Yellow	Black
Randleman Lake	Orange	Orange	Orange	Red	
Reidsville Lake	Yellow	Yellow			Red
Rocky River Reservoir	Yellow	Orange	Orange	Orange	Black
Salters Lake		Yellow		Yellow	
Sandy Creek	Yellow	Yellow	Orange	Orange	
Singleary Lake				Yellow	Yellow
Stony Creek Reservoir		Orange	Red	Orange	
Sutton Lake		Yellow		Yellow	Black
Turner Reservoir	Yellow	Yellow	Orange	Orange	
University Lake	Yellow	Orange	Red	Orange	Red
White Lake		Orange	Yellow	Yellow	Yellow
	No Data				
	Does not meet algal bloom criteria				
Yellow	Yellow Criteria: Unit Density \geq 10,000 and/or biovolume \geq 5,000				
Orange	Orange Criteria: Meets yellow AND dominated by cyanobacteria				
Red	Red Criteria: Meets Orange AND dominated by taxa known to produce cyanotoxins				

2.7.2 Special Studies

2.7.2.1 Cape Fear River Algal Modeling Study

A watershed and receiving water model are being developed for the central portion of the Cape Fear River Basin to assist NPDES permit evaluation in this watershed. Algal assemblage and chlorophyll *a* data are analyzed to assist model representation on algal populations and algal bloom dynamics.

Algal data from 18 Cape Fear River monitoring stations for a total of 221 samples collected over the 2010-2020 timeframe were used for the analysis. These data were collected during episodic algal bloom investigations (mainly 2010-2013), the 2010 summer synoptic study and a two-year intensive special study designed specifically for model development (2019-2020). Due to using episodic sampling, the monitoring frequencies are not consistent overtime and location. However, the 2019-2020 modeling algal study samples were collected approximately monthly at 4 stations in the central portion of the Cape Fear River above the impoundments (B6160000 above Buckhorn dam, B8290000 above LD3, B8339000 above LD2, and B8349000 above LD1).

Of the 221 samples collected, diatoms were identified in 210 samples (95%) and chlorophyta/green algae were in 207 samples (94%). Blue-green/cyanobacteria and cryptomonads were also identified in most of the samples collected. In general, the highest mean algal density and biovolume were observed at three stations in the upper half of the Cape Fear River at

- 1.) Station at the Cape Fear River above the railroad bridge near Brickhaven (CPFRR),
- 2.) Station at Cape Fear River just upstream of Buckhorn dam (CPRBD), and
- 3.) Station B8300000 above LD3.

Diatoms, greens and euglenoids have relatively high abundance (unit density or biovolume values) year-round (early spring to autumn) when water temperatures are around or above 10 degrees Celsius. Blue-greens and cryptomonads however, grow more rapidly during summer when water temperatures are higher. Diatoms had the highest average unit density, followed by blue-green algae, while blue-greens tended to be the dominate species during algal blooms.

There are many controlling factors which affect algal growth and bloom formation throughout the Cape Fear River Basin. This system is very complex, which makes modeling even more challenging. The modeling approach based on the algal species study recommends using a model simulation for two algal groups: one representing cold-water, or spring algal groups and the other representing warm-water algal groups frequently observed in the Cape Fear River. For more detailed results see the *Algal Data Summary for Upper and Middle Cape Fear River December 2021* report in Chapter 2 Appendix.

2.7.2.2 2010 Algal Assemblage Assessment Study

Due to the extensive algal blooms which occurred in the Cape Fear River between June and November 2009, AAP initiated a special study in 2010 to characterize any potential blooms for species composition, magnitude (i.e., density) and duration from July to October 2010. Two stations in the Haw River, two in the Deep River, and 17 stations along the Cape Fear River were sampled; a total of 97 site visits were

completed over the five sampling events (*Figure 2-45*). Algal blooms were documented at multiple locations (*Figure 2-46*). The algae that formed the blooms were specific to the locations where they occurred. Blooms of the filamentous blue-green *Pseudanabaena* occurred above Buckhorn Dam and up in the Haw and Deep Rivers. Blooms of the diatom *Staurosira* occurred from Fayetteville down to Tar Heel. A bloom of *Euglena* and *Chlamydomonas* occurred briefly in the Deep River and a bloom of *Microcystis* occurred in the lower Cape Fear around Lock and Dam #1. Nutrient concentrations, an important requirement for algal growth, were highest in the upper Deep River station and around Tar Heel. Chlorophyll *a* levels exceeded the water quality standard of 40 µg/L 33 % of the time (n=15) in the Cape Fear River above Buckhorn dam.

Phytoplankton samples were quantified, and blooms were determined by measuring unit density. Unit density is a quantitative measure of the number of filaments, colonies or single-celled taxa in the waterbody expressed as units/mL. A bloom magnitude was assigned based on algal densities.

Bloom Magnitude	Density (units/mL)
Mild	10,000 to 20,000
Moderate	20,000 to 30,000
Severe	30,000 to 100,000
Extreme	> 100,000

Overall algal blooms were documented at 36 of the 97 site visits. The blooms occurred in two main stretches of the river.

1) From the upper Haw River down to Buckhorn Dam:

- Blooms were persistent, occurring during 76% of the site visits during every month except July.
- Most of the blooms were categorized as moderate (50%), 35% as mild and 15% were severe.
- Blooms were dominated by the filamentous blue-green alga *Pseudanabaena*. This species is known to be prevalent in large Piedmont reservoirs, like Jordan Lake, during the summer.

2) From Fayetteville down to LD1:

- Blooms occurred at 42% of the sites visited.
- The majority of the blooms were mild (71%), however 21% were severe and one site was categorized as extreme. The extreme bloom occurred on September 23, 2010 at the Tar Heel Station below LD3 [108,000 units/mL of a diatom sp. with a corresponding chlorophyll *a* concentration of 34 µg/L and a daily average flow of 549 cfs (7-day flow average of 578 cfs) at USGS flow gage #02105500, Cape Fear River at William O. Huske lock near Tar Heel, NC; *Figure 2-46*].
- Blooms were dominated by a small diatom, *Staurosira* (2010 blooms species were very different from the 2009 blooms which were dominated by the blue-green *Microcystis*).

Surface bloom occurred in two other stretches of the river. A surface bloom of *Microcystis* occurred below LD1 in July 2010 but was substantially smaller than those that occurred in 2009. The bloom lasted only three to four weeks and there was no evidence of toxic effects or fish kills observed. Unlike the bloom in 2009, the bloom was concentrated only in the main channel within the windrows and eddies.

A surface bloom composed of the green alga *Chlamydomonas* and the euglenoid *Euglena* also occurred in the Deep River. The bloom was two miles long and shore to shore from above the confluence with the Haw River to up past Haywood. These species are common in lakes and ponds throughout North Carolina in the summer. The surface bloom of these algae was indicative of slow flowing or “ponding” conditions coupled with abundant nutrients, warm water, and long summer day length.

Flowing water is not conducive to supporting large populations of phytoplankton. Algal densities were consistently low (<3,000 units/mL) in the upper Deep River, below Buckhorn dam at Lillington and Erwin and at sites below LD1 suggesting faster flowing water (*Figure 2-46*).

The study concluded that the algal assemblage structure and density varied temporally and spatially during the 2010 special study. The observed patterns in structure and density highlighted various characteristics of the river, primarily the effects of the impoundments and the free-flowing stretches of the river. The *Microcystis* surface blooms did occur in 2010 but not to the extent of those observed in 2009. Chemical and physical data were also measured. For additional information and findings, see the Chapter 2 Appendix for the *Algal Assemblage Assessment in the Cape Fear River in 2010* study report.

Figure 2-45: Algal Assemblage Assessment Study Site Locations

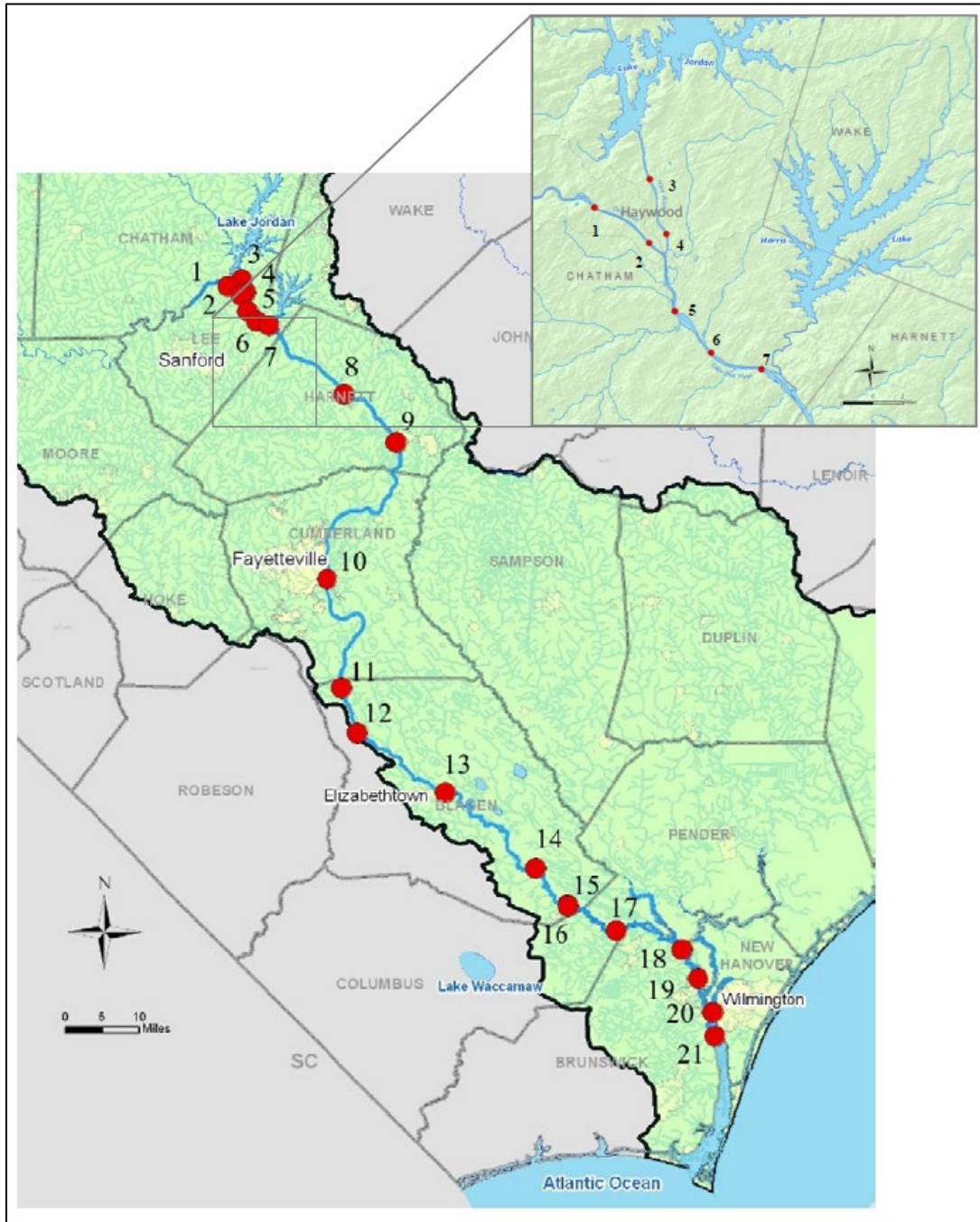
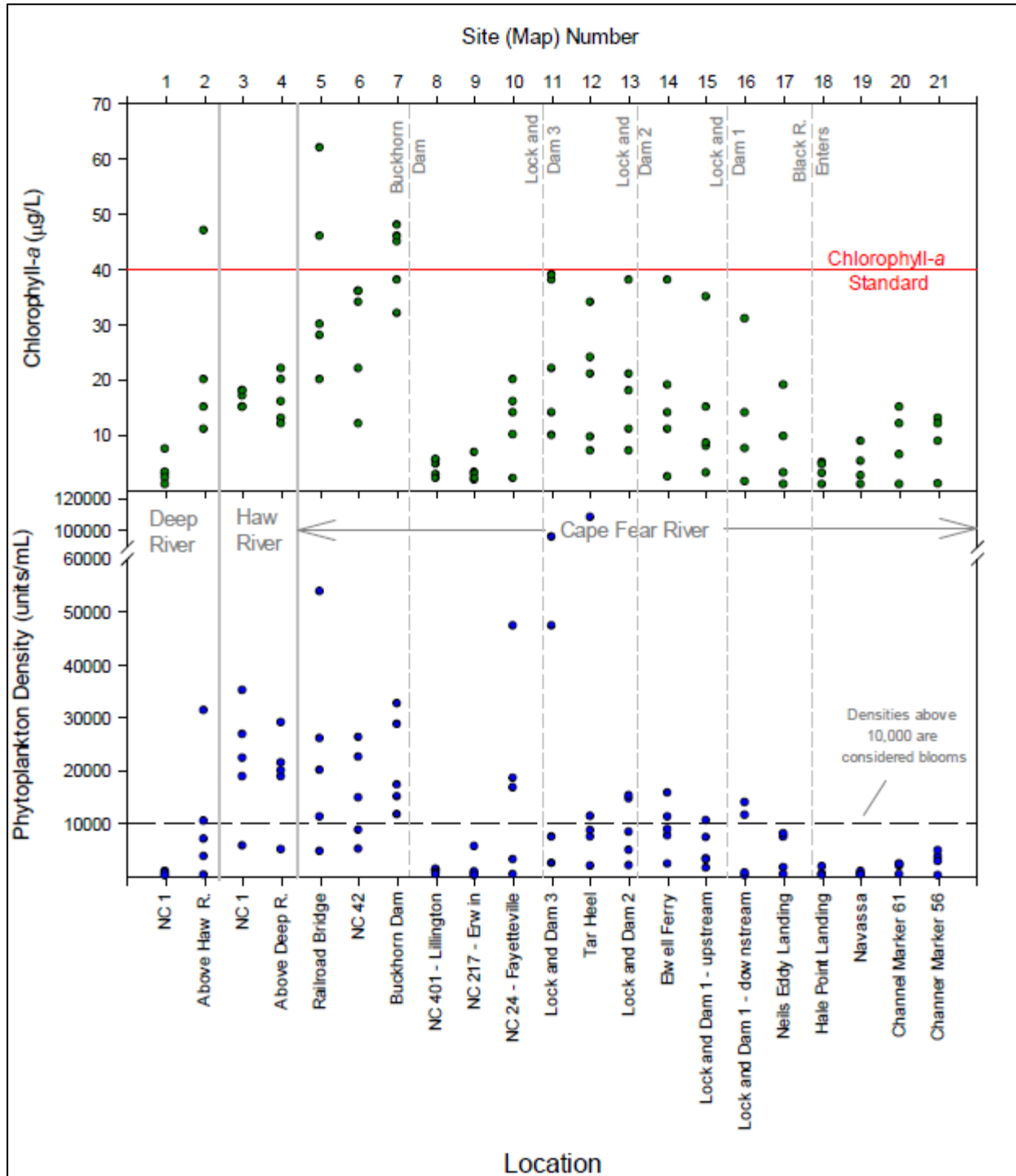


Figure 2-46: Phytoplankton Unit Densities and Chlorophyll a Concentrations from the 2010 Algal Assemblage Assessment Study.



2.7.3 Algae Assessment Program - Episodic Blooms Response

The AAP assesses episodic algal blooms across the state. Algal blooms samples are generally collected in response to a specific event and to support the state algal bloom and fish kill response efforts. AAP maintains an Algal Bloom and Fish Kill Dashboard which displays locations analyzed. To report an algal bloom on your phone, tablet or PC please complete the DWR Citizens Report ([Algal Bloom and Fish Kill Survey](#)) or call the emergency hotline at 1-800-858-0368. Additional information is available on the DWR [Algal Bloom](#) website.

Harmful algal blooms are occurring more frequently across the country. When public health concerns arise from algal blooms, local health departments and the NC Department of Health and Human Services determine an appropriate response with technical support from DWR (NC [DHHS Algal Bloom](#) website). Common actions include swimming closures, contact advisories, and the issuances of public notifications. In addition to environmental and public health concerns, blooms can lead to economic losses due to increased drinking water treatment costs, decreased tourism and recreation, remediation efforts, fisheries losses, and decreased property values. DWR developed a flyer to help identify blue-green algal blooms ([Identification of Cyanobacterial \(Blue-green\) Algal Blooms](#)).

On September 22, 2009, the USACE lockmaster reported an extensive algal bloom in the upper pool of LD1, extending upstream to Elwell Ferry and flowing downstream. DWR biologists responded to the report and found large accumulations of *Microcystis*, a blue-green algae known to be potentially toxic covering a large extent of the river up and down from LD1. The bloom continued to occur throughout the Cape Fear River through early November. The 2009 *Microcystis* blooms were documented on the Cape Fear River from the upstream of LD3



to well downstream of LD1 at the station B9030000 near Sutton Lake. The Cape Fear River continued to experience algal blooms off and on throughout much of 2010 and 2011. *Microcystis* blooms were also documented in the Black River and Northeast Cape Fear River in 2011. An algal bloom timeline and summaries for 2009 through 2011 are included in Chapter 2 Appendix. The photo was taken on October 23, 2009, downstream of LD1.

Based on data available for 2012 to 2019, there were 63 episodic blooms reported in the Cape Fear River Basin (*Table 2-19*). Of the 63 reported blooms, 40 (or 63.5 %) were identified as potentially harmful blue-green algal blooms and 23 (or 36.5%) were non-HAB dominated blooms. The Basin Planning Branch will work with the AAP to develop a more comprehensive assessment of the blooms occurring in the Cape Fear River Basin.

Table 2-19: 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
Total Bloom Count	63	40	23

2.8 Aquatic Weed Control Program

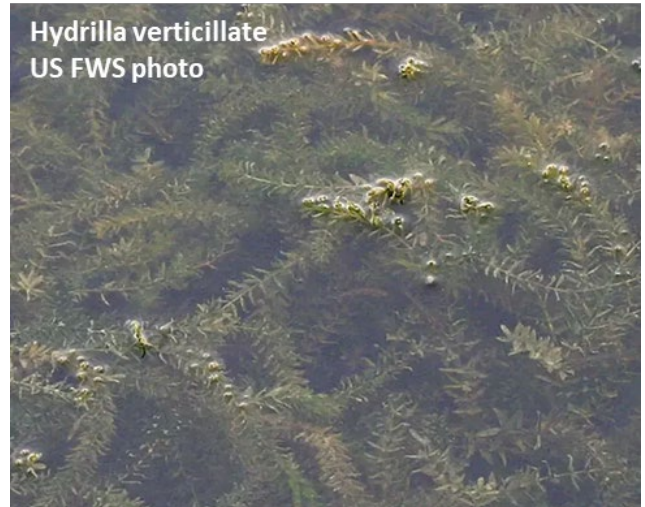
Invasive species come in many forms, including aquatic plants. Invasive aquatic plants are commonly referred to as aquatic weeds. These plants are non-indigenous (exotic) and are known to impose negative environmental and/or economic impacts.

There are many species of non-indigenous plants, including aquatic weeds, in the plant nursery and water garden trade. The availability of a wide variety of exotic plants is a “modern world” occurrence and the development of the global market accounts for a lot of movement of plants all around the world. Most exotic plants are benign, and some are economically important, but a small number of species (much less than 1%) turn out to be invasive. A small number of invasive plants, those that are the most problematic, are prohibited in the trade. The terms “noxious weeds” and “noxious aquatic weeds” are used to describe these species and carry more of a legal significance. The U.S. Department of Agriculture and the NCDA&CS act as regulatory agencies and maintain lists of prohibited plant species. It is unlawful to import, culture, sell, or transport noxious weeds and noxious aquatic weeds.

Unfortunately, hydrilla and alligatorweed, both noxious aquatic weeds, have been introduced to the Cape Fear Basin.

[Hydrilla](#) (*Hydrilla verticillata*) grows as a submersed plant. It can quickly spread throughout a watershed and once established, it typically fills the water column with its vegetative growth. This growth behavior is undesirable because it impacts habitat function, recreation activities, municipal water intakes, irrigation and water flow.

Hydrilla is being actively managed at Lake Reidsville, Lake Townsend, Cane Creek Reservoir, Jordan Lake, Lake Trace (near Sanford), and Mintz Pond (Fayetteville). Hydrilla has been observed in the Deep River and the Cape Fear River, but there is currently no active management in these mainstem rivers.



Hydrilla verticillata
US FWS photo

[Alligatorweed](#) (*Alternanthera philoxeroides*) grows as an emerged plant in shallow water along shorelines and forms floating mats. This plant grows as a perennial in NC as new growth will arise from rhizomes (stems) that persist from the previous growing season. Heavy infestations of alligatorweed can reduce capacity use, interfere with recreation activities, and alter habitat.

Alligatorweed is widespread throughout the Coastal Plain of NC and into the Piedmont. A biocontrol insect called the alligatorweed flea beetle has been introduced in NC. These insects have become established and are likely widespread in the Coastal Plain. Populations of alligatorweed flea beetles are impacted by freezing temperatures, which limits them from expanding outside of the Coastal Plain. Alligatorweed is also managed with aquatic-use herbicide products. There are many alligatorweed sites from the upper reaches of the Cape Fear Basin to the Atlantic Ocean currently being managed with herbicides.



Alligator Weed -
US FWS photo
by Jorge Ayón

Part of the Water Resources Development Grant Program, the [Aquatic Weed Control Program](#) (AWCP) is a state-funded program that provides assistance to local governments, public utilities and other government agencies. The AWCP is staffed with weed specialists and can provide assistance in the form of “boots on the ground” weed management services and technical guidance. A full list of aquatic weed projects may be found in the [AWCP Annual Work Plan](#).

Temporary rules for the Water Resources Development Grant Program became effective on February 8, 2023. The Division of Water Resources is currently working on permanent rules, which are expected to be in place in 2024.

2.9 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). The NC DHHS [website](#) provides the most up to date fish consumption advisories and the list of fish species and consumption recommendations associated with each advisory. Any waterbody with a fish consumption advisory and site-specific fish tissue data are considered to be Exceeding Criteria and included on the 303(d) list of impaired waters. All waterbodies in North Carolina are impaired for fish tissue mercury. Several waterbodies in the lower part of the Cape Fear were impaired for the first time in 2020 due to arsenic and hexavalent chromium fish consumption advisories issued in 2017 (*Table 2-6* and *Table 2-20*). Additional arsenic and hexavalent chromium fish consumption advisories were issued in 2021 and will be on the 2024IR (*Table 2-20*). The newest fish consumption advisory for perfluorooctane sulfonic acid (PFOS) in the Cape Fear River Basin was issued by NC DHHS on June 13, 2023, for over 90 miles of the middle and lower Cape Fear River (*Table 2-20*). PFOS is a type of polyfluoroalkyl substance (PFAS), a Contaminant of Emerging Concern (Section 2.13). This most recent fish consumption advisory will also be added to the 2024IR.

The arsenic and hexavalent chromium fish consumption advisories were the result of two studies done in the mainstem Cape Fear River and Estuary and several tributaries near the Kerr-McGee Chemical Corporation site in Navassa, North Carolina. Kerr-McGee operated as a creosote-based wood-treating facility from 1936 to 1974, was dismantled in 1980, and later placed on the EPA's Superfund National Priorities List (NPL) in 2010. The EPA and DEQ evaluated various fish tissue parameters near the site in 2011 and 2013 including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, mercury, copper, arsenic, and chromium (NC DHHS 2018). PAHs is a contaminant directly associated with creosote. All parameters were detected above levels of concern. However, fish consumption advisories were only issued in 2017 for arsenic and hexavalent chromium (*Table 2-20*) as the existing statewide fish tissue mercury advisory was already more stringent for the species of interest than the other parameters. It should be noted that due to the toxicity of hexavalent chromium and to be highly health protective, all chromium tissue samples were assumed to be hexavalent chromium by DHHS (NC DHHS 2018).

The Duke University Superfund Research Center and the School of Health Sciences at Oakland University and several partners conducted a follow-up study that collected and analyzed fish tissue samples from multiple nearby locations in the Lower Cape Fear and North East Cape Fear subbasins that resulted in the issuance of the additional 2021 hexavalent chromium and arsenic fish consumption advisories (*Table 2-20*). This study (2016-2022) also investigated subsistence fishing in the lower part of the Cape Fear, held focus groups to develop messaging for safer consumption practices, and organized a fish forum to discuss challenges and opportunities to create a more effective fish consumption advisory process in North Carolina (Shapiro-Garza et al. 2022). The study 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 consumption advisories and North Carolina needs to invest in setting and communication of fish

consumption advisories (Shapiro-Garza et al. 2022). Funding is needed to hire NCDHHS and DEQ staff to increase fish tissue collection, testing, data analysis, and public education and outreach.

The newest fish consumption advisory for PFOS in the Cape Fear River Basin was based on a large-scale DEQ and North Carolina Wildlife Resource Commission (NCWRC) study conducted in the summer of 2022 from the Fayetteville Boat Ramp, near the I-95 overpass to the Atlantic Ocean. The study collected over 250 samples of 14 commonly caught and consumed migratory and non-migratory freshwater and marine fish species. The goals of the study were (NCDEQ 2023):

- 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 portion of the Cape Fear River above the bluffs near the I-140 overpass is complete while the marine fish analysis for the Cape Fear estuary is underway. Freshwater fish tissue samples analyzed for 56 types of PFAS found PFOS levels were most concerning in all species. PFOS levels were consistently elevated between sample locations with fish species being the only significant variable (NCDEQ 2023). The consistently elevated concentrations of PFOS in combination with the new, lower reference dose for PFOS released by the EPA in March 2023, informed the decision for the PFOS fish consumption advisories in the middle and lower Cape Fear River (NCDHHS 2023b).

More information about the fish consumption advisories and associated studies is available in Chapter 9.

Table 2-20 NC Fish Consumption Advisories as of January 2023. See NC DHHS Website for the most up to date list of advisories (NC DHHS, 2021).

River	Counties	Location Of Advisory	Pollutant	Species
All waters in the Cape Fear River Basin	All Counties in NC	Statewide	Mercury	Many Species See Website & Flyer
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 US-17 bridge	Arsenic, Hexavalent Chromium	striped bass, striped mullet, blue crab
Burnt Mill Creek	New Hanover	*Near Archie Blue Community Park, Upstream of the confluence with Smith Creek	Arsenic, Hexavalent Chromium	bowfin, bluegill, flathead catfish

River	Counties	Location Of Advisory	Pollutant	Species
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
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
Northeast Cape Fear River	New Hanover, Pender	*Near Riverside Park community building, upstream of I-40 bridge, at Castle Hayne Boat Ramp	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	bluegill, flathead catfish, largemouth bass, redear, blue catfish, American shad, striped bass

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

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

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

*Fish consumption Advisory issued in 2021 and are not listed 2022IR, ^ Fish Consumption Advisory issued in 2017 and is listed on 2022IR, + Fish Consumption Advisory issued in 2023 will be listed on the 2024IR

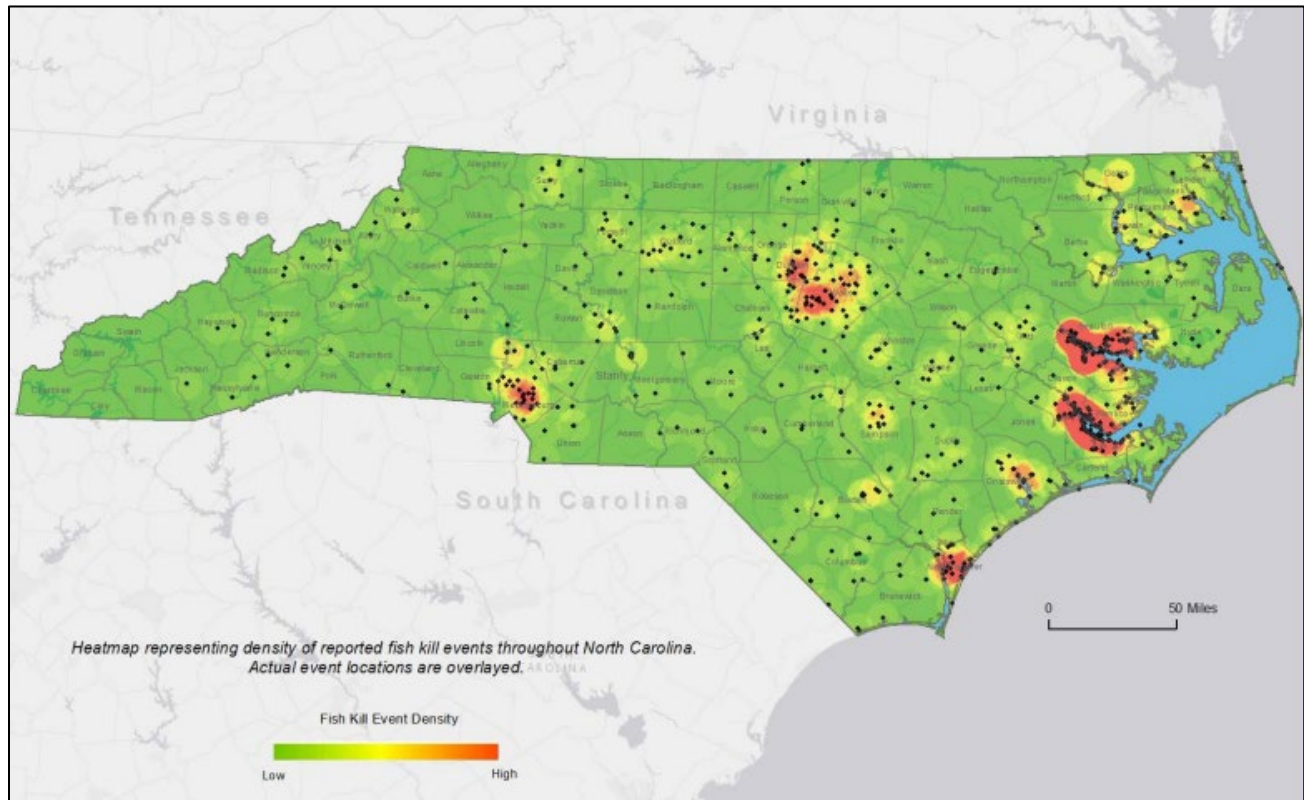
2.10 Fish Kill Assessment

WSS has a [Fish Kill Reporting Application](#) available to the public via phone, tablet or PC. Fish kills (and algal blooms) that are investigated by DWR and public reports are displayed on a map located on the WSS [website](#). WSS and the DEQ Regional Offices work together to check and verify the reported fish kills as resources and safety allow. Fish kill reports were published from 1997 to 2018 and include resident reports and DWR Fish Kill Reports ([NCDWR Annual Report of Fish Kill Events 2018](#)). Yearly historic event details and maps are available from 1997 to 2019 are also available on the DWR's [NC Fish Kill Event website](#). *Figure 2-47* from the most recent 2018 Annual Report shows the density of fish kill events by county from 1996 to 2017, a higher density of fish kills has occurred in the upper and lower sections of the basin. Fish kills have been reported more often by members of the public in recent years in the Cape Fear River Basin. Information on how to report a fish kill, recent fish kill activity, and annual fish kill reports can be found on DWR's WSS [website](#). The United State Fish and Wildlife Service (US FWS) also investigates fish kills in North Carolina.

Floods from hurricanes can flush swamps and backwaters as well as urban areas causing large quantities of oxygen consuming debris and organic matter to enter streams. Extremely depleted oxygen levels in many lakes and rivers can become lethal to aquatic life. Hurricane Florence in 2018 caused fish kills to several waterbodies in the Cape Fear River Basin including Sutton Lake, Greenfield Lake, and the Northeast Cape Fear River near the town of Castle Hayne, and sections of the Cape Fear River near Lock and Dam #1, and Lock and Dam #2.

White Lake in the Lower Cape Fear River subbasin (HUC8 03030005) experienced a large fish kill in May 2018, estimated at about 115,000 fish, 40 to 50% of the total fish population in the lake ([2019 NC DEQ Report](#)). To address concerns with changing water quality conditions, the Town of White Lake applied an alum sulfate treatment to reduce phosphorus concentrations in order to control algal growth in the system. Hours after the alum application started, the fish kill began to occur. There was a large algal bloom occurring at the time of the treatment which resulted in elevated pH levels throughout the lake (as high as 8.5). 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” ([2019 NC DEQ Report](#)). 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”.

Figure 2-47: Fish Kills in North Carolina 1996 to 2017 (DWR 2018)



2.11 Atmospheric Deposition

The [National Atmospheric Deposition Program \(NADP\)](#) is a collaboration between federal, state, and local agencies. The NADP precipitation chemistry network started in 1978 providing water quality information (H⁺ as pH, conductance, calcium, magnesium, sodium, potassium, sulfate, nitrate, chloride, and ammonium) by collecting weekly samples. The NADP National Trends Network (NTN) calculates trends for atmospheric deposition using annual weighted mean concentrations. Depositions are characterized as meeting or not meeting the NADP's data completeness criteria for each 1-year period. The trend line is a smoothed three-year moving average with a one-year time step. The line is only displayed where the minimum data completeness criteria is met for the three-year period.



There are two active NADP NTN sites within the Cape Fear River Basin: [Site NTN NC30](#) - Duke Forest in Orange County within the Haw River subbasin (HUC 030030002) and [Site NTN NC35](#) - Clinton Crops Research Station located in Sampson County within the Black River subbasin (HUC8 03030006). An interactive map with all the NADP sites can be found on their website. The mean yearly nitrate, ammonium, total nitrogen, and sulfate deposition rates are shown in [Figure 2-48](#) to [Figure 2-51](#) for Site NC35 for trend data collected since 1978. Site NC30 only has data available for 2019 and 2020. The nitrate trend line ([Figure 2-48](#)) indicates mean deposition rates remained constant until 2000, ranging from 8 to 12 kg/ha (kilogram/hectare), then the trends declined steadily until 2017, and have ranged from 4 to 6 kg/ha since then. The mean annual ammonium deposition rates have steadily increased since the late 1980s from 2 to 7 kg/ha ([Figure 2-49](#)). Total nitrogen means increased over a ten-year period from the late 1980s to the late 1990s from 3-4 kg/ha to 5-6 kg/ha ([Figure 2-50](#)) and have remained fairly consistent over the last 20+ years. Sulfate levels have declined substantially since the late 1970s, from 22 to 4 kg/ha, and have remained consistent since 2016 ([Figure 2-51](#)). Sulfates contribute to acidification of surface waters and soils and contributes to acid rain which is on the decline as seen by the dramatic increase in pH concentrations over time at NC35 ([Figure 2-52](#)). The pH increased from about 4.5 in the 1980's up to 5.9. in 2020. Soil pH levels ultimately affect the availability of plant nutrients, and with increasing soil pH as a result of this change, increase in the solubility and mobility of organic soil compounds lead to "an increased leakage of organically bound N from soils to aquatic ecosystems" as described by Deininger et al. (2020). This could help explain, in part, the increasing instream organic nitrogen (TKN-NH₃) trends identified across much of North Carolina over the last 20 years and reported in many river basin plans.

The steady increase in atmospheric ammonium concentrations and deposition at the Sampson County Clinton Crop Research station NC35 is likely related to the agricultural intensification in this area over the timeframe ([Figure 2-49](#)). Increases in both swine and poultry animal numbers and transitions from small family farms to large, concentrated animal feed operations in this region have occurred (see Chapter 1, section 1.4.1 and Chapter 3, section 3.6 of the plan). It has been estimated that agricultural sources

account for approximately 82% of all ammonia emission nationally and over 81% globally (Bray et al., 2018; Wyer et al., 2022). The 2021 NADP annual ammonium deposition map (Figure 2-53) shows the very high ammonium deposition rate in the southeastern portion of NC. The 5.6 kg/ha deposition rate is equivalent or higher than most of the highly intensive agricultural areas in the mid-west United States. High atmospheric ammonia can lead to deleterious effects on aquatic ecosystems and human health (Bray et al., 2018; Damme et al., 2021).

To understand changes in atmospheric deposition and the impacts to water quality, it is critical to retain existing National Atmospheric Deposition Program (NADP) stations. *It is recommended that federal, state, and local resources agencies continue to fund and expand the monitoring network in the Cape Fear River Basin and throughout the state.*

Figure 2-48: Trends for Atmospheric Deposition Using Annual Weighted Mean Nitrate Concentrations at NTN Site NC35 - Clinton Crop Research Station (NADP, 2022).

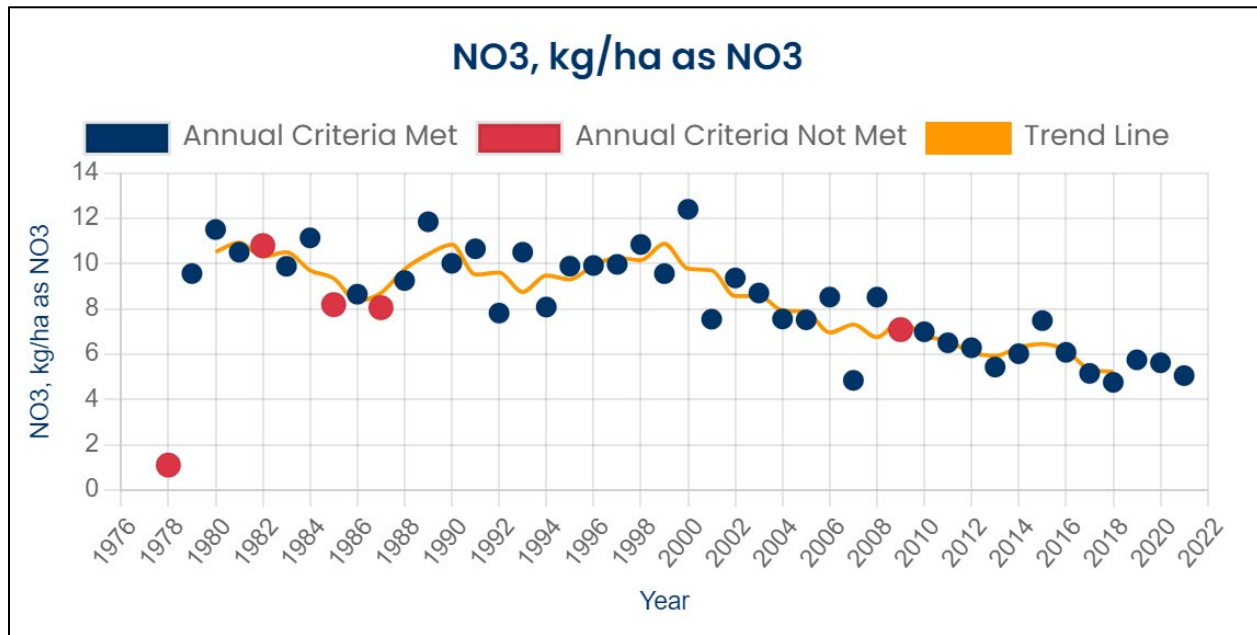


Figure 2-49: Trends for Atmospheric Deposition Using Annual Weighted Mean Ammonium Concentrations at NTN NC35 - Clinton Crop Research Station (NADP, 2022).

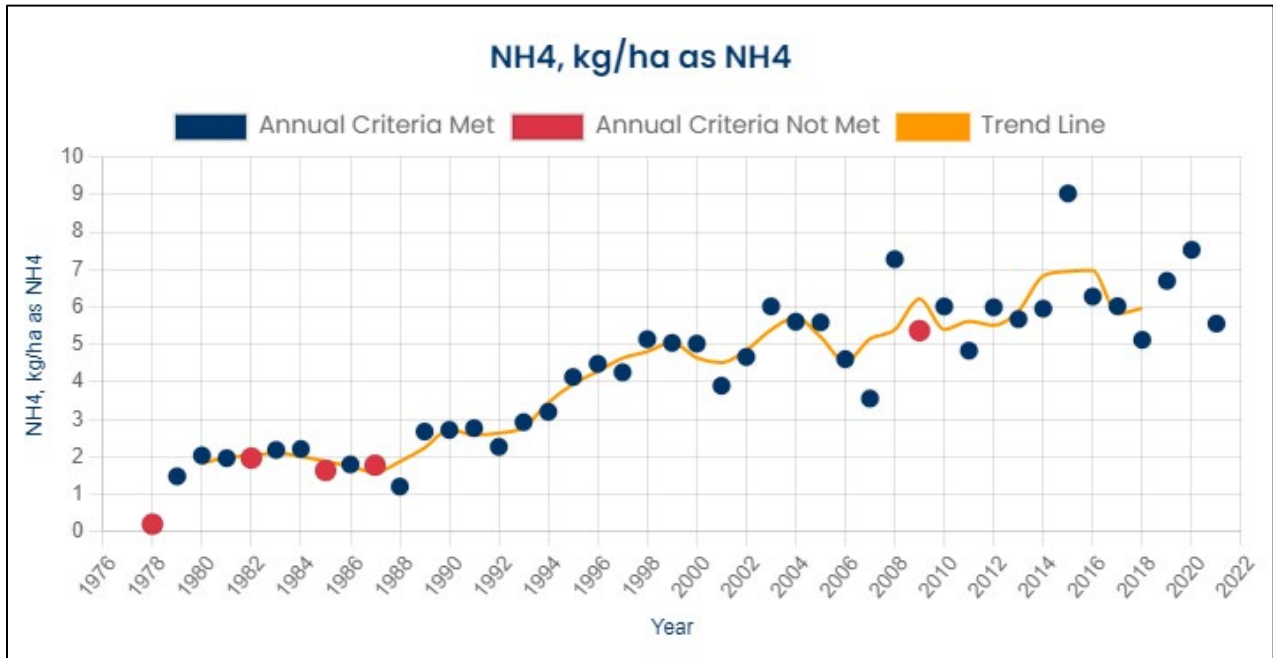


Figure 2-50: Trends for Atmospheric Deposition Using Annual Weighted Mean Total Nitrogen Concentrations at NTN Site NC35 - Clinton Crop Research Station (NADP, 2022).

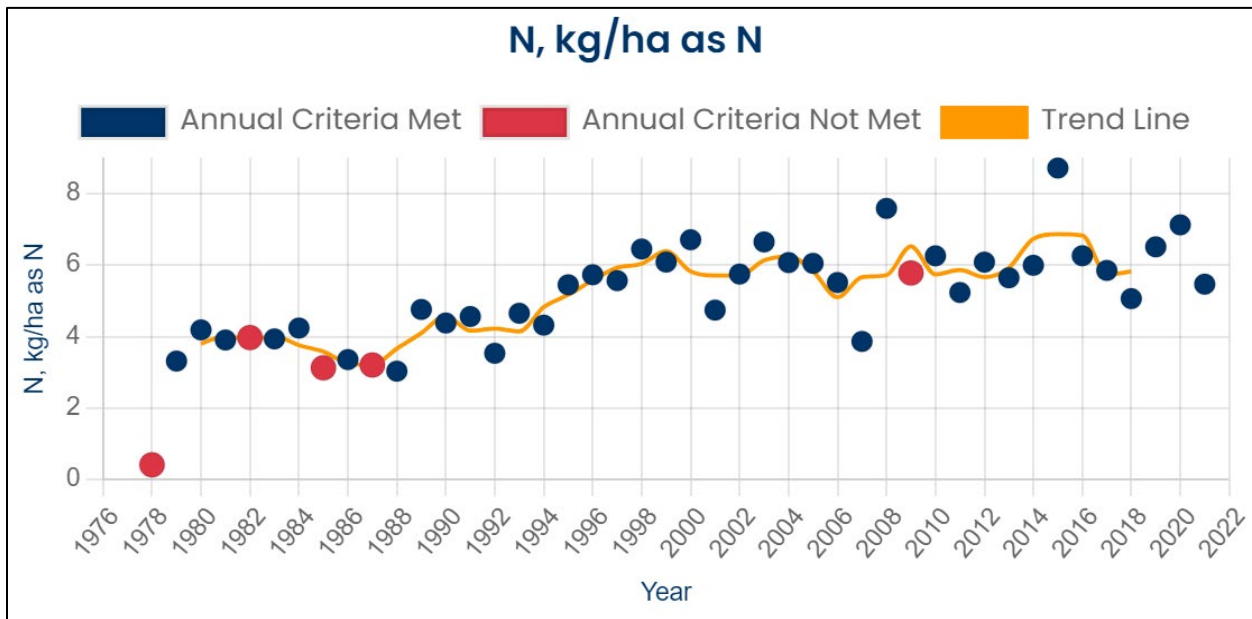


Figure 2-51: Trends for Atmospheric Deposition Using Annual Weighted Mean Sulfate Concentrations at NTN Site NC35 - Clinton Crop Research Station (NADP, 2022).

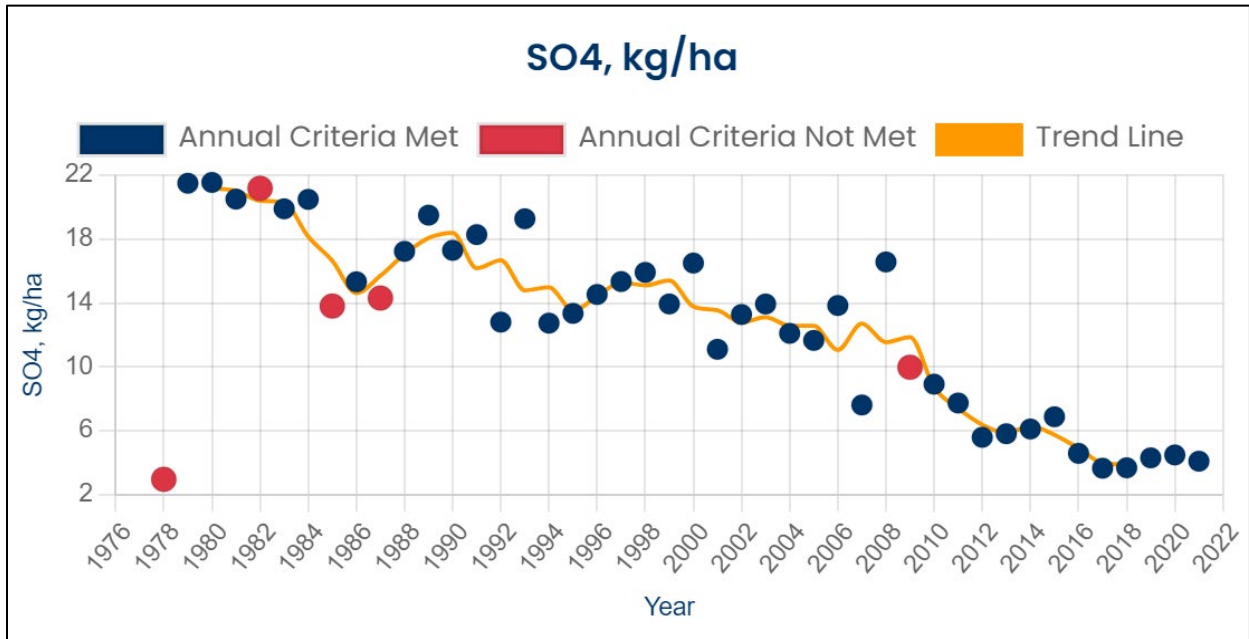


Figure 2-52: Trends for Atmospheric Deposition Using Annual Weighted Mean pH Concentrations at NTN Site NC35 - Clinton Crop Research Station (NADP, 2022)

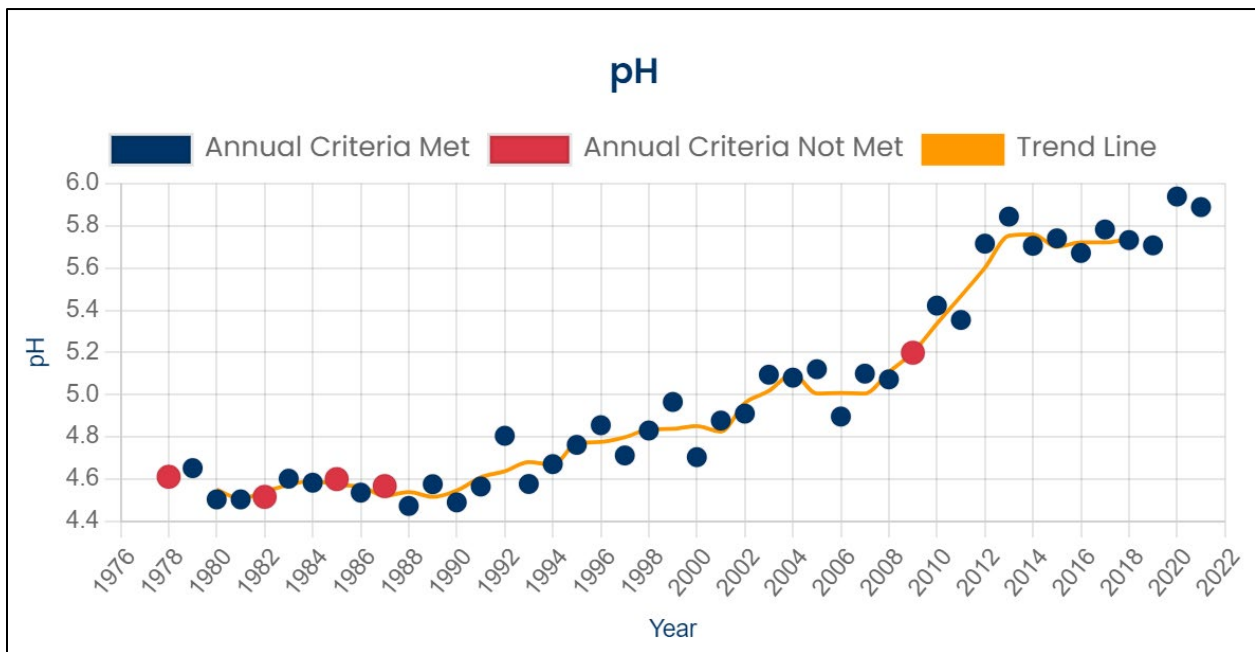
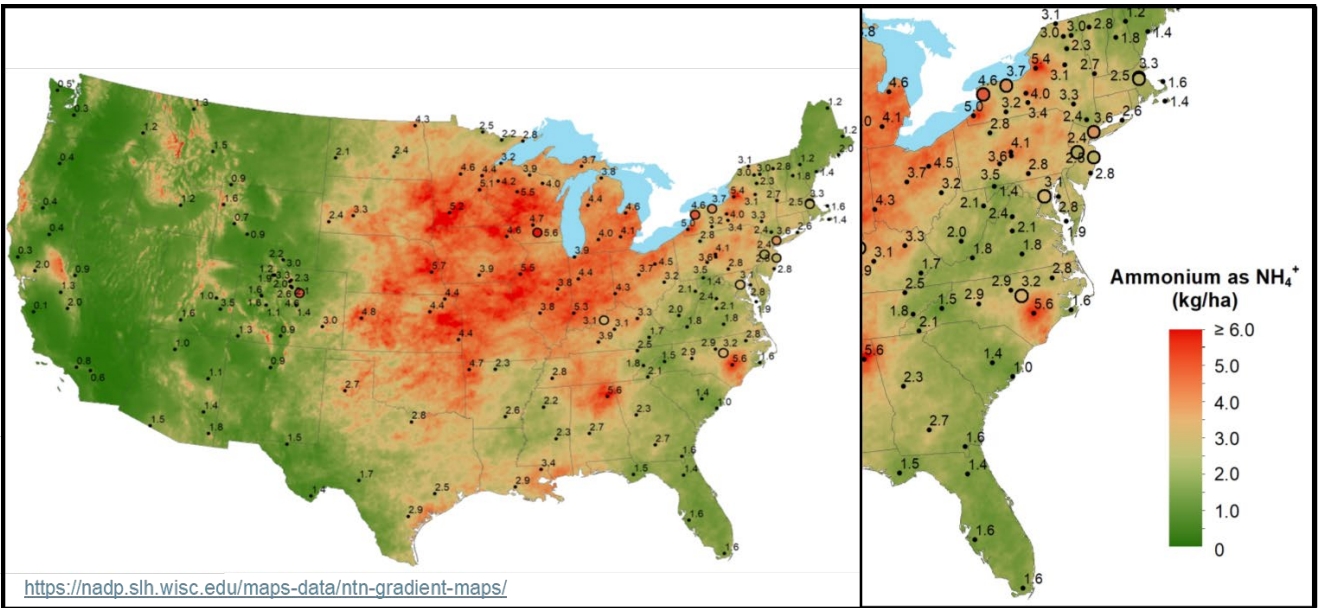


Figure 2-53 National Atmospheric Deposition Program, 2021 Annual NTN Ammonium Deposition Map, Highlighting the Easter USA and NC (<https://nadp.slh.wisc.edu/maps-data/ntn-gradient-maps/>).



2.12 Groundwater Quality

Groundwater is withdrawn extensively for agriculture, mining, commercial and industrial processing, and accounts for nearly half of the state’s drinking water supply (Laughinghouse, 2019). DWR’s Groundwater Resources Section, Groundwater Resources Branch (GWRB) has maintained and operated a statewide monitoring well network (MWN) since the 1960s for groundwater quantity and chloride sampling. Chloride sampling allows the GWRB to monitor salinity levels and trends at the fresh water-saltwater interface within each of the major coastal plain aquifers (Laughinghouse, 2019).

Salinity levels and the location of the interface can change as a result of sea level rise, storm surges during hurricanes, groundwater pumping, and mine-dewatering. Chloride levels are used to determine if groundwater is fresh (< 250 ppm chloride) or salty (≥ 250 ppm chloride). Chloride sampling is also used to identify the transition zone between the fresh and salty zones. This transition zone is characterized by a vertical salinity gradient within the aquifer in which salinity increases with depth, from fresh to salty (Laughinghouse, 2019). The GWRB expanded its scope in 2015 to include groundwater quality monitoring. Together the MWN and groundwater quality programs provide comprehensive coverage, both geographically and geologically, for a statewide characterization of ambient groundwater quantity and quality. These programs advance DWR’s mission by improving knowledge in the following areas:

1. Impacts of land-applied wastes, artificial infiltration practices, or other human activities including:
 - Potential effects on the surficial aquifer and secondary effects on deeper aquifers and surface waters

- Emerging contaminants associated with these activities ([link](#))
 - Effectiveness of regulations and permits
2. Threats to groundwater quality, including:
- Existence, nature, and scope of emerging or existing threats
 - Assessment of the causes and factors of contamination
 - Monitoring the status of groundwater quality across the State

Hence, the goal of DWR is to improve understanding of the causes and extent of problems, minimize human exposure to contaminants and identify areas where regulations or BMPs can be improved to prevent the occurrence of contamination to groundwater. Groundwater levels and other data collected from the monitoring network are available online and include maps, historic and current groundwater levels, chloride measurements, well construction records, well locations and lithologic and geophysical well logs. Hourly water level data is also available upon request for specific wells. To learn more about DWR's monitoring well network and to view or download data, visit the GWRB's [home page](#) and the [groundwater quality](#) and [groundwater education and information](#) pages.

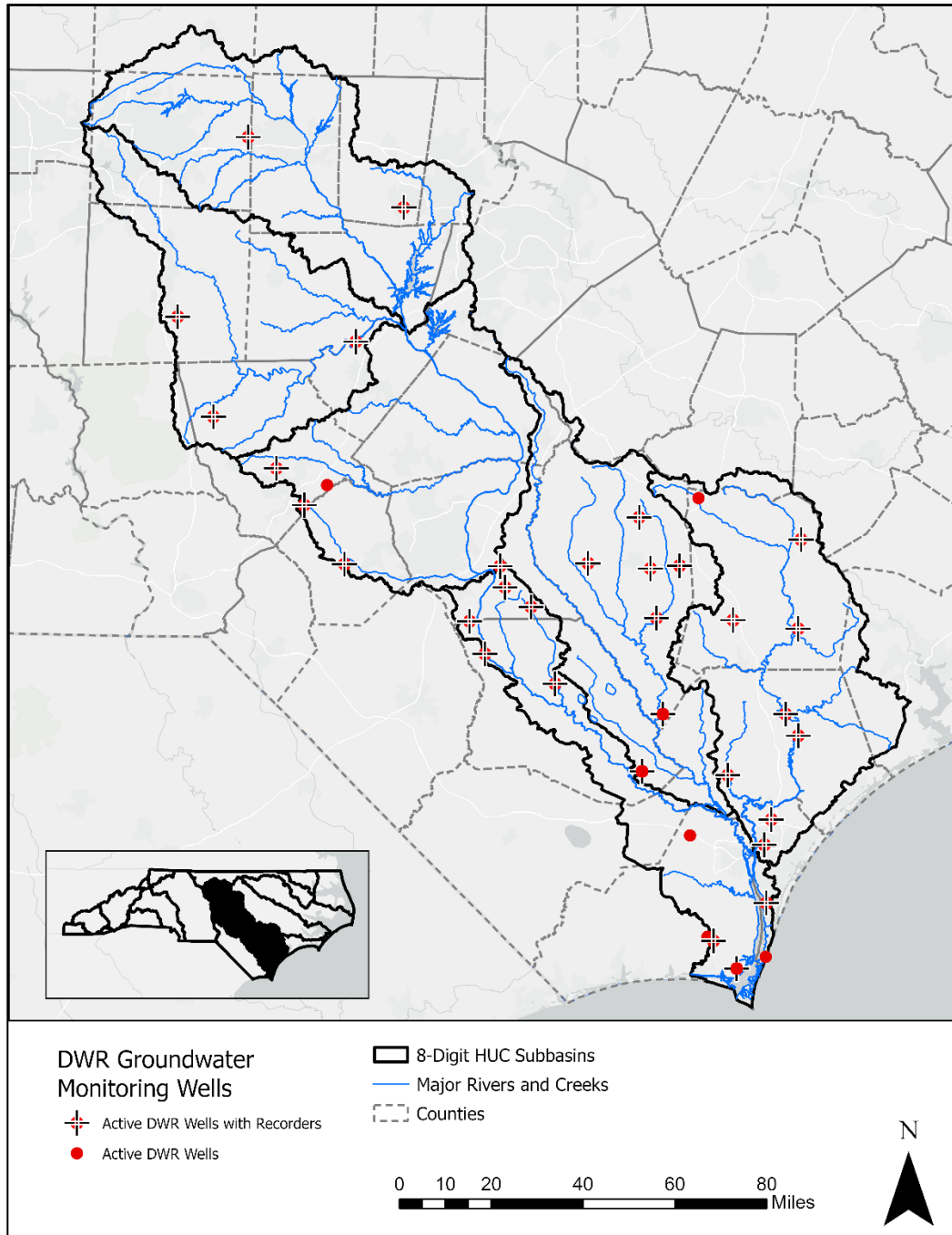
As of 2024, there are approximately 700 wells in MWN statewide located primarily in the coastal plain. DWR has 39 MWN stations in the Cape Fear River Basin (*Figure 2-54*). See chapter 5 for a more detailed discussion on groundwater quality, as well as, groundwater use, water levels, geology, aquifers, and salinity in the Cape Fear River Basin. Additionally, more information about [North Carolina's aquifers](#) and the groundwater quality monitoring programs can be found on the GWRB's [website](#). A complete list of the active groundwater monitoring wells, their depth, and aquifer placement are included in the Chapter 5 appendix. See Chapter 12 for more information regarding the ambient groundwater monitoring well network PFAS sampling.

Groundwater quality information in the basin also comes from the routine sampling of newly constructed private drinking water wells. Under the [statewide private well testing program](#) administered by NCDHHS and local health departments, all new private drinking water wells are sampled by local health departments and analyzed for a standardized list of chemical constituents by the State Laboratory of Public Health in NCDHHS. In addition to their value to individual well users, these samples are the most abundant source of data on the status of groundwater quality across the state. When a constituent within an individual well exceeds drinking water health standards or [groundwater standards](#) established by DEQ for one or more constituents, the local health department, along with NCDHHS, provides the well owner with information about the constituents identified in the groundwater sample and what steps may be necessary to protect the well users' health. More information can be found on NCDHHS's [website](#) or by contacting the local health department.

Given that the groundwater resource will be further stressed to meet the demands of a growing population, as well as to replace/augment currently stressed surface water supplies, it is crucial that North Carolina conduct regional scale groundwater availability studies required to determine sustainable yields and more efficiently manage the resource.

To understand changing groundwater levels and quality, it is critical to retain the existing groundwater monitoring network where feasible. It is recommended that federal, state and local resources agencies continue to fund and expand the well network and water quality sampling efforts throughout the state.

Figure 2-54: DWR Groundwater monitoring wells in the Cape Fear River Basin



2.13 Contaminants of Emerging Concern

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 as well as their by-products, firefighting foams, pesticides, lawn and agricultural products, disinfection products, wood preservatives, home goods, pharmaceutical and personal care products (PCPs) (EPA, 2024). In addition to industrial sources, these contaminants are often sent to landfills and wastewater treatment plants 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, EPA, the NC Collaboratory, public water and wastewater utility providers and other local and state entities.

2.13.1 PFAS Substances

PFAS are of particular concern not only in North Carolina, but globally. PFAS are a group of manufactured chemicals that have been used in industry and consumer products since the 1940s because of their useful properties. There are thousands of different PFAS, some of which have been more widely used and studied than others. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) have been two of the most widely used and studied PFAS chemicals. Scientific studies have shown that exposure to these compounds may be linked to harmful health effects in humans and animals. As a result, PFOA and PFOS have largely been replaced by alternate PFAS compounds. In chemical and product manufacturing, hexafluoropropylene oxide (HFPO) dimer acid, also known as “GenX,” is considered a replacement for PFOA. Perfluorobutane sulfonic acid (PFBS) and the related compound potassium sulfonate (potassium PFBS) are considered replacements for PFOS. Unfortunately, many PFAS compounds, including the more modern PFAS such as GenX and PFBS, also break down very slowly and can build up in people, animals and the environment over time.

Researchers from North Carolina State University (NCSU) detected elevated levels of PFAS (including GenX) in the Cape Fear River in 2016. 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 groundwater throughout the basin. The sources of these compounds into the Cape Fear River systems are from contaminated wastewater, groundwater and atmospheric deposition.

As a result of the contamination from Chemours, North Carolina has been aggressively moving forward to manage the risks of PFAS. In the absence of federal standards or guidance, North Carolina has taken steps

to address contamination from the Chemours Fayetteville Works facility. Through actions by DEQ, the 2019 Consent Order ([Consent Order](#)) and a the 2020 Consent Order addendum ([2020 Addendum](#)), Chemours was required to stop discharging process wastewater, install PFAS capture and treatment systems to prevent PFAS from reaching the Cape Fear River, drastically reduce atmospheric emissions and provide alternate water for thousands of households whose drinking water wells have been contaminated. NC residences are eligible for private well testing in a significant portions of Cumberland, Bladen, Robeson, Sampson, Hoke, and Harnett counties ([DWM well sampling website](#)). In late 2021, DEQ determined that Chemours was likely responsible for contamination of groundwater monitoring wells and water supply wells in four downstream counties: New Hanover, Pender, Columbus and Brunswick ([DWM Lower Cape Fear well sampling website](#)). The Consent Order directed Chemours, among other things, to determine the extent of the PFAS contamination related to the Fayetteville Works site and provide replacement water supplies to affected residents. See Chapter 12, section 12.3.2 for specific details on the corrective actions required by Chemours.

While the spotlight on PFAS in North Carolina arose through GenX and Chemours-related compounds, the issue of PFAS is larger than one compound or one company. DEQ has done significant work responding to PFAS contamination at specific sites. However, DEQ also understood the need for a larger strategy to address these compounds in a comprehensive way and across all Divisions. In June 2022, DEQ released the [Action Strategy for PFAS](#), a comprehensive approach to address PFAS contamination statewide. The DEQ strategy prioritizes three key action areas:

- **Protecting Communities** – DEQ 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** – DEQ 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** – DEQ 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.

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 this plan. The most up to date information on the extent of PFAS contamination within the Cape Fear River Basin, what studies have been completed, and what actions have been taken to date 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. Publicly Owned Treatment Works (POTWs) are not specifically designed to reduce or eliminate emerging contaminants from their waste streams. Research studies revealed that various PFAS

contaminants within the Cape Fear River could not be removed using existing conventional treatment methods of coagulation, sedimentation, dual-media filtration, and chloramination. Many of the public water supply utilities in the Cape Fear River Basin have taken the initiative to upgrade their treatment works to remove PFAS compounds in order to supply finished drink water to their customers below the National Primary Drinking Water Regulations MCLs (see section 12.3.9.2). Several water treatment facilities are installing granular activated carbon (GAC) or Low Pressure Reverse Osmosis (LPRO) to remove PFAS contaminants.

2.13.2 1,4-Dioxane

Following reports of elevated 1,4-dioxane concentrations under the EPA's Third Unregulated Contaminant Monitoring Rule ([UCMR3](#), 2013-2015), DWR initiated a study in October 2014 to assess 1,4-dioxane in surface waters of the Cape Fear River Basin with the objective of identifying potential sources, understanding changes in concentrations, and documenting data that will help the state develop a regulatory strategy ([DWR, 2016](#)).

During the Cape Fear study, elevated levels of 1,4-dioxane were identified mainly downstream of the City of Asheboro, Greensboro and Reidsville 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 Clean Water Act. DWR 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 of the basin plan. A specific chapter (Chapter 13) with detailed Cape Fear River Basin studies and DEQ actions addressing the contaminant is included as part of this basin plan.

1,4-Dioxane persists in water and is readily transported downstream because of a unique combination of physical and chemical properties. 1,4-Dioxane does not readily stick to soil particles, sludge/biosolids or sediments. As a result, when 1,4-dioxane enters a waterway, it remains dissolved and travels long distances, leading to widespread contamination of surface water resources. Conventional wastewater treatment processes and techniques typical of Publicly Owned Treatment Works (POTWs) generally do not remove 1,4-dioxane and so it generally passes through treatment plants and is discharged with wastewater effluent to receiving streams. 1,4-Dioxane is also not readily captured using granulated activated carbon commonly used to capture PFAS compounds ([Wilbur et al., 2012](#) and [Hogue, 2020](#)).

Unlike PFAS, 1,4-dioxane comes from a smaller number of sources and is not widespread across the state. Most of North Carolina's 1,4-dioxane pollution can be traced to specific industrial dischargers in the Cape Fear River Basin and are mainly detectable downstream of the cities of Asheboro, Greensboro and Reidsville. Setting enforceable discharge limits in NPDES permits would address most of the contamination problem.

Emerging Compounds Conclusion

Each investigation and study enhances our understanding of PFAS and 1,4-dioxane, enabling more informed actions to protect communities, drinking water supplies, and the environment. This growing

body of knowledge will help prevent future contamination and enhances the effectiveness of remediation efforts. Reducing contamination at the source is the most effective strategy to protect human health and the environment while minimizing the financial burden to downstream utilities and ratepayers. Collaborative efforts with researchers, dischargers, and industrial producers are advancing the development of the most effective treatment solutions. New and emerging treatment technologies are being implemented at solid waste facilities, centralized wastewater treatment plants, and industrial operations to mitigate PFAS and 1,4-dioxane impacts.

DEQ is working within our authority to understand and address PFAS and 1,4-dioxane in surface waters. DEQ continues to work with the Environmental Management Commission to develop watershed protection measures for all designated uses by identifying, reducing, and remediating PFAS and 1,4-dioxane pollution. As progress is made, updated information can be found on the [DEQ Emerging Compounds website](#).

2.13.3 Unregulated Contaminant Monitoring Rule (UCMR)

The Safe Drinking Water Act (SDWA) requires that once every five years EPA issue a list of unregulated contaminants to be monitored by public water systems (PWSs). The fifth Unregulated Contaminant Monitoring Rule (UCMR5) was published in December 2021. PWSs will collect samples for 29 PFAS and lithium, during a 12-month period from January 2023 through December 2025. All large (serve > 10,000 people) and small (3,300 to 10,000 people) systems must monitor for the 30 contaminants subject to availability of appropriations and sufficient laboratory capacity. A subset of PWSs that serve fewer than 3,000 people were also randomly selected to monitor. Surface water, groundwater under the direct influence of surface water, mixed sources, and groundwater systems are included. EPA continues to be responsible for all analytical costs associated with monitoring of systems serving 10,000 or fewer people. If EPA does not receive the appropriations needed in a given year, then a reduced number of small systems will perform monitoring (EPA, 2023). Statewide, there are 298 PWSs participating in the UCMR5. Sixty-six are in the Cape Fear River Basin (*Table 2-21* and *Figure 2-55*).

Table 2-21: North Carolina Water Systems Requiring UCMR5 Monitoring

NC Basins	No. of Systems	NC Basins	No. of Systems
Broad	8	Neuse	43
Cape Fear	66	New	3
Catawba	38	Pasquotank	12
Chowan	5	Roanoke	9
French Broad	16	Tar	19
Hiwassee	1	White Oak	15
Little Tennessee	5	Yadkin	41
Lumber	17		
Total number of PWSs monitoring in NC = 298			

2.14 Nutrient Criteria Development Plan (NCDP)

In 2001, the US EPA strongly encouraged every state to develop nutrient criteria if states did not currently have site specific criteria in place to protect waterbodies from nutrient over-enrichment (eutrophication) issues. In 2014, North Carolina developed a Nutrient Criteria Development Plan (NCDP) which laid out the approach NC would take to achieve this requirement. The goal is to develop scientifically defensible criteria based primarily on the linkage between nutrient concentrations and protection of designated uses. The EPA-approved North Carolina NCDP identified three specific waterbody types and prioritized the development of criteria in three pilot watersheds. These watersheds were identified as possibly experiencing impacts from excess nutrients and were chosen to facilitate appropriate management actions by DWR based on any new criteria developed. The specific waterbody type and pilot watersheds are:

- 1.) Reservoir and Lakes – High Rock Lake in the Yadkin-Pee Dee River basin;
- 2.) Rivers and Streams – Central portion of the Cape Fear River in the Cape Fear River Basin;
- 3.) Estuaries - Albemarle Sound in the Pasquotank River basin (Chowan River added in 2019).

The NCDP was approved by the EPA in 2014 which was followed by the development of a Science Advisory Council (SAC) and a Criteria Implementation Committee (CIC). The SAC is composed of experts in areas specifically related to water quality including water ecosystems, nutrient response modeling and statistics, nutrient management, hydrology and dams, and point and non-point nutrient abatement and is meant to help provide scientific guidance to DWR for the development of appropriate nutrient related criteria. The CIC members have expertise in wastewater abatement technology, linking nutrient criteria to permitting and management, point and/or nonpoint source pollution, water quality/nutrient management economics, or agriculture, and provides recommendations on the feasibility, application, and implementation of a proposed nutrient criteria.

The development of an appropriate numeric criterion for any waterbody requires many steps. At a minimum, the initial steps include:

- 1.) identification of designated uses for protection,
- 2.) determining of the response variables affected by nitrogen or phosphorus concentrations or loading, and
- 3.) identifying the most sensitive species to these nutrients or uses impaired by them.

These steps must be taken for each specific parameter under consideration. The EPA-approved plan defines “numeric nutrient criteria” and “nutrient criteria” as either of the following:

- Causal and response variables expressed as numerical concentrations and/or mass quantities or loadings.
- Causal and response variables expressed as narrative statements with a scientifically defensible translator mechanism to derive or calculate numerical concentrations and/or mass quantities or loadings. Rule language will clarify that the translator will be used by the implementing programs.

Causal Variables	Response Variables
Nitrogen	Chlorophyll <i>a</i>
Phosphorus	Phytoplankton
	Periphyton
	Macrophytes
	Diurnal Dissolved Oxygen (DO) Range
	Minimum DO
	Diurnal pH Range
	Water Clarity
	Others

The first NCDP-SAC meeting was held on May 6, 2015, with the focus on developing criteria for High Rock Lake. The NCDP process resulted in a proposal for a site-specific chlorophyll *a* criterion for High Rock Lake. This site-specific standard was approved by the North Carolina Environmental Management Commission on July 14, 2022, and subsequently by the EPA on December 7, 2022.

In May 2019, EPA approved a modification to NC’s NCDP to pair the Albemarle Sound and Chowan River waterbodies for development of numeric nutrient criteria. This allows for a more holistic nutrient criteria development strategy for the watershed since the Chowan River directly influences the condition of the Albemarle Sound. The Albemarle/Chowan SAC NCDP kick off meeting was held on October 30, 2019. The progress was slowed during Covid-19, however in 2023, DWR and the SAC are working on water clarity criteria for the protection of SAV. This will likely lead to additional criteria development such as a modified chlorophyll *a* and/or nitrogen and phosphorus criteria. This is an ongoing process (as of publication of this basin plan in 2023).

In the Cape Fear River Basin, model development work is underway to give decision makers the appropriate tools to address the basin needs, including support of the NCDP process. Prior to 2019, DWR’s Modeling and Assessment Branch worked with monitoring coalition programs in the Cape Fear River Basin to increase monitoring of wastewater effluent constituents and participated in a two-year (2019-2020) intensive instream monitoring study. The result of the study will inform model development for the central portion Cape Fear River watershed. For more details on this effort, see the *Central Cape Fear River Modeling and Study Plan* section below. As of 2023, model development is underway with the help of the EPA Region IV’s modeling team. The model development, calibration, and validation are projected to be complete by the end of 2023.

The central portion of the Cape Fear River Basin contains approximately 6,050 miles of rivers and streams and begins below the B. Everett Jordan Reservoir dam along the lower Haw River, and below Randleman Lake dam along the Deep River and extends to U.S. Army Corps of Engineers’ Lock and Dam #1 (LD1) on the Cape Fear River at Riegelwood, approximately 39 miles upstream of Wilmington, NC (figure). This area has been identified as a priority for nutrient management since the early 2000s. This is one of the fastest growing regions of the state and there is a need to determine nutrient allocation for waste assimilation,

assess the effects and management of nutrients discharged from point and nonpoint sources, and likely develop new drinking water sources in this region.

There is a history of high nutrient concentrations throughout much of the Cape Fear River Basin, with algal blooms and high chlorophyll *a* concentrations occurring behind the locks and dams in the central portion of the Cape Fear River, particularly during dryer low flow periods. Nutrient-related impacts are occurring in smaller headwater streams all the way down to the large mainstem Cape Fear River.

As of 2023, NC mainly relies on the statewide chlorophyll *a* standard of 40 µg/L as a response variable to protect the designated uses throughout the state's rivers, lakes, and estuaries from nutrient enrichment issues. This has been used as a one-size-fits-all approach and while chlorophyll *a* is often a clear response in some ecosystems, it is not the most effective response in others such as fast flowing streams where planktonic algae cannot grow due to physical constraints (Section 2.5.8) or in small order streams where algal growth is attached to rocks and stream beds which can inhibit both recreational uses and well as have negative impacts on aquatic habitat and health. Often, chlorophyll *a* is not monitored in flowing streams due to its limited use as a reliable water quality indicator in these systems. A lot of work is underway to better understand this system as a whole. DWR and the NCDP SAC will work together to determine the most appropriate and scientifically defensible criteria to use in protecting the central Cape Fear River system's designated uses so that there is reliable, safe, drinking water, recreational resources and sustainable aquatic health and ecosystems.

For more information see the [NCDP webpage](#) and the [2019 North Carolina Nutrient Criteria Development Plan \(V2\)](#).

Central Cape Fear Modeling and Study Plan

In 2019, DWR began an intensive monitoring study to gather additional information to support Dissolved Oxygen and Nutrient modeling efforts. Both the Upper and Middle Cape Fear River Basin Monitoring Coalitions supported this study by increasing monitoring frequency and parameters at select stations as well as increasing monitoring frequency of several effluent constituents for select dischargers. More information on the study plan is provided [here](#).

EPA Region IV's modeling team is collaborating with DWR's modeling staff to develop both watershed and receiving water models for the areas of interest. These models are needed to support permitting in the basin, inform the development of management strategies for impaired waters, provide information on conditions associated with algal bloom frequency and duration, and provide information on the sources of nutrients and BOD-loading to the lower Cape Fear River.

As currently designed, the modeling will support permitting below Randleman and Jordan Lakes down to Lock and Dam #1, as shown below in [Figure 2-56](#).

Monitoring coalitions and DWR field monitoring and laboratory staff prioritized monitoring in this segment of the Cape Fear River throughout the COVID-19 pandemic in 2020. The DWR Planning Section

would like to acknowledge and commend their efforts to ensure that DWR had the data needed to complete this critically important project.

Figure 2-56: Central Cape Fear River Model



The Areas in Color Represent the “Central Portion” of the Cape Fear River Basin for which Nutrient Criteria are Proposed. (Note: The areas in gray either have a Nutrient Management Strategy and/or a Model or drain to the portion of the Cape Fear River Downstream of Lock and Dam #1 (LD 1). (The subwatersheds in color are either listed as impaired for chlorophyll-*a* or are of concern for nutrient over enrichment.)

2.15 Vibrio Bacteria Advisory

NCDHHS Urges Caution After Three Deaths Due to Vibrio this Summer (2023)

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

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

In July 2023, the North Carolina Department of Health and Human Services put out a press release encouraging North Carolinians to be aware of the potential dangers of having wounds or cuts open to saltwater or brackish water following reports of three deaths due to Vibrio infections in North Carolina residents.

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 for 15 seconds, [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](#).

2.16 Protecting Water Resources in the Cape Fear River Basin

Over the past several years, the North Carolina State Government has struggled to retain and fill positions due to a highly competitive job market. DEQ is no exception to this circumstance and the Department has worked to use all available resources to improve employee pay, increase recruitment efforts and advocate for additional resources.

Development of river basin plans requires high quality, consistently collected instream water quality monitoring data in order to have the information necessary to understand changing water quality conditions and concerns throughout a basin. Without adequate data, making any meaningful assessment will be nearly impossible, impacting permitting and increasing the time needed to make management decisions.

A well-resourced, successful, consistent monitoring program will provide DEQ a better understanding of current water quality conditions, changing conditions and trends analysis, inform modeling for TMDLs, and help develop watershed strategies and restoration plans. Funding and staff are also needed for fish tissue collection, testing, data analysis, and public education and outreach not only in DEQ but all the Department of Health and Human Services (DHHS) which issues fish consumption advisories.

Monitoring

There are many potential point and nonpoint sources of pollutants or stressors that can cause a waterbody to exceed water quality standards. Known permitted facilities or structures (i.e., wastewater irrigation fields or wastewater ponds) are potential sources, but there are often land-use activities that are unknown or not verifiable in a watershed that can contribute significantly to degraded water quality. There are also portions of the watershed where no water quality data are collected, making it difficult to understand water quality conditions. Limited ambient water quality data makes it difficult to evaluate water quality condition and pinpoint the source of water quality problems to prioritize mitigative measures. When resources allow the Basin Planning Branch has the following recommendations for expansion of the ambient, biological, and algal monitoring programs:

- The Basin Planning Branch should work with the AMS program to review the location and parameters monitored. There are known data gaps and areas in which additional parameters such as nutrients, metals (dissolved), bacteria, or chlorophyll *a*, would be beneficial in order to understand areas of concern and potential sources that could be addressed.
- DWR will work with the Cape Fear River Basin Monitoring Coalitions to identify priority water quality stations for dissolved metals monitoring to address historical total metals impairments and to include dissolved metals monitoring at selected coalition monitoring stations to fill data gaps.
- Evaluate the need for additional staffing and resources to enable the Biological Assessment Branch to assess the condition of North Carolina’s aquatic organisms and habitat at the levels previously assessed. In the Cape Fear River Basin, biological sampling declined from 196 sites in 2003 to 82 in 2018.
- Evaluate the resources needed to respond adequately to the increasing incidences of potentially harmful algal blooms (HABs). There is a critical need to grow the algal monitoring program to better assess statewide algal blooms and identify toxins that could be harmful to aquatic life and public health. This could require hiring more field monitoring and laboratory support staff (algal taxonomist and chemist) for toxin analysis.
- Address resource constraints for fish tissue collection and analysis. There are multiple sources of pollutants in the lower Cape Fear River that have the potential to contaminate fish and shellfish tissue and cause health risks. More funding is needed to support tissue collection, testing, data analysis, and outreach at DEQ and NCDHHS.
- Federal, state and local resources agencies should continue to fund and expand the well network and water quality sampling efforts throughout the state to understand changing groundwater levels and quality.

Contaminants of Emerging Concern

- DEQ continues to work with the Environmental Management Commission to develop watershed protection measures for all designated uses by identifying, reducing, and remediating PFAS and 1,4-dioxane pollution.
- DEQ is working within our authority to understand and address PFAS and 1,4-dioxane in surface waters. DWR is working with dischargers to identify potential sources of emerging contaminants and to address or eliminate the contamination at the source prior to being discharged to wastewater treatment plants.

Nutrient/Nutrient Criteria Development Plan (NCDP)

- As directed by the EPA, DWR will work with the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) to develop appropriate instream criteria and response variables that make it possible to accurately assess the health and protect both small streams and large riverine systems in the central Cape Fear River Basin.
- DWR needs to review and/or develop appropriate monitoring protocols needed to accurately assess the biological productivity in the Cape Fear River Basin's flowing streams and rivers.
- Develop appropriate TMDLs and/or nutrient management strategies as needed to reduce nutrient loading from point and nonpoint sources to protect designated uses.

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