Contents

Chapter 1
White Oak River Basin Overview & Basin Characteristics

1.1 Geography & Ecoregion Characteristics

The White Oak River basin is located between the southeast portion of the Cape Fear River basin and southwest portion of the Neuse River basin. The Atlantic coast forms the southeast boundary of the basin. The basin includes the eastern portion of the City of Wilmington within the southwest portion of the basin, the City of Jacksonville within the central portion of the basin and Morehead City within the eastern portion of the basin. The boundaries of the basin include most of Onslow County, almost half of Carteret County, and the southeast portions of New Hanover, Duplin, and Pender counties, the southeast portion of Jones and Craven counties and a tiny portion of southeast Brunswick County.

The White Oak River Basin lies entirely within the Coastal Plain and is composed of four small river systems (New River, White Oak River, Newport River, and North River), which all drain south directly into the Atlantic Ocean and associated sounds (Back, Core and Bogue sounds). The White Oak River is approximately 40 miles long and is a blackwater river. This basin encompasses 1,382 square miles, making it the smallest basin contained entirely within the state. There are 1,571 stream miles, 3,777 acres of freshwater lakes and impoundments, and 1,641 miles of coastline in the basin (NCDWR 2015). Due to the location and size of this basin, there is a relatively small amount of freshwater habitat available, but what is available has the characteristics typical of Coastal Plain streams: meandering waters associated with swamps, hardwood bottomlands, and wetland communities (NCDWQ 2003).

The Division of Water Resources' (DWR) previous basinwide water quality plans used subbasin boundaries that were numbered based on the river basin and location within the river basin. DWR has changed how these subbasins are grouped to conform to the federal cataloging unit known as HUCs. Each HUC is identified by a unique number. The largest HUC is two digits (region). Two additional digits can be added to the HUC to sub-divide it into smaller areas, or watersheds. The HUCs are nested within each other from the largest geographic area (region) to the smallest geographic area (cataloging unit) (USGS, 2020). Each HUC represents the area of the landscape that drains to a portion of the stream network (USGS, 2020).

Figure 1-1 compares the former and current White Oak River Basin hydrologic boundaries. In 2009, the then Division of Water Quality (DWQ) adopted the National Watershed Boundary Dataset (NHD), which is based on the USGS 1:24,000 ridgelines. The White Oak River Basin HUC (03020302) is made up of two subbasins, : White Oak River (Northeast) (HUC 03020301) and New River (Southwest) (HUC 03020302). The White Oak River Basin now includes all of the former DWQ White Oak subbasins subbasins 03-05-01, 03-05-02, 03-05-03, 03-05-04, and 03-05-05, as well as, former Cape Fear River Basin subbasin 03-06-24.

1.2 Population & Land Cover

1.2.1 Population

Information on population density is useful in determining what watersheds are likely to have the most impacts as a result of population growth. Information on population densities can also identify where there may be opportunities for preservation or restoration activities. Population information is intended to present an estimate of expected population growth in the counties and municipalities located wholly or partially in the White Oak River basin. County populations were obtained from the North Carolina Office of State Budget and Management (OSBM) in 2014 and can be projected out to 2030. Population projections for public water supply (PWS) systems are projected out to 2060 and are required as part of the local water supply plan (LWSP) (Chapter 8).

According to data available through OSBM, the counties in the basin with the largest projected population growth between 2010 and 2030 are Brunswick (58.98%), Pender (46.77%), and New Hanover (35.16%). Only one county, Craven, is projected to have a slight decline in population (-0.09%) (Table 1-1).

Recreational opportunities in the basin often lead to portions of the basin being frequented by tourists. This influx of people, or seasonal population, can stress existing municipal water and wastewater systems as well as contribute to increases in nonpoint and point sources of pollution. Proper land use planning can assist local leaders in establishing long-range goals, help control the rate of development and growth patterns, and ensure open space is conserved throughout the basin.

Figure 1-1: Historic and Current Subbasin Boundaries

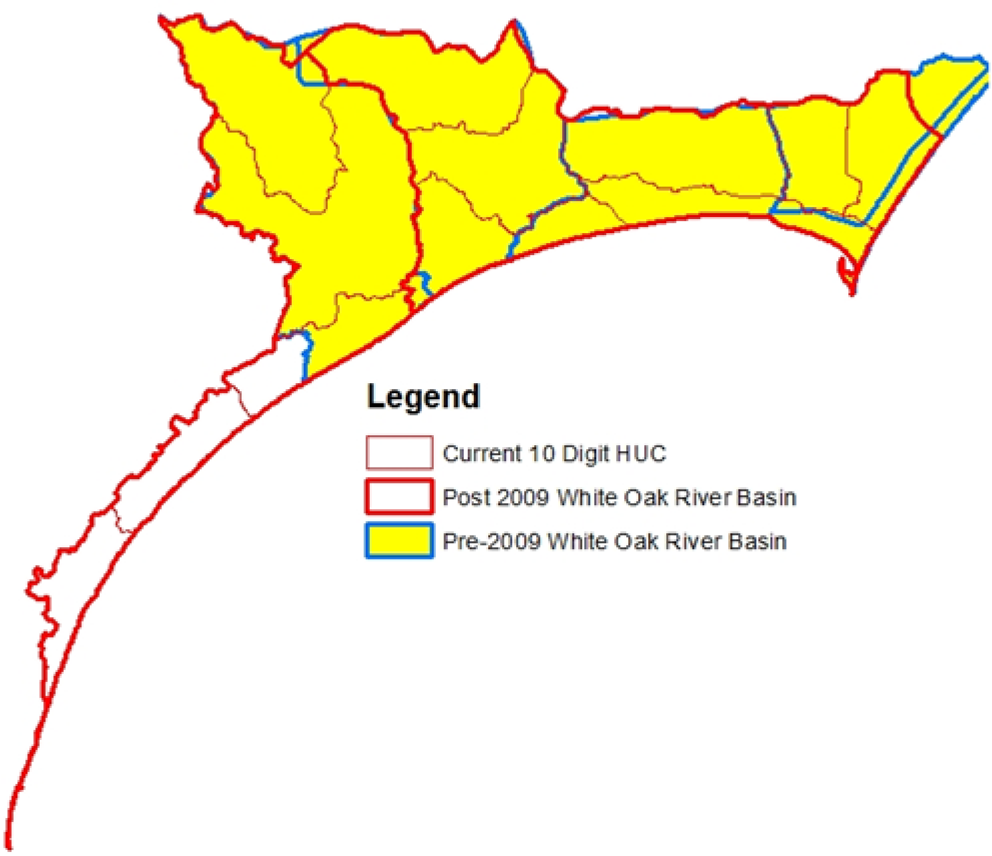


Table 1-1: Population Growth and Projections - County (OSBM, 2019)

County Name	County Area (mi²)	Percent County in the Basin	Area in Basin (mi²)	July 2010	July 2020	July 2030	Percent Growth July 2010 - July 2020	Percent Growth July 2020 - July 2030	Percent Growth July 2010 - July 2030
Onslow	819	80.48	659.5	150,495	162,425	179,976	7.93	10.81	19.59
Carteret	1,040	43.93	456.7	29,297	31,476	33,992	7.44	7.99	16.03
New Hanover	220	31.56	69.3	64,173	75,197	86,738	17.18	15.35	35.16
Jones	475	18.53	87.9	1,867	1,919	1,919	2.78	0.01	2.79
Pender	880	7.18	63.2	3,757	4,660	5,515	24.03	18.34	46.77
Craven	771	5.72	44.1	5,962	5,946	5,956	-0.27	0.18	-0.09
Brunswick*	896	0.04	0.4	45	59	72	30.96	21.40	58.98
Duplin*	819	0.04	0.3	24	25	24	1.25	-0.77	0.47
Totals	**5,920**		**1,381.5**	**255,621**	**281,707**	**314,193**	**10.20**	**11.53**	**22.91**

*The numbers reported here reflect percent county population within the White Oak River basin. The intent is to demonstrate growth for counties located partially or entirely within the basin.

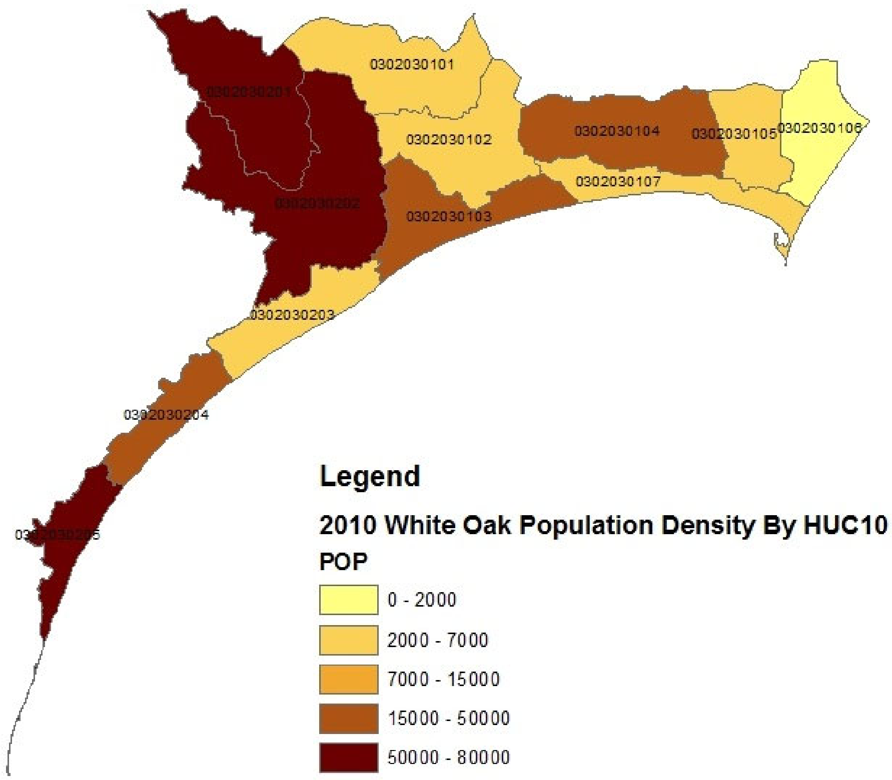
Using county projections from OSBM, land use and parcel datasets, population can be estimated for each HUC 10 in the White Oak River basin. New River and Masonboro Inlet are the most populated watersheds. Oyster Creek – Jarrett Bay is the least populated. (Table 1.2, Figure 1.2). The numbers presented in Table 1-2 and Figure 1-2 are based of the 2010 Census and reported by OSBM in 2014. Land area was calculated from the 2011 National Land Cover Database (NLCD) dataset.

Table 1-2: Estimate Population Projections – HUC 10 (OSBM, 2014)

HUC 10 Watershed Name	HUC 10	Land Area (mi²)	Population 2010	Population 2020	Population 2030
Headwaters White Oak River	0302030101	142.4	3,793	3,878	3,917
Outlet White Oak River	0302030102	131.0	7,927	8,376	8,659
Bogue Banks - Bogue Sound	0302030103	104.9	22,874	24,145	24,956
Newport River	0302030104	148.7	26,333	28,093	29,187
North River	0302030105	68.5	6,482	6,915	7,184
Oyster Creek - Jarrett Bay	0302030106	83.5	1,987	2,119	2,202
Bogue Banks - Shackleford Banks	0302030107	78.5	16,342	17,434	18,113
Headwaters New River	0302030201	161.1	56,774	59,625	61,477
New River	0302030202	254.8	82,567	86,711	89,400
Headwaters New River Inlet	0302030203	81.2	10,527	11,260	11,818
Topsail Beach	0302030204	63.6	17,536	21,631	25,582
Masonboro Inlet	0302030205	63.5	76,360	91,469	106,000
	Total	**1381.5**	**329,504**	**361,655**	**388,495**

Note: The numbers reported here reflect county population. The county is not necessarily entirely within the basin.

Figure 1-2: HUC 10 Estimated Population 2010 (OSMB, 2014)



1.2.2 Land Use – National Land Cover Data

Land cover information can assist local, state and federal managers and officials assess ecosystem status and health. Land cover can also assist with modeling nutrient and pesticide runoff, understanding spatial patterns in biodiversity, developing land use management policies, and evaluating the effects of land use changes on water quality (NLCD, 2016). North Carolina uses land cover datasets available from the NLCD. Land cover types, number of acres and percent coverage are included in Table 1.3. Spatial distribution is shown in Figure 1.3.

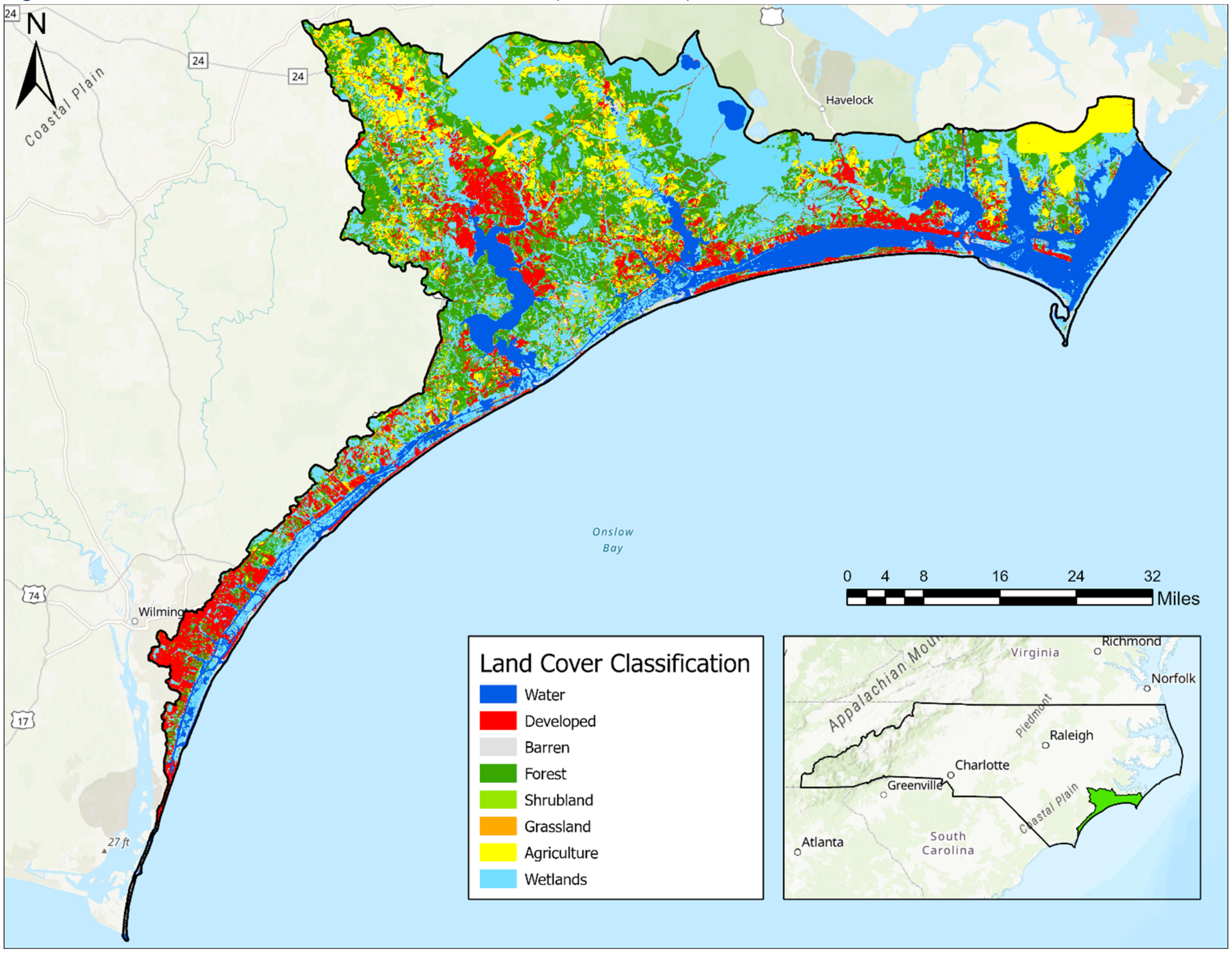
Table 1-3 Land Use on the Basin and HUC Scale in the White Oak River Basin (NLCD, 2016)

2016 Land Cover	White Oak River Basin HUC6 030203		White Oak Subbasin HUC8 03020301		New River Subbasin HUC 8 03020302	
	Area Square Miles	Percentage Basin Coverage	Area Square Miles	Percentage Basin Coverage	Area Square Miles	Percentage Basin Coverage
Water	217.08	**15.71**	155.03	**20.47**	61.96	**9.93**
Developed	178.95	**12.95**	61.64	**8.14**	117.24	**18.79**
Barren	19.04	**1.38**	10.46	**1.38**	8.50	**1.36**
Forest	313.23	**22.67**	151.20	**19.97**	161.97	**25.96**
Shrubland	38.41	**2.78**	17.48	**2.31**	20.92	**3.35**
Grassland	23.21	**1.68**	9.35	**1.23**	13.86	**2.22**
Agriculture	141.33	**10.23**	79.48	**10.50**	61.81	**9.91**
Wetlands	450.37	**32.60**	272.64	**36.00**	177.65	**28.47**
Total	1381.62	**100.00**	757.27	**100.00**	623.91	**100.00**

Some of the largest impacts to water quality are based on land use adjacent to and the headwaters of a watershed. In municipal areas, impervious surfaces can prevent rainfall from filtering into the ground. This filtering, in turn, can remove some of the nutrients and bacteria found in stormwater before the water enters the nearest waterbody. Stormwater and snow melt also recharges groundwater supplies.

In impervious areas, much of the stormwater is sent directly to storm drains and culverts. Many of the storm drains and culverts empty into the nearest waterbody. The direct delivery of stormwater to a stream can have multiple negative impacts to water quality and aquatic habitat including: elevated water temperature, increased sediment and nutrient delivery including chemical compounds that can be found on highways, city streets and neighborhood driveways, and excess erosion due to increased stream velocity. Slowing and diverting stormwater from streams can, in some cases, protect streams from severe erosion and sedimentation.

Figure 1-3: Land Use Cover – White Oak River Basin (NCLD, 2016)



1.3 Point Source Pollution

Point source pollution refers to pollution that enters surface waters through "any discernable, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container" (US EPA, 2019). Point source pollutants are primarily associated with wastewater and stormwater discharges from municipal (city and county) and industrial wastewater treatment facilities. They can also originate from small, domestic wastewater systems that serve schools, commercial properties, residential subdivisions, and individual homes. To ensure that point source pollution does not negatively impact water quality or human health, wastewater, and stormwater point source pollutants are regulated through the National Pollutant Discharge Elimination System (NPDES) Program. The NPDES permitting program sets monitoring and treatment requirements for facilities discharging wastes directly to surface waters (US EPA, 2019). The program also keeps records of the spatial location of point sources of pollution. This information from the NPDES program can be assessed alongside ambient water quality data to ensure that both permit requirements are being met and are sufficient to protect the water quality of receiving streams and rivers. More information about permitted programs can be found in Permitted and Registered Activities chapter (Chapter 7).

1.4 Nonpoint Source Pollution

Nonpoint source pollution (NPS) is defined to mean "any source of water pollution that does not meet the legal definition of "point source" in Section 502(14) of the Clean Water Act (CWA)" (US EPA, 2020). NPS can result from any number of activities and land uses. Construction and land clearing activities, agriculture, golf courses, mining operations, solid waste disposal sites, urban landscapes, and on-site wastewater treatment systems (septic systems) all contribute to NPS and can add sediment, nutrients, bacteria, heavy metals, oil, and grease to a waterbody. NPS is difficult to monitor and account for. DWR works with several state and local agencies to identify potential NPS and the types of activities that may be impacting water quality in the area, but data gaps exist. These unknowns include, but are not limited to, the amount of fertilizers, pesticides, herbicides, and dry-litter animal waste applied to land, as well as the level at which these same pollutants may be impacting groundwater and air quantity and eventually reaching surface waters through base flow or atmospheric deposition.

There are several programs in place through various organizations that protect water resources from NPS. Many include funding for best management practices (BMPs) that can reduce the amount of sediment, nutrients, and bacteria entering a waterbody as well as protect streambanks, reduce erosion, and manage waste. More information about these programs can be found in the Statewide, Regional and Local Initiatives chapter (Chapter 6).

The New River and several of its tributaries are identified as Nutrient Sensitive Waters (NSW). Management strategies were put into place in 1991 to help control the amount of nutrients entering the river from point sources of pollution. In addition, many areas in the basin are identified as shellfish growing areas. Shellfish growing areas can be impacted from both point and nonpoint sources of pollution. To better understand where potential nutrient sources may be contributing to water quality impairments in the basin, information on the location of potential nutrient sources (including dry litter poultry operations and manure hauling) could help DWR adapt the basinwide ambient monitoring program, identify new water quality monitoring stations, and help create a mass balance of nitrogen and phosphorus for the basin. Stream monitoring data has historically been valuable in understanding and addressing nutrient related impacts to recreational use, the economic well-being, and overall ecological integrity of the basin (Deerhake, personal communication). DEQ will continue to work collaboratively with federal, state, and local agencies, as well as stakeholders in the basin, to target water quality monitoring and BMP implementation throughout the basin.

1.4.1 Agriculture

Approximately 10 percent of the land use in the White Oak River basin is identified as agriculture (Table 1.3). Excess nutrients, pesticides, herbicides, bacteria, and sediment are often associated with agricultural activities. To understand how agriculture has changed over the past 10 to 15 years, the USDA, National Agricultural Statistic Service's (NASS) Census of Agriculture was reviewed. The USDA publishes the Census of Agriculture every five years. The data collected by and reported in the census provide an overview of agricultural operations on a national, state, county, or county equivalent scale to show the importance and value of agriculture to a particular region. It also helps evaluate historic agricultural trends to formulate policies, develop programs, and identify and allocate local and national funds for agricultural programs. The data can be queried at the state, county, or watershed scale. Agriculture data was queried at the county scale for counties with more than 15 percent of their land area located entirely or partially within the White Oak River basin. This included Onslow, Carteret, Jones, and New Hanover counties. Less than 10 percent of the land area in Pender, Craven, Brunswick, and Duplin counties are located in the basin. Therefore, they were not included in the query for agriculture statistics. Information that is obtained through the Census of Agriculture is for information purposes only and basin planning does not evaluate or use the data for statistical purposes. In addition, the data cannot be used to identify the extent of potential impacts of animal agriculture, animal waste application, or crop management on water quality. It can, however, be used to compare changes over time to help basin planners understand what types of agriculture operations exist in each county.

Per the 2017 Census of Agriculture, a total of 734 farm are operating on a total of 181,765 acres (284 mi^2) in Onslow, Carteret, Jones, and New Hanover counties. This is a slight decrease from what was reported in the 2007 Census of Agriculture when 792 farms were operating on a total of 184,092 acres (287 mi^2). The total number of acres identified as cropland has remained steady with a slight decrease from 131,070 acres (205 mi^2) in 2007 to 129,646 acres (203 mi^2) in 2017. Pastureland has also seen a decline of nearly 4,000 acres (6 mi^2) since 2007 while the total number of acres identified as woodland saw a slight increase from 33,765 (53 mi^2) acres in 2007 to 34,551 acres (54 mi^2) in 2017 (Table 1-4).

To understand how animal agriculture has changed over time, the Census was queried for chickens (broilers), hogs, cattle (including calves), and equine (horses and ponies). Inventory was used in the query animal numbers to provide consistency across all animal types. Per the 2017 Census of Agriculture, the poultry inventory increased significantly between 2007 and 2012 from 276,581 birds (chickens, broilers) on 12 farms to 1.7 million birds (chickens, broilers) on 26 farms. In 2017, the total number of birds and total of number of farms increases again to nearly 2.9 million birds (chickens, broilers) on 53 farms (Table 1-4). Jones County had the highest inventory followed by Onslow (Table 1+5). While poultry numbers increased, livestock inventory for cattle, hogs, and equine decreased between 2007 and 2017 (Table 1-5) (USDA, 2017).

Animal operations are defined under General Statute 143.215.10B as feedlots that have more than 250 swine, 100 confined cattle, 75 horses, 1,000 sheep, or 30,000 confined poultry with a liquid waste management system. All permitted animal operations are required to have a Certified Animal Waste Management Plan (CAWMP). The CAWMP is incorporated into the animal permit issued by DWR by reference and defines the fields to which waste is land applied, crops to be grown, and other details about the operation. All waste must be applied at no greater than agronomic rates (an amount that can be used productively by the crops that are planted) (General Statute 143-215.10C). These permitted animal facilities are inspected annually. As of May 2020, there were 46 permitted animal operations in the White Oak River basin. All are permitted swine operations. Four are individual permits and 42 are Certificates of Coverage (COC). A locational map of permitted facilities can be found in Chapter 7 and a table can be found in Appendix VII. There are no permitted poultry, cattle, or horse operations in the White Oak River basin.

Table 1-4 USDA Census of Agriculture Onslow, Carteret, Jones, and New Hanover Counties 2007, 2012, 2017

Commodity	2007	2012	2017	2007	2012	2017
	Number of Operations			Number of Acres		
Number of Farms & Land Area	792	692	734	184,092	182,727	181,765
Land Use						
Irrigated Acres	165	105	59	7,440	2,864	1,100
Practices, Land Drained, Artificial Ditches	-	-	300	-	-	80,672
Practices, Land Drained, Tiles	-	-	55	-	-	3,722
Total Cropland	579	484	473	131,070	130,403	129,646
Total Cropland, Harvested	435	395	381	119,316	122,619	119,102
Total Pastureland	368	299	300	14,664	10,514	10,763
Total Woodland	392	366	330	33,765	36,436	34,551
Crops						
Corn, Grain	169	139	130	44,711	15,005	22,114
Cotton	26	47	41	11,365	24,773	15,979
Forage (Hay & Haylage)	151	118	105	4,815	3,465	3,088
Peanuts	9	12	10	907	1,818	496
Soybeans	146	146	138	44,993	47,799	27,817
Tobacco	29	13	12	2,749	2,086	2,028
Wheat	56	69	39	12,152	15,723	6,155
Fertilizers						
Manure	131	87	126	9,539	8,272	7,261
Total	407	318	329	106,739	108,472	98,559
Livestock Inventory	**Number of Operations**			**Number of Animals**		
Cattle (Including Calves)*	135	158	154	5,683	3,277	3,244
Chickens (Broilers)*	12	26	53	276,581	1,718,222	2,889,069
Equine (Horses & Ponies)	194	153	110	1,337	1,086	773
Hogs*	148	109	115	479,014	688,072	494,594

* Information withheld from one or more counties to avoid disclosing data for individual farms (USDA, 2017).

- = Data not collected during the 2007 or 2012 Census

Table 1-5 USDA Census of Agriculture Animal Inventories 2007, 2012, 2017

Commodity	County	Inventory (End of December)			Number of Operations		
		2007	2012	2017	2007	2012	2017
CHICKENS, BROILERS	CARTERET	36	100	1,805	3	4	7
	JONES	276,545	682,010	2,354,080	3	10	16
	NEW HANOVER		(D)	180	0	1	6
	ONSLOW	(D)	1,036,112	533,004	6	11	24
	TOTAL	**276,581**	**1,718,222**	**2,889,069**	**12**	**26**	**53**
HOGS	CARTERET		42	88	0	6	8
	JONES	201,120	366,159	306,594	50	35	36
	NEW HANOVER		(D)		0	2	0
	ONSLOW	277,894	321,871	187,912	98	66	71
	TOTAL	**479,014**	**688,072**	**494,594**	**148**	**109**	**115**
CATTLE, INCLUDING CALVES	CARTERET	159	293	351	8	18	19
	JONES	3,538	1,098	830	38	46	39
	NEW HANOVER		(D)	(D)	0	2	1
	ONSLOW	1,986	1,886	2,063	89	92	95
	TOTAL	**5,683**	**3,277**	**3,244**	**135**	**158**	**154**
EQUINE, HORSES & PONIES	CARTERET	306	214	412	47	34	39
	JONES	172	158	104	29	34	26
	NEW HANOVER	94	81	96	9	14	11
	ONSLOW	765	633	161	109	71	34
	TOTAL	**1,337**	**1,086**	**773**	**194**	**153**	**110**

(D) Information withheld from one or more counties to avoid disclosing data from individual farms (USDA, 2017)

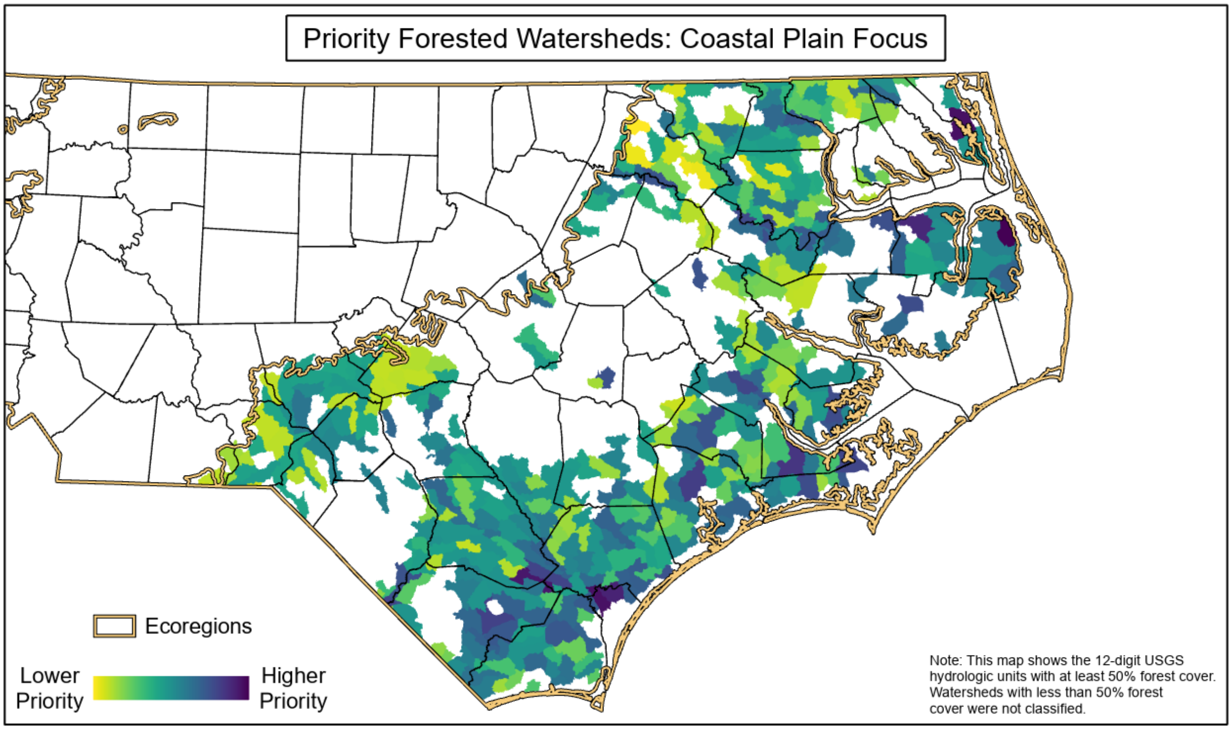
Most poultry operations in North Carolina use a dry waste management system and are referred to as dry litter poultry operations. Such operations are deemed permitted under administrative code (NCAC) 15A NCAC 02T .1303. Owners or operators of dry litter poultry operations with 30,000 or more birds are required to adhere to rules set forth under 15A NCAC 02T .1303 and General Statute 143-215.10C. These requirements include minimum stream setbacks, land application rates, soil and waste analysis, and recordkeeping. This information is included in a waste utilization plan (WUP) (also known as a nutrient management plan (NMP)). Producers are required to keep WUPs (NMPs) on file at the farm and do not have to submit the plan to DWR for review.

1.4.2 Forestry

Nearly 23 percent (313 mi^2) of land use in the White Oak River basin is identified as forest. Forests across the state provide watershed ecosystem services (i.e., nutrient cycling, carbon storage, erosion and sediment control, water filtration and storage, flood control, recreational opportunities, etc.). Forestry (silviculture) activities are identified as a potential nonpoint source of pollution because poorly implemented or managed forestry practices can impact water quality by altering stream habitat, introducing sediment, debris, and nutrients into waterbodies, and changing watershed functions. Properly planned and executed forest management practices, however, facilitate the sustainable harvest of forest products while also protecting water quality. There are multiple federal and state-adopted rules and standards governing silviculture, and the state has a suite of forestry Best

Management Practices (BMPs) to protect water resources. The [2020 North Carolina Forest Action Plan] identified priority forested watersheds of the coastal plain ecoregion. Many are located in the White Oak River basin (Figure 1.4).

Figure 0 Priority Forested Watersheds in the Coastal Plain (NCFS, 2020)



Forest Practices Guidelines (FPG) Related to Water Quality

The North Carolina Forest Service (NCFS) is delegated the authority to monitor forestry operations in North Carolina for compliance with the "Forest Practice Guidelines (FPGs) Related to Water Quality." The FPGs are a set of results-based guidelines meant to protect water quality and are mandatory, statewide requirements defined by North Carolina Administrative Code (02 NCAC 60C .0100-.0209). All forestry-related, site-disturbing activities must comply with the FPGs if that activity is to remain exempt from permitting and other requirements specified in the North Carolina Sedimentation Pollution Control Act (SPCA) of 1973 (NCFS, 2017). Per rule, there are nine FPGs. Each has a narrative performance standard associated with it. One example is the establishment of a Streamside Management Zone (SMZ) along the margins of intermittent and perennial streams and perennial waterbodies. Per 02 NCAC 60C. .0201, the SMZ shall "confine visible sediment resulting from accelerated erosion." The FPGs also prohibit stream obstructions, require installation of effective erosion and sedimentation control measures and site stabilization upon job completion. FPGs are not BMPs. BMPs can be used to ensure that the forest operators and landowners remain in compliance with the FPGs. Inspections often involve NCFS staff visiting the same site multiple times to provide forest operators and landowners technical assistance for BMPs to minimize impacts of forestry on water quality. On average, the NCFS conducts approximately 5,000 to 6,000 statewide inspections annually, including initial visits and follow-up re-inspections.

Forestry Best Management Practices (BMPs)

Implementing forestry BMPs is strongly encouraged to protect the water and soil resources of North Carolina efficiently and effectively. The NC Forestry BMP Manual details specific tools and methods which can be used during forestry operations to attain compliance with the FPGs. From 2013 to 2016, the NCFS conducted surveys across the state to assess the implementation of BMPs on timber harvests. These surveys provide a snapshot of practices used in different areas of the state, and help identify where targeted assistance, education or training may be needed. In the White Oak River Basin, BMP surveys were conducted on 3 sites, assessing 486 total BMPs, which were implemented at an 96% rate, higher than the statewide average.

During timber harvesting, the use of temporary bridges has shown to an effective alternative solution for crossing waterways because the equipment and logs stay out of the stream channel. A sub-set of temporary bridges are portable ‘bridgemats’ which can be fabricated from steel or heavy timbers. To help protect waterways and encourage their use, the NCFS loans bridgemats to loggers and maintains some bridgemats at its Winsor/Wilmington district office. More information is available on the NCFS website: https://www.ncforestservice.gov/water_quality/bridgemats.htm

Timber Harvest Inspections

Figures 1-5 and 1-6 illustrate locations where the NCFS inspected timber harvests from 2007-2017. Some of the large, forested areas of this river basin are managed by large-scale timberland management real estate investment companies, while other areas include large acreages of forested wetlands within wildlife refuges and other publicly-owned reserves.

From July 1st, 2007, to June 30th, 2012, the NCFS inspected 125 timber harvests, totaling 9,343 acres, and found 3 harvests to be out of compliance. The violations were related to streamside management zones, debris entering streams, or stream crossings.

From July 1st, 2012, to June 30th, 2017, the NCFS inspected 176 timber harvests, totaling 11,253 acres, and found 8 harvests to be out of compliance. The most common violations were related to debris entering streams, stream crossings, or rehabilitation of the project site.

From July 1st, 2017, to June 30th, 2020, the NCFS inspected 79 timber harvests, totaling 5,486 acres, and found 3 harvests to be out of compliance. The most common violations were related to waste entering waterbodies, or rehabilitation of the project site.

Table 0-6 Number of Timber Harvest Inspections Conducted by NCFS in the White Oak River Basin (2007 – 2020)

Time Period	# Inspected Timber Harvests	Total Acres	# Out of Compliance
07/2007-06/2012	125	9,343	3
07/2012-06/2017	176	11,253	8
07/2017-06/2020	79	5,486	3

Figure 1-5. Water Quality Inspections in the White Oak River Basin July 2007-June 2012 (NCFS, 2020)

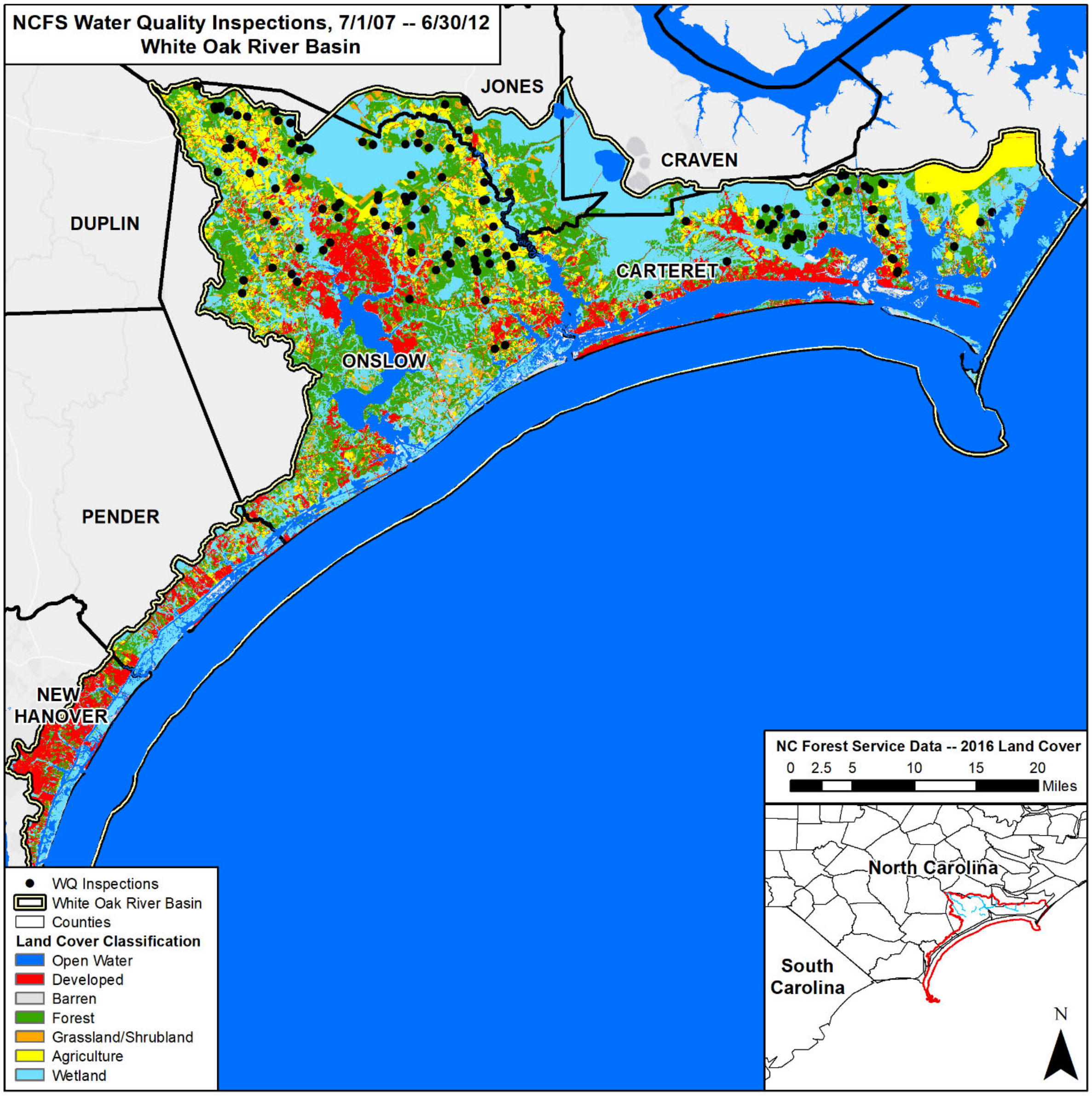
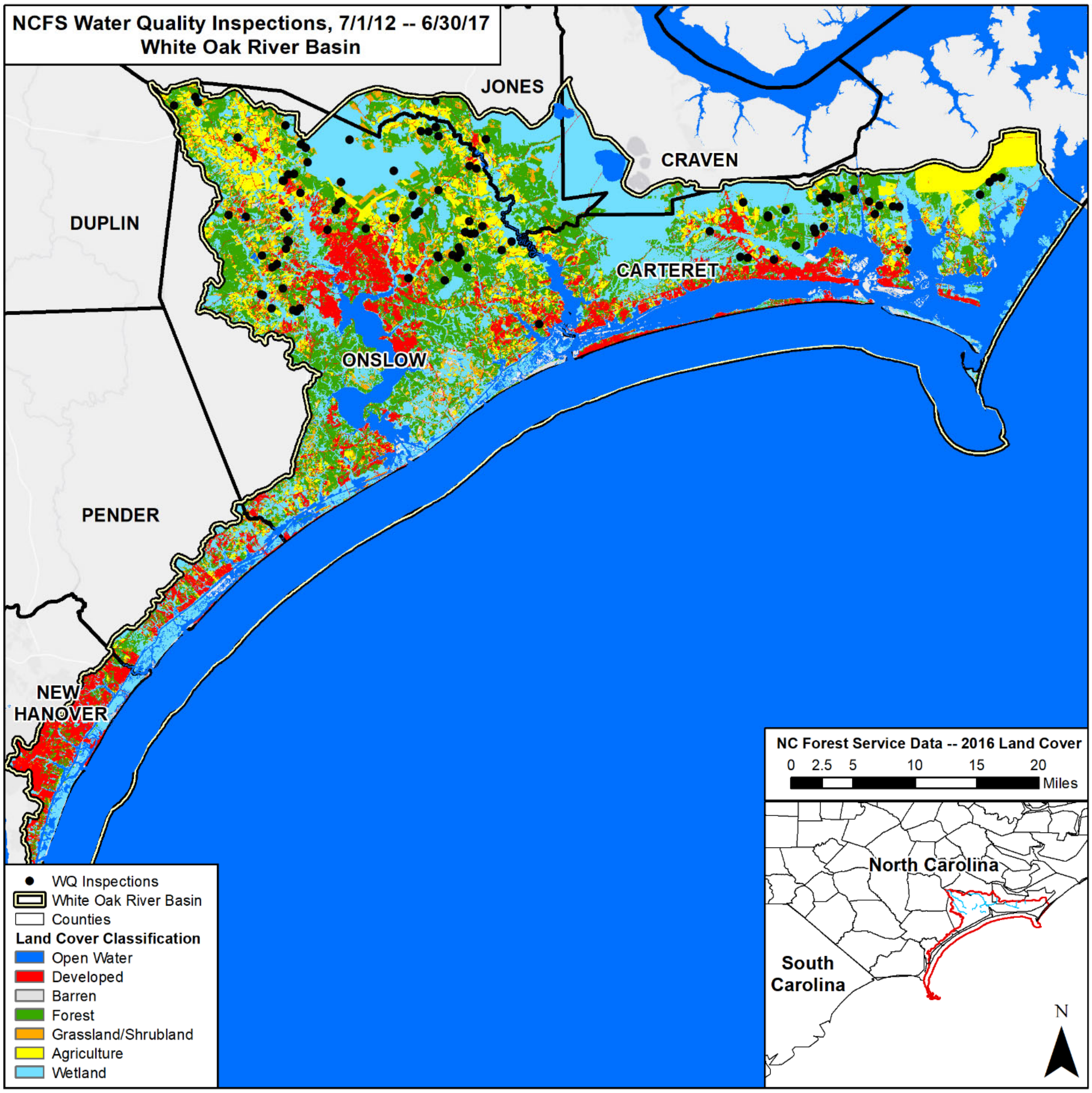


Figure 1-6. Water Quality Inspections in the White Oak River Basin July 2012-June 2017 (NCFS, 2020)



1.4.3 Golf Courses

The NLCD classifies golf course land cover as developed land. These facilities utilize intensive turf management practices that often rely heavily on the use of fertilizers and chemical pesticides. Stormwater runoff then carries these pollutants to nearby streams, impacting aquatic life and habitat. The construction of golf courses can also introduce sediment into streams and destabilize streams that are straightened or altered to meet the design of the golf course (NC DWR, 2008). There are approximately 19 public and semi-private golf course in the White Oak River Basin with most located in coastal recreation areas (NCGolf, n.d.). Eight golf facilities reported water use to the Water Withdrawal and Transfer Registration program in 2018. (Chapter 8). Because there is little information on stormwater management and the amount of commercial fertilizers or pesticides used for turf management on golf courses, it is difficult to assess the impact they may be having on water quality in the White Oak River basin.

1.4.4 Stormwater

Stormwater runoff is rainfall or snowmelt that flows across the ground and impervious surfaces (e.g., buildings, roads, parking lots, etc.). In urbanized areas, stormwater systems often concentrate stormwater runoff into smooth, straight conduits. The runoff gathers speed and volume as it travels through the system before it is released. The outfall is often directed to a surface waterbody where the high velocity can scour streambeds, damage streambanks and vegetation, and destroy aquatic habitat. The volume can cause flooding, damage infrastructure, and cause unnaturally high fluctuations in stream flow.

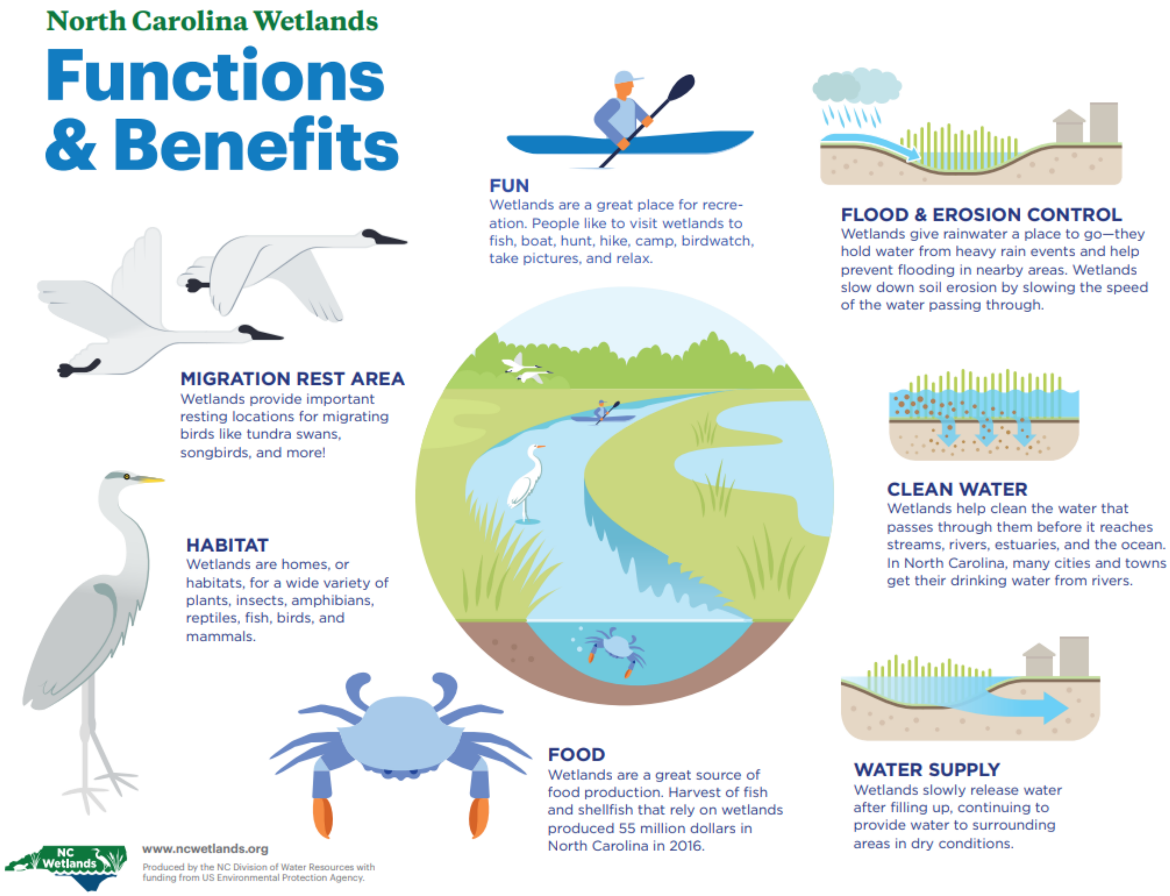
Many daily activities have the potential to cause stormwater pollution, and in an area where activities (e.g., construction, land clearing) have the potential to contribute more pollutants through stormwater runoff, measures should be taken to minimize impacts from runoff. One major component in reducing impacts from stormwater runoff involves planning up front during the design process. New construction designs should include plans to prevent or minimize the amount of runoff leaving the site. Wide streets, large cul-de-sacs, long driveways, and sidewalks lining both sides of the street are all features of urbanizing areas that create excess impervious cover and consume natural areas. Green infrastructure (GI) can be used to minimize the impact from runoff. GI has several definitions but generally involves the use of natural landscape features (e.g., soil, vegetation, forests, wetlands, etc.) to help maintain ecological processes, sustain natural resources, and contribute to community and individual health and quality of life (Firehock, 2013).

The presence of intact riparian buffers, floodplains and/or wetlands in urban areas can also reduce the impacts of development. These porous, natural landscapes hold rainwater and snowmelt and allow the water to infiltrate slowly. This slow infiltration also helps recharge groundwater supplies. Where feasible, establishing and protecting existing buffers, floodplains and wetlands should be considered, and the amount of impervious cover should be limited as much as possible. Preserving the natural streamside vegetation or riparian buffer is one of the most economical and efficient BMPs for reducing the amount of stormwater reaching surface waters. In addition, riparian buffers provide a variety of benefits including: moderation of water temperature by providing shade, holding water and decreasing the high temperatures often measured in stormwater runoff; preventing erosion and lose of land; providing flood control; moderating streamflow; and providing food and habitat to aquatic and terrestrial life (Burgess, 2004). For more information on stormwater and how to manage it, refer to the Division of Energy, Mineral and Land Resources (DEMLR) Stormwater website: https://deq.nc.gov/about/divisions/energy-mineral-land-resources/stormwater.

1.5 Wetlands in the White Oak River Basin

North Carolina's wetlands are diverse habitats found in natural depressions in the landscape or transitional areas where land meets water in low-lying flat areas or near streams, rivers, lakes, and estuaries. Wetlands have three key characteristics: hydrology, wetland soils that form under wet conditions, and wetland plants adapted for growing in water or wet soils (Mitch and Gosselink, 2000). In the White Oak River basin, wetlands are especially important as they cover nearly one-third of the landscape with over 400 mi^2 of freshwater (palustrine) and saltwater (estuarine) wetlands (NLCD, 2016). Healthy wetlands are an integral component of healthy watersheds and provide many essential ecosystem services that benefit humans, natural communities, and watershed functions (Figure 1-7).

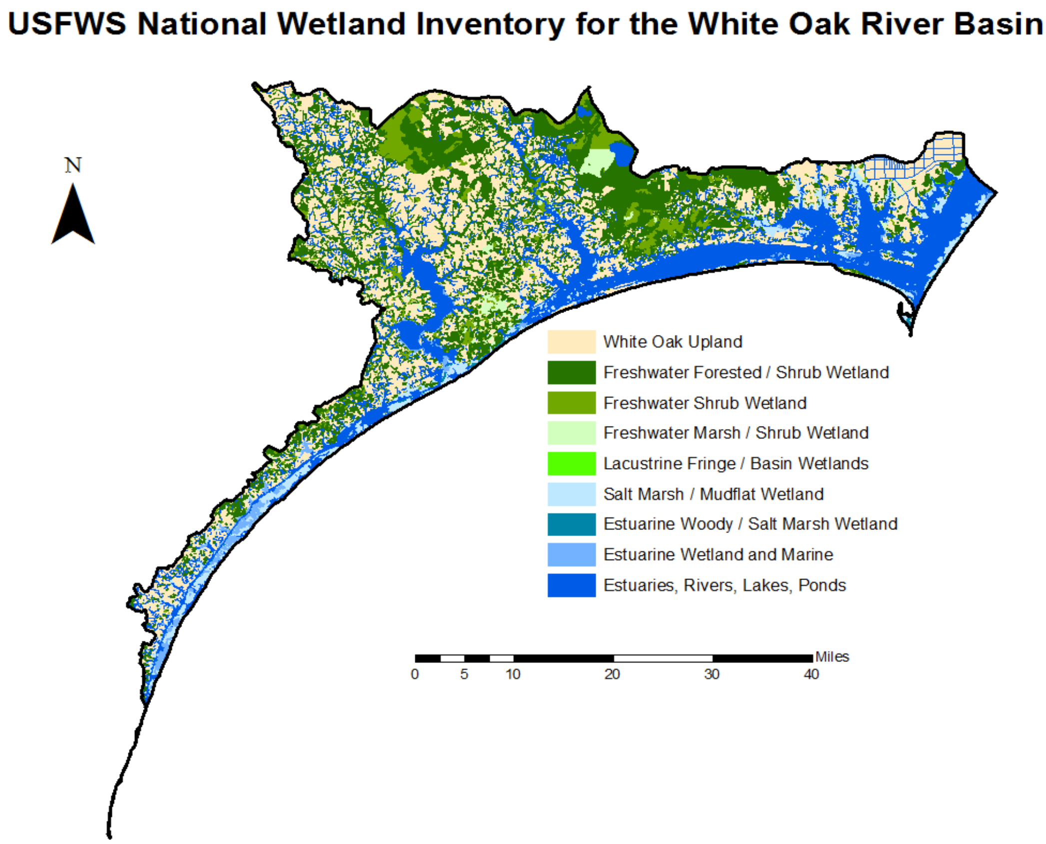
Figure 1-7 North Carolina Wetland Functions and Benefits (Image source: http://www.ncwetlands.org/).



Different wetland habitat types are identified by the depth, duration, and type and source of water (fresh or salt), the landscape position, the soil type, and the dominant vegetation (NC FAT, 2016). The White Oak River basin has many diverse wetland habitats (Figure 1-8) with approximately 77 percent of the wetlands identified as palustrine and 23 percent identified as estuarine (USFWS, 2019). Estuarine wetlands (over 55,000 acres) include a mix of saltwater and brackish marshes and mudflats fringing the shoreline of the many bays, inlets, and barrier islands, providing protection from storm surges. These highly productive wetlands have rapid-growing vegetation that promotes carbon sequestration at a faster rate than other terrestrial ecosystems (NOAA, n.d.).

Riverine swamp forests are found further inland along the White Oak, New, and New Port rivers and associated tributaries. Large swaths of Pocosin wetlands occur in some of the low-lying, non-riparian areas to the east of the White Oak River in the Croatan National Forest Pocosin Wilderness Area and along inland areas between the New and White Oak river drainage areas (Figure 1-8). Pocosins are densely, shrub-covered wetlands, found only from Virginia to South Carolina, that are an important carbon sink due to their deep organic peat soils (Kozak, 2019). There is also a series of small basin wetlands (ponded bowl-shaped wetlands) scattered in different non-riparian areas of the basin, including the Croatan National Forest.

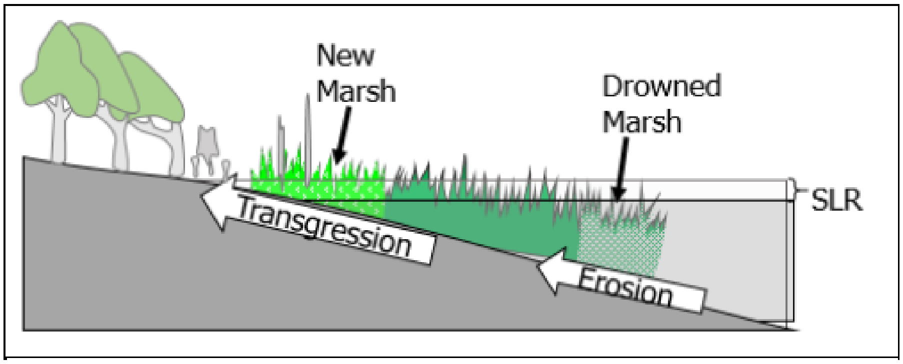
Figure 1-8. Examples of White Oak River basin wetlands (basin wetland, salt marsh and riverine swamp forest NC DWR photos from ncwetlands.org; Pocosin wetland photo from wilderness.net).



1.5.1 Defense Coastal/Estuarine Research Program (DCERP)

In the White Oak River basin, the Department of Defense (DoD) funded a ten-year study from 2007 to 2017 called the Defense Coastal/Estuarine Research Program (DCERP) which focused on environmental issues and land and aquatic resource management on US Marine Corps Base Camp Lejeune (MCBCL). The DCERP study funded multiple research projects including some on estuarine and freshwater wetlands. Researchers showed that coastal wetlands capture sediment from the watershed, improve water quality by trapping or adsorbing nutrients, serve as nursery areas for fish and shellfish, and protect uplands (land lying above the level where water flows or flooding occurs) from storm erosion. Climate change and the effects on sea level rise have emerged as a key threat for DoD held lands, which has more than 25 percent of its military bases in coastal locations. Salt marshes have the capacity to be resilient to sea level rise through sediment accretion, which stimulates plant growth and enables the salt marsh to migrate landward (Figure 1-8). Hard barriers, like sea walls and bulkheads, hinder this natural progression, and in some situations, salt marsh migration may not be able to keep up with sea level rise. The DCERP study used modeling and field data to show that while some of the salt marshes located in the intracoastal waterway were keeping pace with sea-level rise, others were not (DCERP, 2018).

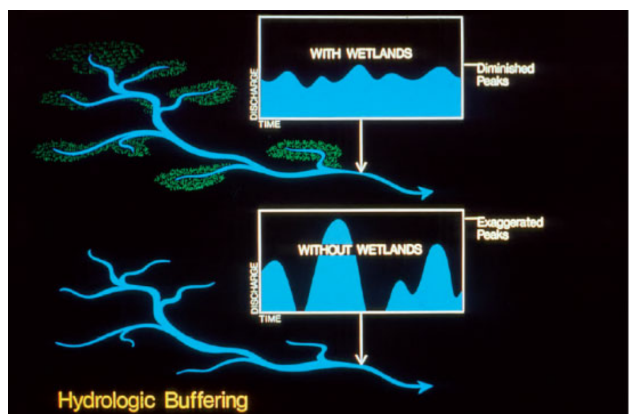
Figure 1-8. Landward migration of salt marsh with sea level rise (SRL). (Figure courtesy of DCERP 2 Final Report, 2018.)



1.5.2 Wetland Loss and Alteration

Wetlands are highly important for water quality because they filter water by assimilating and processing nutrients and other pollutants, thereby protecting adjacent and downstream waterbodies (DWR, 2018). The loss or alteration of wetlands (i.e., ditching, drainage tiles, non-native vegetation, soil compaction, vegetation removal, and fill), however, inhibits many wetlands from performing water quality and water storage functions and can greatly reduce, or eliminate, wetland hydrologic function. Ground-disturbing activities, such as farming, logging, and construction, can also stress wetlands through soil compaction or the introduction of invasive plant species (Native Plant Society, n.d.).

Figure 1-9 Wetland Hydrologic Buffering (Welsch et al. 1995)



Vegetation removal resulting in permanent loss and conversion of a forest-land cover to a non-forest land cover type can also decrease or eliminate the ability of wetlands to reduce flood peaks (Figure 1-9) (Wolkowski & Lowery, 2008). Loss of mature forested areas also reduces habitat for migratory bird species and wildlife that depend on tree cavities (USFWS n.d.; WWF, 2019). Landscapes with a mosaic of diverse mature forests, successional uplands, and wetlands offers the best variety of wildlife habitat.

Currently, under Section 404 of the Clean Water Act (CWA), administered by the US Army Corps of Engineers (ACOE), it is unlawful to discharge dredged or fill material into jurisdictional waters of the United States without federal approval, unless the discharge is covered under an exemption (refer to Chapter 7 for more information about Wetland, Stream, and Buffer Permitting Programs). Although federal and state regulations have slowed the loss of wetlands since the mid-1980s, approximately one-third of alterations to wetlands in the Coastal Plain have occurred since the 1950s, primarily due to agricultural and managed forest conversion (USGS, 1996). “The Food Security Act of 1985 is often referred to as the 1985 Farm Bill. The Highly Erodible Land and Wetland Conservation provisions of the Act (16 U.S.C. 3801-3862) are administered by the USDA’s Farm Service Agency (FSA). The Wetland Conservation provision, commonly called “Swampbuster,” was written to discourage the conversion of wetlands to non-wetland areas for the production of commodity crops. If a farmer converts wetlands to non-wetland areas after December 23, 1985 the farmer becomes ineligible for benefits through the Federal farm program (commodity price support, farm storage facility loans, disaster payments, and several other benefits). Other provisions of the Act include the Highly Erodible Land provisions, commonly referred to as the "Sodbuster" and "Conservation Compliance" provisions. Farmers become ineligible for federal farm program benefits if, after December 23, 1985, they convert or produce crops on highly erodible land without adequate conservation practices in place to control erosion and sedimentation." (NC DWR, 2015).

Most routine farming, ranching, or silviculture activities that are part of an "on-going" farming or forestry operation and do not convert a wetland area to an upland are considered exempt and do not require a Section 404 permit or DWR certification. There are provisions that must be followed in order to retain that exemption. Those provision include required BMPs for forest roads and skid trails and that the silviculture activity must also not immediately or gradually convert a wetland to a non-wetland. The requirements are in 33 CFR 323.4: https://ecfr.federalregister.gov/current/title-33/chapter-II/part-323/section-323.4. If a wetland is being harvested to convert it to a non-forestry land use, then permitting and compensatory mitigation may be needed.

1.5.3 Protecting Wetlands

Protecting and recovering benefits that have been lost due to wetland impacts or conversions can help sustain long-term watershed functions. Restoring wetlands helps recover lost wetland functions and improve watershed function and water quality. Preservation of existing wetlands can also safeguard a watershed from further negative impacts from wetland loss/change. Additionally, creating more living shorelines (in place of hardened bulkheads or walls) can provide more protection from wave-energy while providing additional habitat and space for valuable coastal marshes to migrate inland with sea level rise.

The North Carolina Wetland Program Plan (WPP) 2021-2025 identifies DEQ's wetland goals and specific activities for the next five years. The WPP states that "North Carolina state agency support for voluntary restoration and protection includes project guidance, low-interest loans, and grant funding for proposed projects." In addition, conducting research and sharing resultant data can provide guidance and assist with implementing successful restoration and protection methods to help improve water quality. The WPP commits the use of state agency staff to use their expertise to assist with outreach and education efforts and encourage the use of nature-based solutions to meet wetland protection and restoration goals within North Carolina. The WPP also suggests that restoration efforts should prioritize areas that are strategically located to protect or improve water quality (i.e., headwater or riparian areas), mitigate local flooding issues, have connectivity to existing wetland or upland wildlife habitat, or have deep organic soils which can serve as a carbon sink and support climate resiliency. Preservation efforts should prioritize areas that serve as corridors between upland and wetland habitats, protect communities or agricultural areas from flooding or storm surges, protect water quality, have mature forests or a mosaic of mature and successional forest, or have deep organic soils.

1.6 Climate Resiliency

In October of 2018, Governor Roy Cooper signed Executive Order 80 (EO80), "North Carolina's commitment to address climate change and transition to a clean energy economy". Section 9 of EO80 was a directive to the cabinet agencies to integrate climate adaptation and resilience planning into cabinet agency policies, programs, and operations (DEQ, 2020).

In June 2020, the North Carolina Climate Risk Assessment and Resiliency Plan (2020 Resiliency Plan) was published by DEQ. It defined a resilient North Carolina as "a state where our communities, economics, and ecosystems are better able to rebound, positively adapt to, and thrive amid changing conditions and challenges, including disasters and climate change; to maintain quality of life, healthy growth, and durable systems; and to conserve resources for present and future generations" (DEQ, 2020). The 2020 Resiliency plan includes the recommendations of the agencies involved with executing EO80, as well as stakeholders throughout the state, on how to integrate climate adaptation and resiliency planning into their policies, programs, and operations. It provides the state's best understanding of projected change in climate; considers climate justice issues; evaluates state infrastructure, assets, programs, and services that are vulnerable and at risk to climate and non-climate stressors; and includes preliminary actions currently underway or which can be taken to reduce risk. It also includes nature-based solutions and recommendations to enhance ecosystem resiliency and sequester carbon through natural and working lands (NWL). The plan concludes by describing next steps for implementing and updating the 2020 Resiliency Plan as well as strategic resilience initiatives (DEQ, 2020).

One of the first steps in developing the 2020 Resiliency Plan was for DEQ to work with the North Carolina Institute for Climate Studies (North Carolina State University), representatives from many major higher education institutions, and subject matter experts to develop the North Carolina Climate Science Report (NCCSR). Key findings were categorized by percent probability and, except where noted, referred to future changes through the end of the century. Definitions for virtually certain, very likely, likely, unlikely, etc. are included in the NCCSR as well as Chapter 3 and Appendix A of the 2020 Resiliency Plan. Key findings of the NCCSR include:

- Sea level: It is ***virtually certain*** that sea level will continue to rise along North Carolina's coast due to the expansion of ocean water from warming and melting of ice in Greenland and the Antarctic ice sheets.
- Flooding: It is ***virtually certain*** that rising sea level and increasing storm intensity will lead to an increase in storm surge flooding in coastal North Carolina. Inland flooding is also ***likely*** to increase due to extreme precipitation events.
- Temperature: It is ***very likely*** that temperatures in North Carolina will increase substantially in all seasons and that the number of warm and very warm nights will increase and that the summer heat index will increase due to increases in absolute humidity. It is **likely** that the number of hot and very hot days will increase and that that the number of cold days (daytime maximum temperatures below 32°F) will decrease.
- Precipitation: It is ***very likely*** that extreme precipitation frequency and intensity will increase statewide due to increases in atmospheric water vapor content, and it is ***likely*** that total annual precipitation will increase.
- Drought and wildfires: It is ***likely*** there will be more frequent and intense droughts across the state and that this increase will ***likely*** increase wildfires.

The 2020 Resiliency Plan evaluated these findings to determine how these changes would affect the health, safety, and economy of the state. The Plan identified these impacts:

- Ecosystem and habitat loss: Sea level rise will result in a loss of wetlands and the habitats associated with them. The loss of wetlands will impact not only commercial and recreational fisheries, but also adversely impact water quality, decrease a buffers capacity to attenuate nonpoint source pollution runoff, and reduce the resilience of coastal communities. Due to warmer temperatures, harmful algal blooms may increase impacting aquatic organisms and human health.
- Public health: Saltwater intrusion due to climate change will impact both groundwater and surface water drinking water sources and impact the amount of freshwater available to irrigate agricultural crops. Extreme weather events will put more stress on emergency management, public services, and institutions, and require more resources to address the impacts. Poor air quality, injuries, and loss due to flooding, heat-related illnesses, and increased areas where disease-carrying vectors, such as mosquitoes, will all impact human health.
- Non-climate stressors: Many of these impacts will be compounded by non-climate stressors such as population growth, urbanization, and economic inequality. Climate-related impacts will likely have greater effects on vulnerable populations, exacerbating disparities that already exist (Kunkel, et al., 2020; DEQ, 2020).

Programs with DEQ's DWR that may be impacted by climate change include:

- Non-Point Source Pollution: More frequent and severe precipitation events can increase the delivery of nonpoint source pollution loads to surface waters impacting aquatic habitats, water supply intakes, dam maintenance (i.e., sediment build up and removal), etc.
- Water Quality: Increases to temperature and the length of the warm season can result in increased algal production, lower dissolved oxygen concentrations, degraded aquatic communities, and impacts to commercial and recreational fisheries (i.e., fish kills, trout reproduction, shellfish harvesting).
- Water Supply Planning: Water supply planning will be affected by decreased water availability from more frequent drought conditions.
- Water and Wastewater Facilities: More frequent and intense rain events increase the flood risk to many facilities that DWR regulates such as wastewater treatment plants and animal operations. Discharges permitted through NPDES are currently based on low-flow statistics calculated with historical stream flow data. Variable precipitation in the future could affect typical low flows, changing the capacity of receiving streams to assimilate pollutant loads.

Basinwide planning can support climate resilience by identifying natural resources that may be affected by climate change, providing recommendations for adaptive management, and recognizing nature-based solutions to climate impacts. Basin plans frequently recommend protecting wetlands and floodplains, installing stormwater BMPs, identifying and retrofitting high-risk infrastructure, projecting and planning for changes in water use and availability, identifying areas that are disproportionately burdened with environmental hazards, and implementing green infrastructure (GI), low-impact development and living shorelines (Atkins, 2015; US EPA, 2016; DEQ 2020). Many of these same strategies fall in line with those identified in the 2020 Resiliency Plan.

Many of the recommendations presented in basins plans have also been identified as means to mitigate impacts from increased precipitation and flood events caused by climate change. One example, found in Chapter 5 of the 2020 Resiliency Plan, is land use guidance which includes protecting riparian buffers. This is also one of several strategies identified in basin plans to increase North Carolina's resilience to water quality impacts from flooding. Chapter 5 in the 2020 Resiliency Plan notes that several watersheds have rules in place that protect riparian buffers. Many of these rules were put into place to reduce the amount of nutrients entering waterways from point and nonpoint sources of pollution, but they can also help alleviate impacts from flooding. In addition to rules to protect riparian buffers, the NC Flood Act of 2000 required that communities regulating land use "prohibit certain uses in the 100-year floodplain". Prohibited uses include new solid waste disposal facilities, hazardous waste management facilities, salvage yards, and chemical storage facilities. By expanding and enforcing these protections statewide, state and local governments increase the capacity of the natural landscape to assimilate pollutants before they enter a waterbody (DEQ, 2020). Since inland flooding is projected to increase, it is critical to adopt practices that reduce storm-driven nonpoint point source pollution.

Basin plans also encourage the collection of more data for many different DWR programs to garner a deeper understanding of current conditions and changes over time. They also encourage the use of natural and working lands (NWL) to protect water resources. The basin plans will continue to be a source of this information and will increasingly analyze NC's major river basins with a lens towards climate resiliency. More information about the global impacts of climate change can be found on the Fourth National Climate Assessment website (https://nca2018.globalchange.gov/). For more information on North Carolina's efforts to address climate change, visit https://deq.nc.gov/energy-climate/climate-change. More information about NWL can be found here: https://nicholasinstitute.duke.edu/project/north-carolina-natural-and-working-lands.

1.6.1 Planning for Changes in Sea Level

Sea level rise is expected to adversely impact North Carolina's coastline and will likely intensify already existing natural hazards and impacts associated with flooding, storm surges, shoreline erosion, eutrophication, and shoreline recession (Moorman, 2014). Natural or human modifications to the elevation of barrier islands are also predicted to accelerate the erosion of coastal and estuarine shorelines leaving these areas vulnerable during storm events (Riggs and Ames, 2003).

The Salinization Adaptive Capacity Building for Land Use and Tourism Development project is an interdisciplinary group from North Carolina State University (NCSU), University of North Carolina-Chapel Hill (UNC-CH), and Duke University funded by the National Science Foundation (NSF). This group aimed to "answer key questions about climate change and its effects on the people and natural resources of coastal North Carolina" (NCSU, n.d.). The location of their study was the Albemarle-Pamlico Peninsula, but are also applicable to counties in the White Oak River basin. Several publications (link) were produced on impacts to land and water resources including (NCSU, n.d.):

- *Rural Coastal Community Resilience: Assessing a Framework in Eastern North Carolina. (link)*
- *Sea Level Rise Impacts on Rural Coastal Social-Ecological Systems and the Implications for Decision Making. (link)*
- *Marsh Bird Occupancy Along a Shoreline-to-Forest Gradient as Marshes Migrate from Rising Sea Level. (link)*

- *Use of Autonomous Recording Units Increased Detection of a Secretive Marsh Bird. (link)*
- *Bird Community Shifts Associated with Saltwater Exposure in Coastal Forests at the Leading Edge of Rising Sea Level. (link)*
- *Decadal-Scale Vegetation Change Driven by Salinity at Leading Edge of Rising Sea Level. (link)*
- *Evaluating the Effects of Land-Use Change and Future Climate Change on Vulnerability of Coastal Landscapes to Saltwater Intrusion. (link)*
- *'A Commons Before the Sea:' Climate Justice Considerations for Coastal Zone Management. (link)*

A multi-state collaborative project funded by the US Climate Alliance led to the Coastal Protection and Blue Carbon: Mid-Atlantic States project (link). The project "considers both the current status of coastal habitats and potential future changes due to sea level rise to assess habitats' ability to store carbon long-term and protect vulnerable ecological and human communities into the future" (Warnell K., n.d.). Additional information about sea level rise can be found on the Coastal Resource Commission's (CRC) website and associated North Carolina Sea Level Rise Assessment Report (2015) (https://deq.nc.gov/about/divisions/coastal-management/coastal-resources-commission/sea-level-rise-study-update).

1.6.2 Hurricanes and Flooding

North Carolina has been affected by 413 tropical or subtropical cyclones (of which 47 became hurricanes) from 1851 until present.. Many hurricanes have hit the state directly, while others have caused extensive damage merely passing near the state. Historically, North Carolina ranks fourth nationally in number of hurricanes that have impacted the state. Estimated cost in lives is almost 1,000 fatalities and over $11 billion dollars in damage.

According to statistical research from the North Carolina State Climate Office (SCO), a hurricane makes landfall along the North Carolina coast about every four years and an estimated 17.5 percent of all North Atlantic hurricanes have affected the state. Cape Hatteras is most affected by hurricanes, followed by Cape Lookout and Cape Fear. The Outer Banks are also heavily impacted by hurricanes because of their location along the easternmost edge of the state. Although the eastern portion of the state frequently bears the brunt of Atlantic hurricanes, remnants from Gulf Coast and other southeastern hurricanes have historically caused significant damage in both the Piedmont and mountain regions of the state.

Hurricanes have typically affected North Carolina between May and December, although the official hurricane season for North Carolina is June 1 to November 30, with the 80 percent of the hurricanes that have affected the state arriving between August and October. The earliest storm to hit the state was Subtropical Storm Andrea on May 7, 2007. The latest was a tropical storm that hit the Outer Banks on December 2, 1925. The most powerful hurricane to hit the state was Hurricane Hazel, a Category 4 hurricane that landed on October 15, 1954.

One of the most active and the costliest eras of hurricane activity in North Carolina occurred in between 1980 and 2010. Of these, Hurricane Fran stands out as the strongest hurricane as a Category 3, and Hurricane Florence as the deadliest with 53 fatalities attributed to this storm and record-breaking flooding in the eastern region of the state.

The list below (from the website https://www.nhc.noaa.gov/outreach/history/) captures significant North Carolina hurricane history since 1954.

1954 Hurricane Hazel on October 15 became the most intense hurricane to make landfall in North Carolina during the 20th century. The Category 4 hurricane swept inland near South Carolina, making shambles of many North Carolina beach communities. Destructive winds affected the eastern quarter of the state, with reports of 100 mph+ gusts north to the Virginia border. Isolated flash flooding occurred west of Hazel's track.

1955 Hurricanes Connie, Diane and Ione struck within six weeks causing epic flooding in eastern sections. Connie on August 11-12, Diane on August 16-17 and Ione on September 19 dumped a combined 48.9 inches at the Maysville cooperative weather station. Connie and Ione were Category 2 hurricanes at landfall, while Diane was a Category1.

1960 Category 3 Hurricane Donna plowed just inside the Outer Banks region on September 12, making landfall at Cape Fear. Sustained winds were 115 mph at Cape Fear and remained above hurricane force throughout Donna's 150-mile trek through the state. Rainfall totals were generally 4 to 8 inches, with some higher amounts.

1972 Hurricane Agnes made landfall on the Florida Gulf coast, before tracking through the southeastern US. Torrential rainfall pummeled the western two-thirds of North Carolina on June 20-22 causing extensive flooding.

1989 Hurricane Hugo struck near Charleston, South Carolina, on September 21-22, then gradually swung northwest, north and northeast. The Category 4 weakened to a Category 1 as it plunged more than 200 miles inland before tracking through the Charlotte area. It caused extensive damage with winds still gusting near 100 mph.

1996 Hurricane Bertha struck the state on July 12, with a peak gust of 108 mph. Hurricane Fran churned through eastern North Carolina on September 5, with sustained winds up to 115 mph. Not since 1955 had the state experienced two hurricane landfalls in the same season.

1999 Hurricane Dennis soaked the state in late August and early September followed by Hurricane Floyd on September 16. Floyd, a Category 2 storm that made landfall just west of Cape Hatteras, dumped 10 to more than 20 inches in eastern North Carolina causing record flooding and an environmental catastrophe.

2003 On September 18, Hurricane Isabel slammed Ocracoke and proceeded to plow through northeastern North Carolina. Category 2 Isabel caused widespread power outages and coastal flooding. It blew down countless trees.

2011 Hurricane Irene came ashore in eastern North Carolina on August 27 as a Category 1 storm, with 85 mph sustained winds. More than 1100 homes were destroyed. Irene became only the third hurricane to make landfall on the U.S. East Coast north of Florida in this century.

2012 Hurricane Sandy passed by the state dropping heavy rain and causing a significant storm surge.

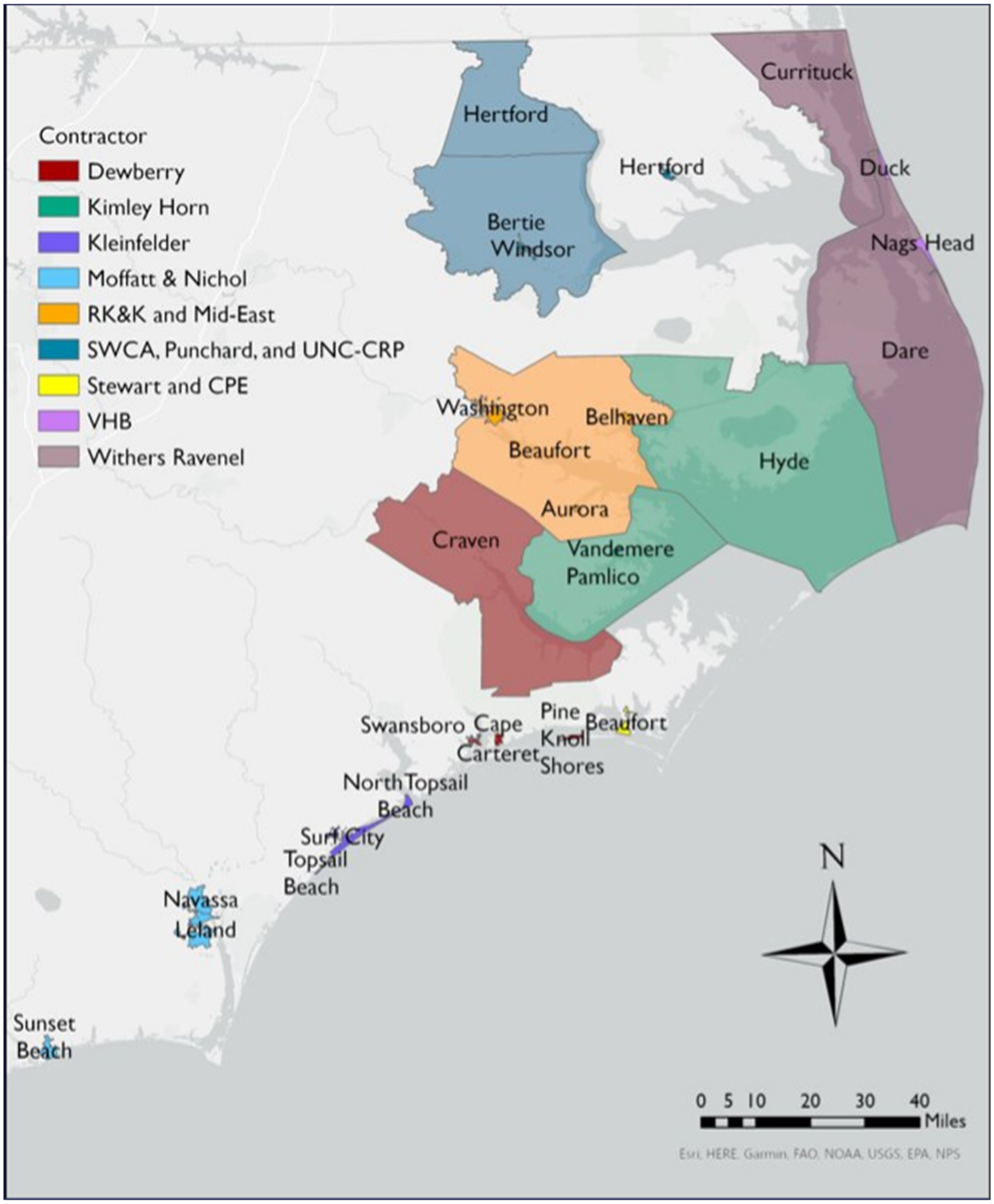
2016 Hurricane Matthew hugged the NC coast after making landfall in South Carolina, causing torrential rains. Wilmington set a new storm tide (water level measured relative to high tide) record at 3.53 ft (1.08 m), beating the previous one of 3.47 ft (1.06 m) set during Hurricane Hazel on October 15, 1954. Matthew caused total devastation in Robeson County, especially Lumberton. At least 28 people were killed, making Matthew the deadliest hurricane in North Carolina since Floyd killed 35 in 1999.

2018 Hurricane Florence made landfall near Wrightsville Beach early on Friday, September 14, and weakened further as it slowly moved inland. Florence caused significant storm surge flooding in portions of eastern North Carolina. Florence produced extensive wind damage along the *North Carolina* coast from Cape Lookout, across Carteret, Onslow, Pender and New Hanover counties. Florence resulted in 22 direct deaths and was also associated with 31 indirect fatalities. The state now estimates that Hurricane Florence did nearly $17 billion in damage to homes, businesses, farms and governments in North Carolina. Estimates from the state Department of Insurance found that the physical and economic harm caused by Hurricane Florence has outstripped the combined damages of two previous storms, Hurricanes Matthew and Floyd. Matthew did an estimated $4.8 billion in damage in 2016, while Floyd, which caused similar flooding in Eastern North Carolina in 1999, did between $7 billion and $9.4 billion, when adjusted for inflation.

In 2016, the General Assembly established the North Carolina Resilient Redevelopment Planning Program to provide a guide to rebuild communities damaged by Hurricane Matthew. This program produced Hurricane Matthew Resilient Redevelopment Plans for 50 counties available through North Carolina Office of Recovery and Resiliency (NCORR). To continue to build resiliency in North Carolina, a workgroup was formed to produce the Action Plan for Nature-based Stormwater Strategies: Promoting Natural Designs that Reduce Flooding and Improve Water Quality in North Carolina. This action plan has recommendations to make our communities more resilient by protecting, restoring, and mimicking our state's natural watershed hydrology. The workgroup's recommendations encourage collaborative, efficient approaches so that efforts consider both reduced flooding and improved water quality as objectives, and can be effectively sited and designed (NCCF, 2021).

Between 2016 and 2018, DCM developed a pilot program to better understand the needs of communities dealing with natural disasters. The study affirmed the needs for resilience evaluation and a needs assessment framework for coastal communities in North Carolina (link). Therefore, DCM started the NC Resilient Coastal Communities Program to provide financial grants and technical assistance for coastal resilience planning and project implementation in the 20 CAMA counties. Currituck, Bertie, and Dare counties along with the Towns of Duck, Hertford, Nags Head were selected as 2021 program participants (Figure 1-10).

Figure 1-10 North Carolina Resilient Coastal Communicates Program 2021



Stakeholders working on resiliency in their community also have web-based mapping resources such as the Department of Public Safety (DPS) North Carolina Flood Risk Information System (FRIS). This tool enables local and regional stakeholders to more accurately predict flood hazards and prepare for flood risks (https://fris.nc.gov/fris/Home.aspx?ST=NC). DPS has also developed the Flood Inundation Mapping and Alert Network (FIMAN) which provides rain and stage gage information, flood inundation maps, flooding impacts and alerts in real-time to support risk-based decisions regarding flooding (https://fiman.nc.gov/).

1.7 References

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