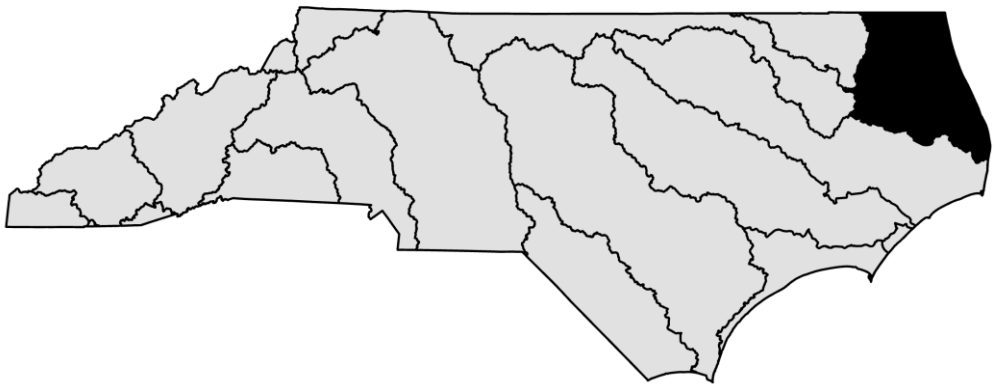
Chapter 1 Contents

Chapter 1 Pasquotank Basin Overview

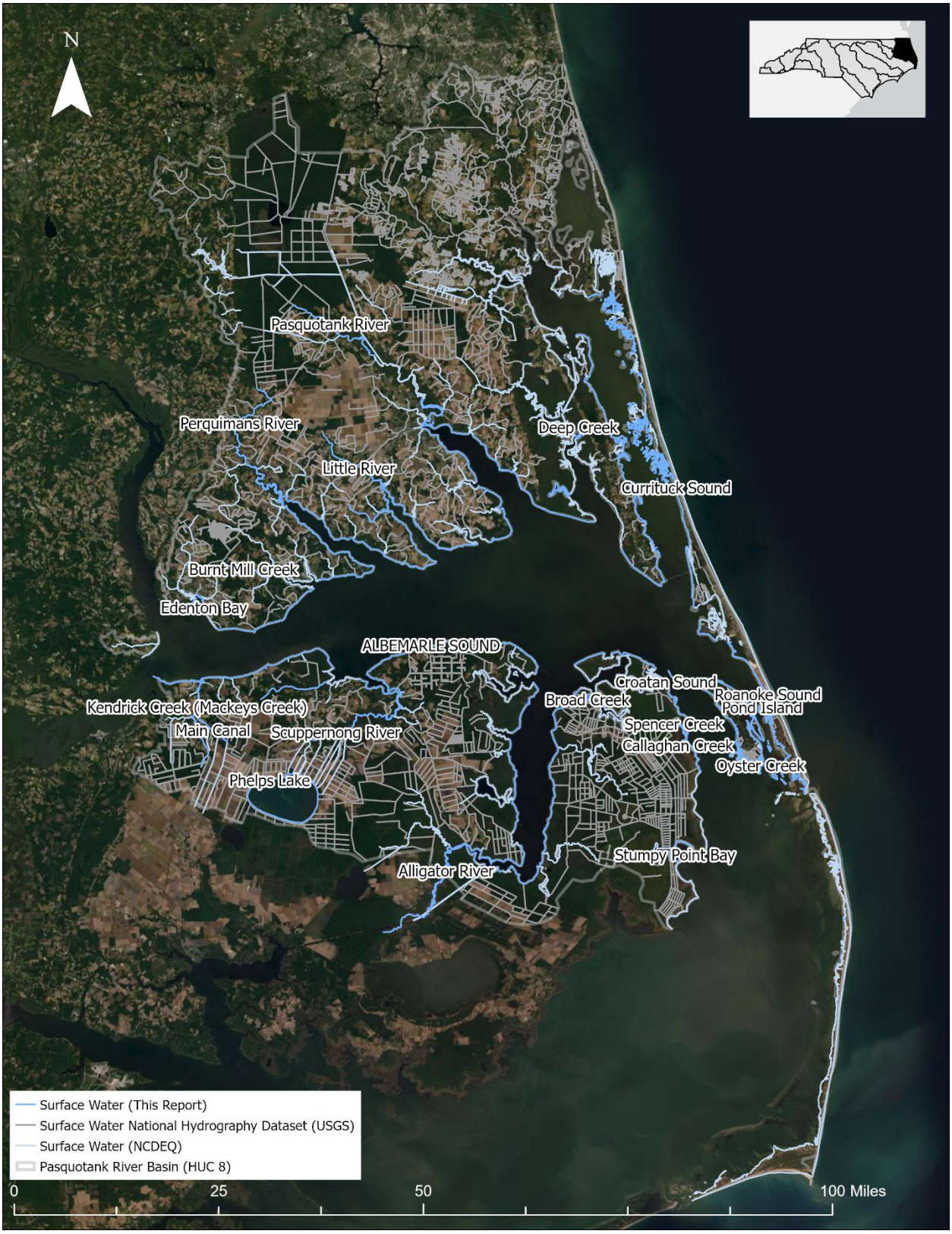


1.1 General Description

The North Carolina portion of the Pasquotank River basin is located in the northeastern coastal plain. This river basin contains the Albemarle, Currituck, Roanoke, Croatan and Pamlico sounds, as well as, the Pasquotank, Little, Perquimans, Alligator, Scuppernong, and Yeopim rivers and numerous small watersheds (Figure 1-1). These streams receive runoff from several municipalities, including Elizabeth City, Edenton, and Kitty Hawk (Figure 1-2 and Figure 1-3). The North Carolina portion of the Pasquotank River basin spans 3,367 square miles (mi^2) with primarily open water (37.4%), followed by wetlands (33.1%), agriculture (19.9%), forest (5.1%), developed lands (3.4%), scrub/shrub (0.5%), barren land (0.3%), and grassland/herbaceous (0.2%) land cover (Figure 1-4 and Table 1-3). Approximately 577 mi^2 of land area in the Pasquotank River basin is located in Virginia. The Pasquotank River basin contains many Significant Natural Heritage Areas as designated by the North Carolina Department of Natural and Cultural Resources' Natural Heritage Program by the North Carolina Nature Preserves Act. These areas include the Currituck Sound Significant Natural Heritage Area, North River Significant Natural Heritage Area, and the Great Dismal Swamp Significant Natural Heritage Area (NCDEQ, 2007). Refer to the 2007 Pasquotank River basin plan for more details regarding these and other Significant Natural Heritage Areas.

The Pasquotank River basin is part of the larger Albemarle-Chowan River basin (Hydrologic Unit Code: 030102), which includes southeastern Virginia and northeastern North Carolina. This basin also contains the Albemarle Sound that is part of the Albemarle-Pamlico Estuarine System. It is the second largest estuarine system in the United States, following the Chesapeake Bay, and includes portions of or all of the Chowan, Pasquotank, Roanoke, Tar-Pamlico, Neuse, and White Oak river basins. In recognition of the numerous benefits provided by the Albemarle and Pamlico sounds, the United States Congress designated the Albemarle-Pamlico Estuarine System an “estuary of national significance” in 1987. That same year, the Albemarle-Pamlico Estuarine Study (APES) was among the first of 28 National Estuary Programs established by the Environmental Protection Agency (EPA) through amendments to the Clean Water Act (CWA). Upon adoption of its first Comprehensive Conservation Management Plan (CCMP) in 1994, the program became known as the Albemarle-Pamlico National Estuary Program (APNEP) and it broadened its mission to include applied conservation, management and engagement initiatives to protect natural resources within the region. In 2012, the program was formally renamed and identified as a Partnership, reflecting the importance of coordinated and integrated efforts for protecting and restoring the estuarine ecosystem in the region. In the Albemarle-Pamlico Estuary environmental stress can be seen in the form of declining fisheries, algal blooms, closure of shellfish waters, loss of historical submerged aquatic vegetation beds, and degradation of wetlands, fish and upland habitats (US EPA, 2001).

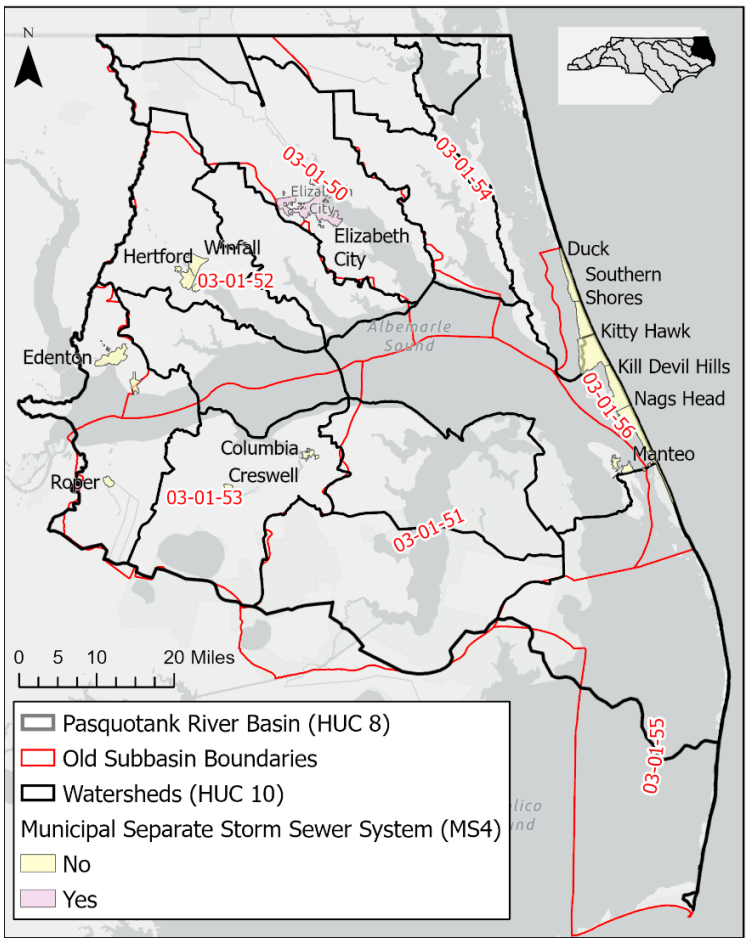
Figure 1-1 Streams and sounds of the Pasquotank River basin.



1.2 Watershed Boundaries in the Pasquotank River Basin

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 Hydrologic Unit Codes (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). The conversion from DWR subbasins to ten digit HUCs (HUC 10) is illustrated in Figure 1-2. Note that a portion of the Chowan River basin near Edenton is now in the Pasquotank River basin based on the United States Geological Survey (USGS) Watershed Boundary Dataset (USGS, 2020).

Figure 1-2 Historical DWR subbasin boundaries overlain by USGS HUC10 watershed boundary dataset with counties and municipalities which have municipal separate storm sewer system.



1.3 Aquatic Habitats

The areas where rivers and sounds meet are described as "drowned river estuaries" (Riggs and Ames 2003). Due to the retreat of the last glacial maximum, the old river channels were submerged over the past 17,000 years due to sea-level rise. The transition zone from river to estuary occurs in a broad zone where riverine processes become estuarine. In the Pasquotank River basin, the Chowan and Roanoke rivers discharge large volumes of fresh water into the Albemarle Sound estuary behind the Outer Banks.

1.3.1 Types of Aquatic Habitats

The Fisheries Reform Act was passed in 1997 by the North Carolina General Assembly in recognition that protecting habitat is as important as preventing overfishing. The act established the requirement to develop a Coastal Habitat Protection Plan (CHPP) to protect and enhance important coastal fisheries habitats. The CHPP lists six distinguishable habitat types along the state's coast: water column, submerged aquatic vegetation, shell, soft and hard bottom habitats, and wetlands (NCDMF, 2016). Please refer to Chapter 8 for more information about the CHPP goals and recommendations.

1. *Water Column*

The water column is a unique, dynamic habitat with changing physical and chemical properties that links all the various habitats and provides the means of transport of organisms from one habitat type to another. Water depth and direction of flow can vary depending on meteorological events, such as precipitation and wind direction, tidal events, and proximity to inflow from inland rivers and outflow through the coastal inlets. These factors also influence mixing of the water column's dissolved gases and ions, suspended particles, and temperature.

2. *Submerged Aquatic Vegetation (SAV)*

The submerged aquatic vegetation (SAV) habitat is populated with various species of plants that are not able to support themselves out of the water. The plant composition is dependent upon factors such as depth, salinity, wave action and water clarity. The SAV provide surface area for organism residency and egg deposition, refuge from predation, and food matter for grazers and detritivores. Please refer to Chapter 6 for information about SAV in the Pasquotank River Basin.

3. *Shell Bottom Habitat*

Shell bottom habitat is comprised of, as the name suggests, both living oysters, clams and other shellfish and the shell remnants of these organisms. Some of these habitats are called beds, rocks, or reefs while others may be layers of heavily weathered and broken shell fragments upon finer, underlying sediments. Established mollusks beds can function as "living shorelines," defusing wave action and reducing the rate of shoreline erosion.

4. *Soft Bottom Habitat*

The unconsolidated, unvegetated soft bottom habitat is not unique to the marine, or brackish-water environments, but extends up to the headwaters of freshwater channel networks. Soft bottom habitat is nourished and maintained by shoreline erosion and stormwater runoff throughout the basin and by transport from the headwaters to the estuaries and sounds. The composition of the bottom can vary from organic detrital material to fine silt, clay, and sand to coarse sands.

5. *Hard Bottom Habitat*

The hard bottom habitat is typically located offshore, beyond the breakers. Hard bottom is colonized by sessile organisms and provides vertical relief, which attracts and sustains economically important species and their prey. The establishment of artificial reefs, both in the sounds and the ocean, as well as shipwrecks helps to supplement hard bottom habitat. Near shore and in the estuaries, this habitat can be negatively impacted by degraded water quality.

Hard and shell bottom habitats are less abundant in the Pasquotank River basin due to the low salinity levels. Low salinity limits the distribution of oysters, clams and other marine mollusks, and sediment load deposited on the estuary bottom. The sole artificial reef built in the Albemarle Sound is at the mouth of the Chowan River, named Black Walnut Point Reef (AR-191). The reef was established in the mid-1980's to create additional hard bottom habitat, attract sport fish and provide a recreational opportunity accessible for small vessels.

6. *Wetlands*

Wetlands are often found in transition zones between terrestrial and aquatic habitats. Different wetland habitat types are identified by the depth, duration, and source and type (fresh or salt) of water, the landscape position, the soil type, and the dominant vegetation (NC FAT, 2016). Wetland habitats comprise nearly a third of the Pasquotank basin area, and include various types such as riverine swamp forests, brackish marshes, pocosins, non-riverine swamp forests, and wet pine flats (NCLD 2016, US FWS 2020, NC

DCM, 2020). Please refer to Section 1.7 of this chapter for more information about wetlands in the Pasquotank River basin.

1.4 Population and Land Cover

Population and density data help identify the watersheds likely to have the most impacts from urban growth. Increases in population often result in more impervious surface cover which often increases the amount of nonpoint source pollution and stormwater runoff. Increases in stormwater runoff can impact aquatic habitats, stream flow, and downstream flooding. Population data can also be used to project future water demand and assist with local water supply planning efforts. Population information presented here is intended to estimate expected population growth in the counties and municipalities located wholly or partially in the Pasquotank River basin. Information presented here is available on North Carolina's Office of State Budget and Management (OSBM) website.

1.4.1 Population

There are 11 counties and 13 municipalities located wholly or partially in the Pasquotank River basin (Figure 1-3). The counties that comprise this river basin saw increasing populations between 2000 and 2010; with the exception of Hyde and Washington which had slight declines in population (Table 1-1). Based on the OSBM 2020 population projection, the populations in Bertie, Chowan, Gates, Hyde, Pasquotank, Tyrrell, and Washington counties are expected to decrease. Between 2010 and 2030, Chowan, Hyde, and Washington counties are projected to continue to decline while populations in Bertie, Gates, Pasquotank, and Tyrrell counties are projected to vary slightly (less than 5%). OSBM projects increasing populations in Camden, Currituck, and Dare counties between 2010 and 2030; with a slight increase (3.4%) in Perquimans County (Table 1-1). Dare counties contain the municipalities of Duck, Kill Devil Hills, Kitty Hawk, Manteo, Nags Head, and Southern Shores; these municipalities have all seen approximately 10% increases in their populations between 2010 and 2019 (Table 1-1 and Table 1-2).

Figure 1-3 Counties and municipalities in the Pasquotank River Basin

Although OSBM only reports a 10% increase in population, the seasonal populations and tourism in Northeastern North Carolina can result in a doubling or quintupling of the population in these counties and municipalities (Please refer to Chapter 9 for information about seasonal population). According to the 2017 Albemarle Commission Comprehensive Regional Economic Development Strategy, "Within the Commission's 10 County Region, in 2015 tourism has a $1,349 million impact for expenditures, a Regional

payroll of $274 million, and employs more than 15,490 employees. Tourism from the Albemarle Commission's Region generates more than $65 million in state tax receipts, and $61 million in local tax receipts saving local residents more than $4,522 per resident each year.". This seasonal flux of population can act as a stressor through increased demand from water utilities, impacts to aquatic life and habitats, and contributing to point and nonpoint sources of pollution.

Table 1-1 Percentage of counties in the Pasquotank River basin, population, and population projections by county between 2000 and 2030 (OSBM, 2020).

County	Percent of County in Basin	Population 2000	Population 2010	Percent Growth 2000-2010	Population Projection 2020	Percent Growth 2010-2020	Population Projection 2030	Percent Growth 2010-2030
Bertie	1.1	19,773	21,282	7.6	19,601	-8.6	19,601	-8.6
Camden	100.0	6,885	9,980	45.0	10,717	6.9	11,266	11.4
Chowan	56.4	14,526	14,793	1.8	14,074	-5.1	13,592	-8.8
Currituck	100	18,190	23,547	29.5	27,952	15.8	32,219	26.9
Dare	89.4	29,967	33,920	13.2	37,560	9.7	39,333	13.8
Gates	20.0	10,516	12,197	16.0	12,165	-0.3	12,254	0.5
Hyde	8.8	5,826	5,810	-0.3	5,156	-12.7	4,929	-17.9
Pasquotank	100	34,897	40,661	16.5	39,685	-2.5	39,591	-2.7
Perquimans	99.9	11,368	13,453	18.3	13,637	1.3	13,923	3.4
Tyrrell	92.4	4,149	4,407	6.2	4,260	-3.5	4,259	-3.5
Washington	64.2	13,723	13,228	-3.6	11,987	-10.4	11,159	-18.5

Note: The numbers reported here reflect county population. Some counties are not located entirely within the basin. The intent is to demonstrate growth for counties located wholly or partially in the basin.

Table 1-2 Population and population projections by municipality between 2010 and 2019 (OSBM, 2020).

Municipality	Population 2010	Population 2015	Percent Growth 2010-2015	Population 2019	Percent Growth 2015-2019	Percent Growth 2010-2019
Columbia	891	823	-7.6%	759	-7.8%	-14.8%
Creswell	276	263	-4.7%	256	-2.7%	-7.2%
Duck	369	390	5.7%	405	3.8%	9.8%
Edenton	5,004	4,765	-4.8%	4,612	-3.2%	-7.8%
Elizabeth City (Camden)	45	45	0.0%	44	-2.2%	-2.2%
Elizabeth City (Pasquotank)	18,638	17,736	-4.8%	17,721	-0.1%	-4.9%
Hertford	2,143	2,140	-0.1%	2,105	-1.6%	-1.8%
Kill Devil Hills	6,683	7,061	5.7%	7,378	4.5%	10.4%
Kitty Hawk	3,272	3,460	5.7%	3,619	4.6%	10.6%
Manteo	1,434	1,532	6.8%	1,618	5.6%	12.8%
Nags Head	2,757	2,934	6.4%	3,069	4.6%	11.3%
Roper	611	586	-4.1%	571	-2.6%	-6.5%
Southern Shores	2,714	2,897	6.7%	3,059	5.6%	12.7%
Winfall	594	604	1.7%	610	1.0%	2.7%

1.4.2 Land Cover

Land cover assists with developing land use management policies, modeling nutrient and pesticide runoff, understanding spatial patterns in biodiversity, ecosystem status and health, and evaluating the effects of land use changes on water quality over time (Homer et al., 2012). North Carolina uses land cover datasets available from the National Land Cover Database (NLCD) for the Pasquotank River basin (Figure 1-4). Overall, between the 2001 and 2016-time frame, the largest changes in land cover occurred in herbaceous/grassland (-15.1%), scrub/shrub (-6.9%), and developed (+7.4%) land (Table 1-3). Agriculture, barren land, open water, and wetlands stayed relatively stable (± 5.0%). Between the 2001 and 2011-time frame, forest land cover decreased by 17% appearing to be replaced by herbaceous/grassland and scrub/shrub land cover. The forest land cover appears to have recovered by 2016 as there was only a slight difference (+0.8%) is land cover area compare to 2001.

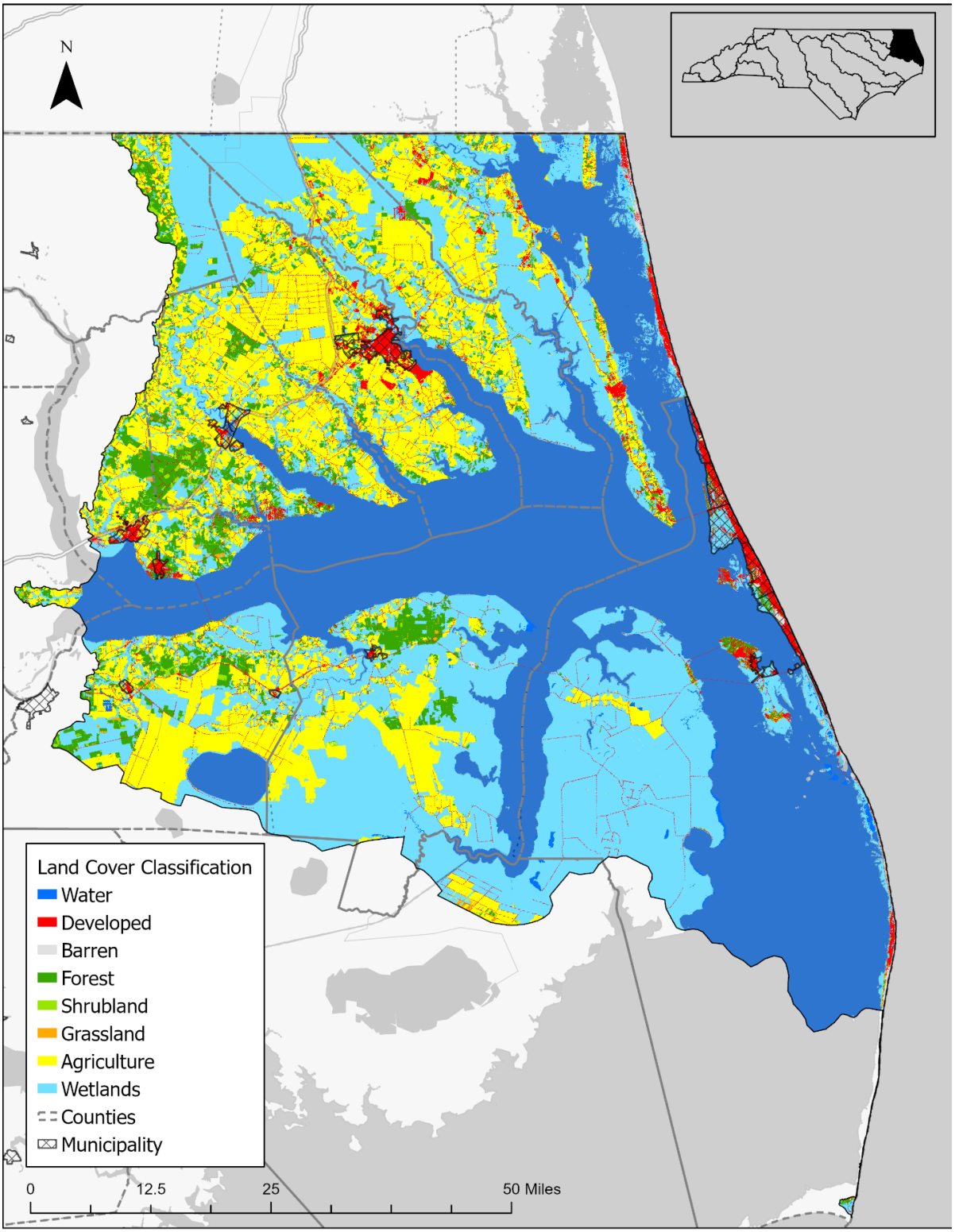
Table 1-3 Land cover for the North Carolina portion of the Pasquotank River basin (NLCD, 2016).

Land Cover Type	2001		2011		Percent Change 2001-2011	2016		Percent Change 2011-2016	Percent Change 2001-2016
	Area (mi^2)	Total (%)	Area (mi^2)	Total (%)		Area (mi^2)	Total (%)		
Agriculture	678.3	20.2%	668.4	19.9%	-1.5%	669.7	19.9%	0.2%	-1.3%
Barren Land	10.6	0.3%	10.8	0.3%	1.9%	10.9	0.3%	0.9%	2.8%
Developed	107.4	3.2%	114.2	3.4%	6.3%	115.3	3.4%	1.0%	7.4%
Forest	171.3	5.1%	142.2	4.2%	-17.0%	172.7	5.1%	21.4%	0.8%
Herbaceous/ Grassland	8.6	0.3%	18.4	0.6%	114.0%	7.3	0.2%	-60.3%	-15.1%
Open Water	1256.2	37.3%	1262.1	37.5%	0.5%	1260.1	37.4%	-0.2%	0.3%
Scrub/Shrub	17.5	0.5%	38.2	1.1%	118.3%	16.3	0.5%	-57.3%	-6.9%
Wetlands	1116.7	33.2%	1112.3	33.0%	-0.4%	1114.2	33.1%	0.2%	-0.2%

1.5 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. Please refer to Chapter 7 for more about permitted programs.

Figure 1-4 Land cover in the Pasquotank River basin (NCLD, 2016).



Developed, Forest, Grassland/Shrubland, Agriculture, and Wetland classes were created by aggregating two or more 2016 NLCD classifications. Developed is a combination of Developed, Open Space, Developed, Low Intensity, Developed, Medium Intensity, and Developed High Intensity. Forest represents deciduous, evergreen, and mixed forest classes. Grassland/Shrubland is Grassland/Herbaceous and Shrub/Scrub. Agriculture is Pasture/Hay and Cultivated Crops. Wetland is Woody Wetlands and Emergent Herbaceous Wetlands. 2016 NLCD definitions of classifications are found at https://www.mrlc.gov/data/legends/national-land-cover-database-2016-nlcd2016-legend

1.6 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 quality and eventually reaching surface waters through baseflow 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. Please refer to Chapter 8 for more information about these programs.

> ***Best management practice (BMP)*** *is defined as "a structural or nonstructural management-based practice used to singularly or in combination to reduce point source or nonpoint source inputs to receiving waters in order to achieve water quality protection goals" (15A NCAC 02B .0202).*

1.6.1 Agriculture

Nearly 20 percent (670 mi^2) of the land cover in the North Carolina portion of the Pasquotank River basin is identified as agriculture. 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 United States Department of Agriculture (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 (USDA, 2017). Because portions of Virginia are included in the watershed query, data was queried and aggregated at the county scale for counties with more than 50 percent land area in the basin. This included Camden, Chowan, Currituck, Dare, Pasquotank, Perquimans, Tyrrell, and Washington counties (Table 1-4).

Per the 2017 Census of Agriculture, a total of 783 farm operations are operating on a total of 448,065 acres (700 mi^2) in counties with more than 50 percent land area in the basin. This is a decrease from what was reported in the 2007 Census of Agriculture when a total of 923 farm operations were operating on a total of 467,216 acres (730 mi^2). The total number of acres identified as cropland, pastureland, and woodland has also decreased across the entire basin between 2007 and 2017 (Table 1-4).

Livestock inventory numbers have also decreased over time. Per the 2017 Census of Agriculture, the poultry inventory decreased from 1.9 million birds (chickens, broilers) on 29 farms in 2007 to 1.2 million birds (chickens, broilers) on 29 farms in 2017. Chowan, Perquimans, and Washington counties are the only three counties with reported poultry inventory numbers in 2007, 2012, and 2017. Currituck County

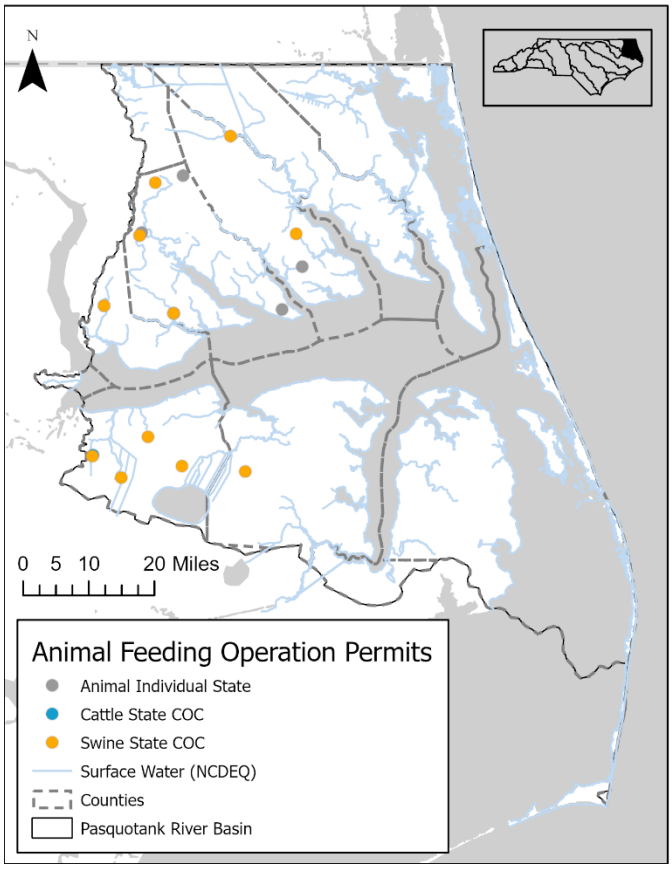
reported one poultry operation in 2017, but total inventory numbers were not reported. The livestock inventory for cattle and hogs also decreased between 2007 and 2017 (Table 1-4) (USDA, 2017). Information that is obtained through the Census of Agriculture can only be used to compare changes over time. It does not allow DWR to assess the extent of potential impacts of animal operations and animal waste on water quality in the basin.

Table 1-4 USDA Census of Agriculture (2007, 2012, 2017)

Data Item	2007	2012	2017	2007	2012	2017
	Number of Operations			Number of Acres		
Number of Farms & Land Area*	923	847	783	467,216	451,186	448,065
Land Use						
Total Cropland*	773	702	600	408,748	400,252	404,477
Total Pastureland*	295	225	255	7,861	8,154	6,297
Total Woodland*	421	377	313	41,911	38,004	31,980
Harvested Cropland*	658	620	508	394,921	392,404	391,912
Irrigated Acres*	122	87	74	11,360	10,396	6,611
Crops						
Corn, Grain*	385	331	269	130,890	119,085	104,047
Soybeans*	484	478	403	184,237	185,374	216,968
Cotton*	145	125	69	38,233	38,029	23,186
Tobacco*	12	9	5	267	605	306
Peanuts*	131	74	55	12,643	8,189	7,654
Wheat*	288	341	151	87,029	99,306	46,576
Forage (Hay & Haylage)*	71	56	59	1,464	1,253	4,683
Fertilizers						
Manure	86	61	67	7,834	4,768	8,871
Total	652	587	512	367,501	321,904	319,392
Livestock Inventory	**Number of Operations**			**Number of Animals**		
Cattle (Including Calves)*	155	130	132	4,589	4,198	3,497
Hogs*	34	18	27	81,171	8,697	816
Chickens (Broilers)*	29	22	29	1,854,859	2,000,723	1,243,836
* Information withheld from one or more counties to avoid disclosing data for individual farms (USDA, 2017).						

Animal operations are defined under North Carolina 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, the 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) (North Carolina General Statute 143-215.10C). These permitted animal facilities are inspected annually. As of June 2021, there were 15 permitted animal feeding operations in the Pasquotank River basin (Figure 1-5). More information about North Carolina's Animal Feeding Operations Program and the design capacity of permitted operations can be found in Chapter 7 and Appendix VII.

Figure 1-5 Animal feeding operation permits in the Pasquotank River basin (2021)



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 North Carolina 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 North Carolina 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. Deemed permitted facilities are only inspected if a compliant if filed.

Soil and water technicians and resource conservationists along with the Albemarle Resource Conservation and Development Council, Inc. (ARCD) are continually working with agricultural operations to identify areas to implement nutrient and sediment reducing BMPs as well as identifying how best to redesign drainage ditches from agricultural fields to reduce the amount and speed at which stormwater runoff enters a waterbody. Between June 2012 and June 2020, approximately 2 million dollars were spent by the Soil and Water Conservation Districts (SWCDs) through various cost share programs managed by the North Carolina Department of Agriculture & Consumer Services (NCDA&CS) Division of Soil and Water Conservation (DSWC) to install BMPs throughout the basin. Several practices have also been installed using funds available through programs managed by the USDA Natural Resource Conservation Service

(NRCS). A list of practices that have been installed in the basin can be found in the Chapter 3, Chapter 4, Chapter 5, and Chapter 8. BMPs that target nutrient reduction and sediment removal should continue to be prioritized and implemented throughout the Pasquotank River basin.

State and local agencies, as well as individual cooperators and landowners, should invest in nutrient reducing activities including:

- Identify and expand educational opportunities to work with private landowners on nutrient management and the benefits of implementing BMPs, maintaining riparian buffers and conducting soil tests.
- Provide new funding to hire additional personnel (DSWC) to promote BMPs in the region and work with landowners on new and innovative practices that can reduce nutrients, manage water levels in the field, and explore the benefits of forested buffers and wetlands to reduce nutrients and mitigate flood damage.
- Promote BMPs to reduce the loading of phosphorus into the whole Albemarle Sound system, with a focus on reducing phosphorus bound to sediments that can increase instream total phosphorus concentrations during runoff events.
- Encourage the use of nutrient management plans to ensure efficient use of fertilizers.
- Provide sufficient funding for adequate technical assistance and voluntary implementation of BMPs through the state's existing cost share programs managed by the DSWC as well as federal cost share programs and/or grants.

Identify and evaluate opportunities to continue promoting and implementing nutrient reducing BMPs throughout the basin including:

- Review and reevaluate existing policies that may limit a BMP's use in the basin.
- Enroll the support of academic researchers to identify new, cost-effective nutrient reducing BMPs for the region based on soil type, current and future crop rotations and specialty crops, organic and inorganic fertilizer management, etc.
- Identify new funding to hire additional soil and water conservation district staff at the local level to work with landowners on implementing nutrient reducing BMPs and identifying grant opportunities for additional cost share money.

Locally, the University of Mount Olive's Lois G. Britt Agribusiness was awarded funding from the North Carolina Agricultural Development and Farmland Preservation Trust Fund Center to develop Agricultural Development Plans for Chowan, Perquimans, Pasquotank, and Currituck counties. "The plan is intended to serve as a guide for actions to provide farmers, landowners and citizens an increased awareness of farmland preservation opportunities." (Dixon and Emory, 2017). The six core recommendation include (Dixon and Emory, 2017):

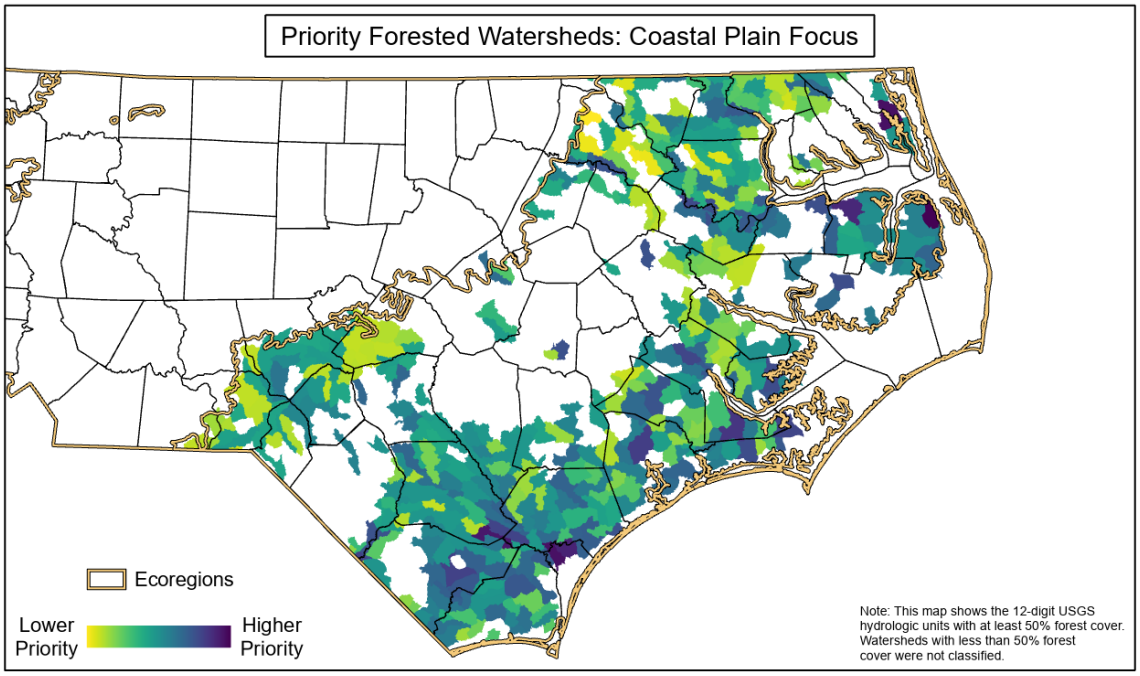
- Support Measures to Protect and Promote Forest and Farmland in Chowan, Perquimans, Pasquotank, and Currituck County.
- Develop, Adopt and Implement Voluntary Agricultural District and Enhanced Voluntary Agricultural District Programs.

- Develop and Conduct Programs to Assist Chowan, Perquimans, Pasquotank, and Currituck County Farm and Forest Landowners with Farm Transition Planning.
- Promote Appreciation and Awareness of the Benefits of Agriculture to Chowan, Perquimans, Pasquotank, and Currituck Elected Officials and Citizens.
- Expand and Support Youth Agricultural Educational Programs.
- Develop Technical, Business and Marketing Training for the Maintenance and Expansion of Agriculture in Chowan, Perquimans, Pasquotank, and Currituck County.

1.6.2 Forestry

Nearly five percent (173 mi^2) of the land use in the North Carolina portion of the Pasquotank 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.) (EPA, 2012). 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, introduce sediment, debris, and nutrients into waterbodies, and change 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 BMPs to protect water resources. The map below is from the 2020 North Carolina Forest Action Plan, illustrating priority forested watersheds of the coastal plain ecoregion (Figure 1-6).

Figure 1-6 Priority forested watersheds with a coastal plain focus (Map Source: NCFS).



1.6.2.1 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 NCAC (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). The FPGs require, among other things, that a protective streamside management zone (SMZ) be established along intermittent streams, 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 and require effective erosion and sedimentation control measures be installed and that the site be stabilized 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.

1.6.2.2 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 North Carolina 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 helps to identify where targeted assistance, education or training may be needed. In the Pasquotank River basin, BMP surveys were conducted on 7 sites, assessing 484 total BMPs, which were implemented at an 89% rate, higher than the statewide average.

During timber harvesting, the use of temporary bridges has shown to an effective alternative solution for crossing waterways since the equipment and logs stay out of the water 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 Elizabeth City district office. More information is available on the NCFS website: https://www.ncforestservice.gov/water_quality/bridgemats.htm.

1.6.2.3 Timber Harvest Inspections

Figure 1-7 and Figure 1-8 illustrate locations where the NCFS inspected timber harvests from 2007-2017. With the exception of a two-acre harvest on Manteo Island in 2007, the NCFS did not inspect any harvests outside of the North Carolina mainland. 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 535 timber harvests, totaling 27,910 acres, and found 12 harvests to be out of compliance (Table 1-5). The most common violations were related to debris entering streams.

From July 1st, 2012, to June 30th, 2017, the NCFS inspected 397 timber harvests, totaling 23,686 acres, and found 2 harvests to be out of compliance (Table 1-5). The most common violations were related to stream crossings.

From July 1st, 2017, to June 30th, 2020, the NCFS inspected 280 timber harvests, totaling 16,876 acres, and found 4 harvests to be out of compliance (Table 1-5). The most common violations were related to streamside management zones or debris entering waterbodies.

Table 1-5 Number of Inspections Conducted by NCFS in the Pasquotank River Basin

Time Period	# Inspected Timber Harvests	Total Acres	# Out of Compliance
07/2007-06/2012	535	27,910	12
07/2012-06/2017	397	23,686	2
07/2017-06/2020	280	16,876	4

1.6.2.4 Bottomland Swamp Forests

Since the previous basin plan cycle, there has been a renewed focus on some water quality concerns and their potential connections to forestry practices, in particular the harvesting of timber from bottomland swamp forests. In 2017, the NCFS and its cooperators convened a multi-day Bottomland & Swamp Forest Symposium to present a range of perspectives on managing, conserving and sustaining these forests. That symposium was one outcome from a grant provided to the NCFS by the USDA-Forest Service, which also included the creation of a series of Forestry Leaflets for landowners, and the implementation of a rapid assessment of tree regeneration in recently-harvested swamp forests. That assessment found suitable regeneration of tree species in nearly all of the 24 sites surveyed. On the few sites that did not yet exhibit tree regeneration, the main reason was due to artificially impounded water and/or invasive plants. Findings from this study were published in the journal *FORESTS*, available as an open-access article from this link: https://doi.org/10.3390/f11080854

Listed below are two references summarizing the status and trends of bottomland swamp forests in this region of interest, both produced by the USDA-Forest Service since the previous basin plan:

- "Status of Bottomland Forests in the Albemarle Sound of North Carolina and Virginia, 1984-2012." Published 2015, e-Research Paper #SRS-54. https://www.fs.usda.gov/treesearch/pubs/48894
- "Status and Trends of Bottomland Hardwood Forests in the mid-Atlantic Region." Published 2016, General Technical Report #SRS-217. https://www.fs.usda.gov/treesearch/pubs/53238

Local stakeholders have been working with the NCFS and local foresters in the Pasquotank and Chowan basins to identify ways to protect forested swamps. One recommendation is to establish a conservation program for swamp forest buffers similar to existing federal and state cost share programs for agricultural lands. The program could provide an economic incentive to landowners to conserve and manage swamp forest buffers. Conserving and managing the swamp forest buffers, in turn, could protect critical drainage areas, protect water quality, and provide aquatic and terrestrial habitat throughout the basin. Additionally, developing a designed study to evaluate water quality parameters stemming from managed forest land and provide recommendations for improving harvesting techniques and/or practices. The study would require substantial new funding for five or more years, landowner commitment, and experienced foresters and researchers to conduct the study. NCFS has offered to assist with project scoping, selecting foresters and researchers willing to participate in such a project, provide technical expertise on forestry practices, provide applicable references for literature review and general review and oversight. More information and frequently asked questions about logging in North Carolina can be found on NCFS's website.

Figure 1-7 Water quality inspections in the Pasquotank River basin July 2007 through June 2012 (NCFS, 2020)

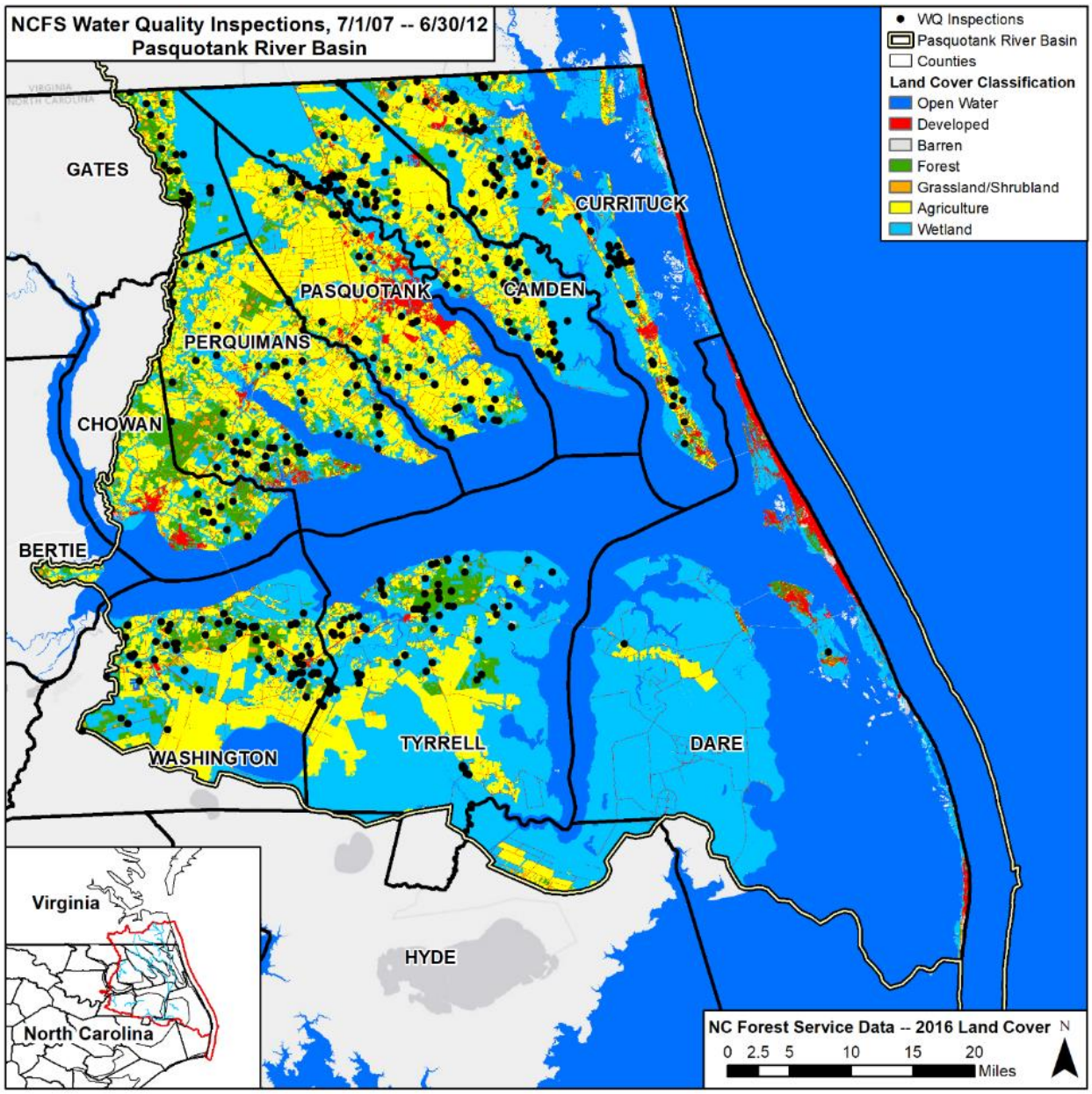
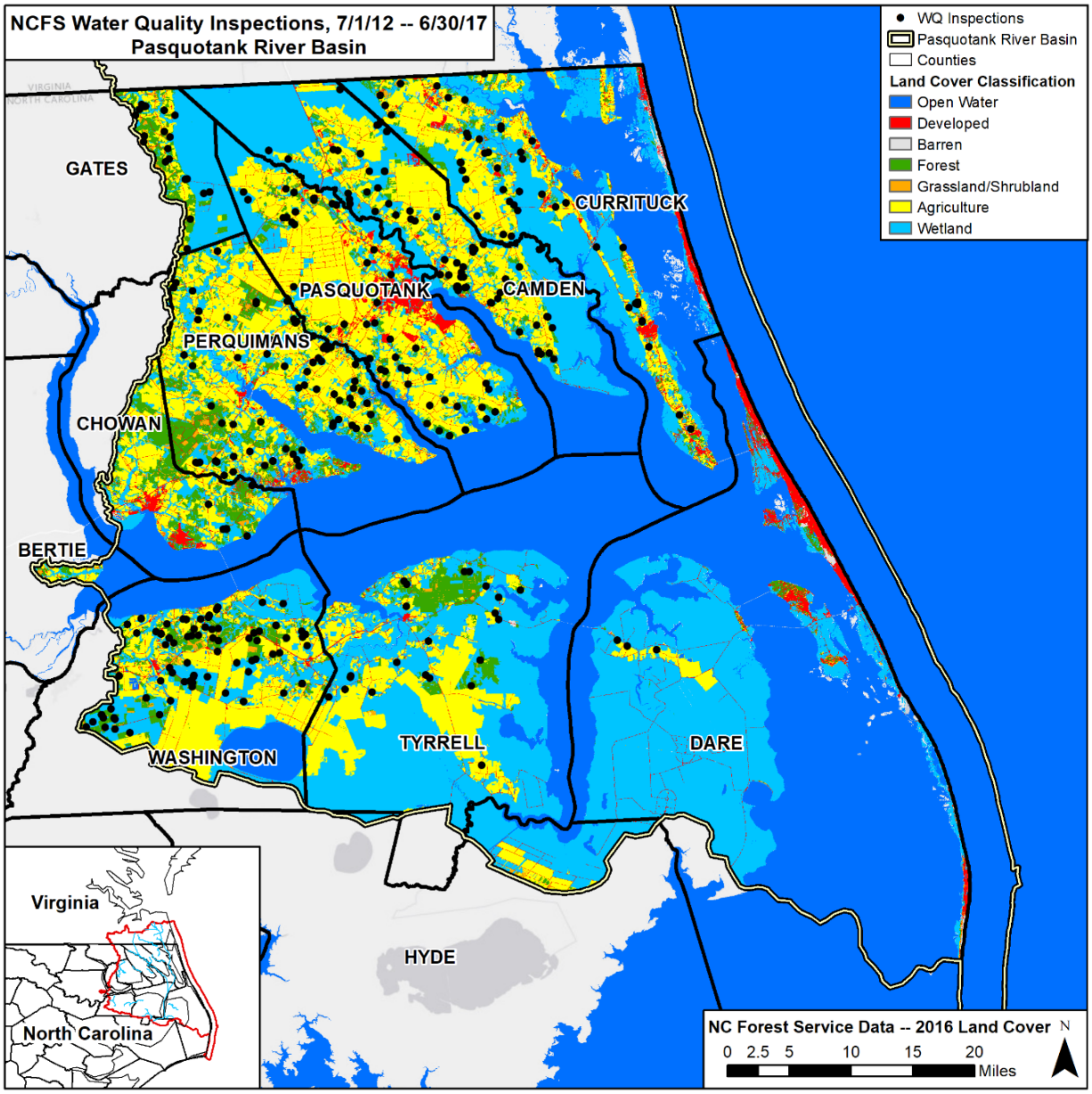


Figure 1-8 Water quality inspections in the Pasquotank River basin July 2012 through June 2017 (NCFS, 2020)



1.6.3 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. In some cases, stormwater runoff drains directly into streams, rivers, lakes and oceans. In other cases, particularly in urbanized areas, stormwater first drains into streets and manmade drainage systems consisting of inlets and underground pipes, commonly referred to as a storm sewer system.

Many daily activities have the potential to cause stormwater pollution, and in an area where activities (e.g., construction, land clearing, etc.) have the potential to contribute more pollutants through stormwater runoff, measures should be taken to minimize impacts from runoff. Planning up front during the design process can reduce impacts from stormwater runoff. 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: moderating 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 stream flow; 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. The North Carolina Department of Environmental Quality (NCDEQ) can offer some guidance for setting up voluntary urban stormwater programs in the Pasquotank River basin, if there is interest on the part of local governments. NCDEQ runs nonpoint source related grant programs that local governments can use to develop voluntary stormwater plans, map stormwater systems, create watershed restoration plans, develop innovative stormwater treatments, and implement stormwater retrofits to prevent the situation from getting worse. North Carolina State University Department of Biological and Agricultural Engineering has a useful fact sheet on their website. Local and county governments should work to identify areas impacted by stormwater runoff and how best to address stormwater issues and coordinate with community residents to:

- Voluntarily increase tree canopy cover, reduce fertilized landscaping, and minimize impervious surfaces with a primary focus on waterfront communities in areas with bloom activity.
- Allow economic growth to occur but maintain water quality through a comprehensive stormwater management program.
- Encourage Green infrastructure to minimize the impact from runoff.
- Work with local governments to identify and fund cost-effective stormwater retrofit projects, with a focus on local flood resiliency (maximize co-benefits).

1.6.4 Golf Courses

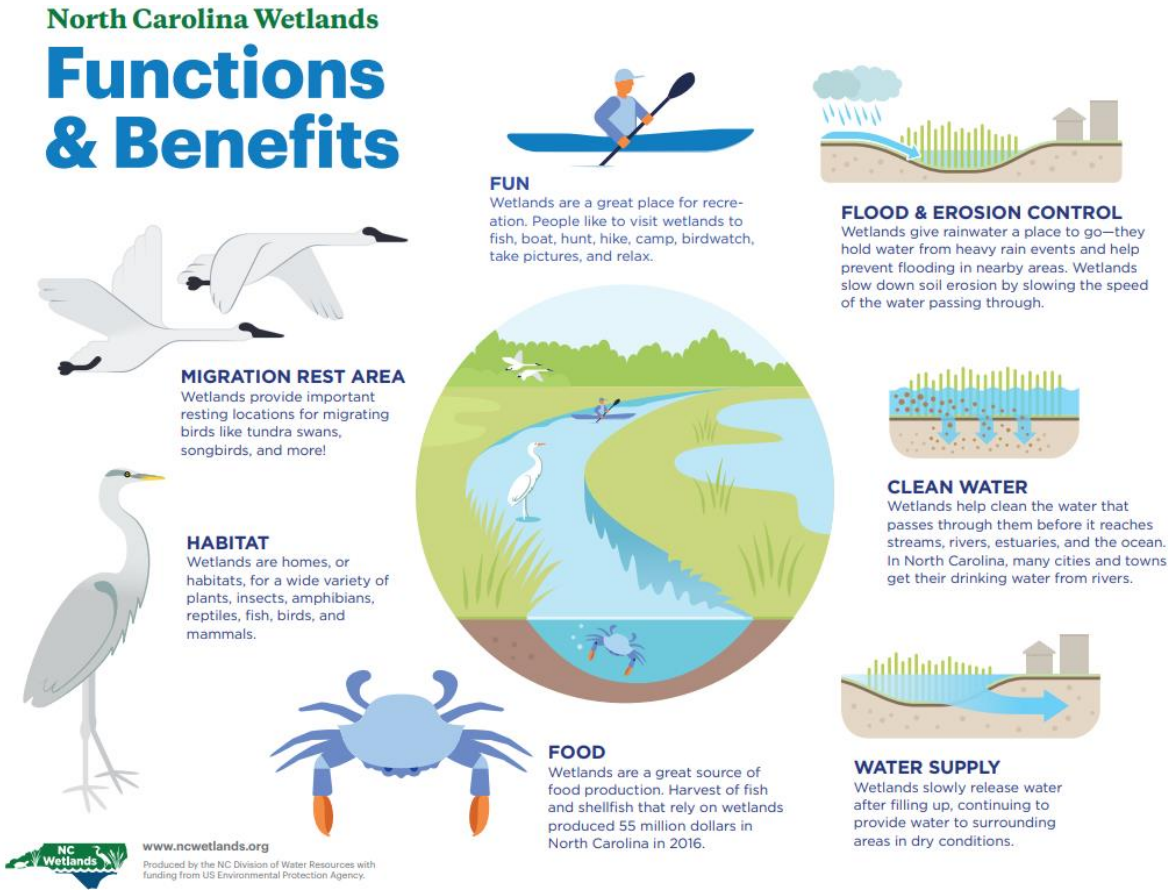
The NLCD classifies golf course land cover as developed land. These facilities utilize intensive turf management practices that often rely heavily on the use of fertilizers and chemical pesticides. Stormwater runoff then carries these pollutants to nearby streams, impacting aquatic life and habitat. 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. There are approximately 13 public and semi-private golf course in the Pasquotank River basin with many located on the Outer Banks (NCGolf n.d.). Eight golf facilities reported water use to the Water Withdrawal and Transfer Registration program in 2018 (Please refer to Chapter 9 for more information about water use). 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 Pasquotank River basin.

1.7 Wetlands

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 water or wet soils (Mitch and Gosselink, 2000). In the Pasquotank River basin, wetlands are especially important as they cover nearly a third of the landscape, a higher percentage than any other North Carolina river basin, with over 1,100 mi^2 of freshwater (palustrine) and saltwater (estuarine) wetlands (Figure 1-4, NLCD, 2016 and US FWS, 2020). Healthy wetlands are an integral component of healthy watersheds and they provide many essential ecosystem services that benefit humans, natural communities, and watershed functions (Figure 1-9).

Figure 1-9 North Carolina Wetlands Function and Benefits (Image Source: http://www.ncwetlands.org/) .



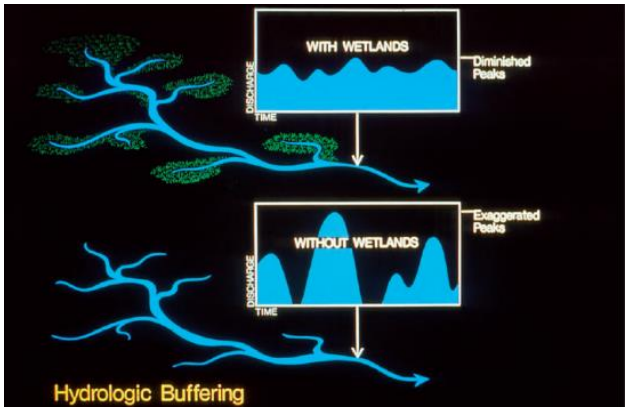
Different wetland habitat types are identified by the depth, duration, and type and source of water (fresh or salt), the landscape position, the soil type, and the dominant vegetation (NC FAT, 2016). The Pasquotank River basin has many diverse wetland habitats with approximately 92 percent of the wetlands identified as palustrine and eight percent identified as estuarine (US FWS, 2020). Estuarine wetlands fringe some of the coastal areas closer to the mouth of the Albemarle Sound, Currituck Sound, and the intercoastal waterway. Palustrine wetlands are found in association with the Pasquotank's many rivers and creeks and in some of the low flat or depressional areas of the basin, primarily in Dare and Tyrell counties in the southeast and Great Dismal Swamp in the northwest portions of the basin (US FWS, 2020).

Estuarine wetlands include a mix of saltwater and brackish marshes and mudflats fringing the shoreline and 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 (US NOAA, n.d.). Productive and dense salt marsh vegetation collect suspended sediment from the water column, and over time, rise vertically and migrate landward. Studies have shown salt marshes naturally keep up with sea level rise but may not be able to in the future if the rate of sea level rise increases (Northeim and RTI International n.d. and National Center for Coastal Ocean Science 2017).

Both riverine and non-riverine wetlands are found throughout the Pasquotank watershed. An extensive system of riparian riverine swamps exists along the North, Pasquotank, Scuppernong, Alligator, and Little Alligator Rivers and Bunton Creek. Riverine swamps also occur along the Little and Perquimans Rivers, the edge of Lakes Phelps, and other smaller creeks and tributaries to a lesser degree. Much of the low, flat areas of Dare and Tyrell counties are covered with non-riparian wetlands including pocosins, non-riverine swamp forests, and wet pine flats (NC DCM, 2020). 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).

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 (NC DWR, 2018). The ability of wetlands to perform their water quality and storage functions is inhibited by the many stressors that have caused the loss or alteration of wetlands in North Carolina and the Pasquotank River basin, including ditching, drainage tiles, non-native vegetation, soil compaction, vegetation removal, and fill. It is estimated that by the 1980s, only half of all natural, unaltered wetlands that existed prior to colonization remained (USGS, 1996). Ditching and drainage tile installation used to drain many wetlands can greatly reduce or eliminate wetland hydrologic function. Ground-disturbing activities, such as farming, logging, and construction can cause wetland stress through soil compaction or the introduction of invasive plant species (Native Plant Society, n.d.).

Figure 1-10 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 1-10) (Welsch et al., 1995). Loss of mature forested areas also reduces habitat for migratory bird species and wildlife that depend on tree cavities (US FWS 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), which is 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 US Department of Agriculture's Farm Service Agency. 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 WPP, 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. Although, discharges of dredged or fill material associated with established, ongoing and normal silviculture practices in wetlands are exempted from permitting under the Clean Water Act there are provision that must be followed in order to retain that exemption. Those provision include required BMPs for forest roads and skid trails and also 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.

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 State of North Carolina Wetland Program Plan 2021-2025" (NC WPP) provides North Carolina DEQ's wetland goals and specific activities for the next five years. As stated in the North Carolina WPP, "North Carolina state agency support for voluntary restoration and protection includes project guidance, low-interest loans, and grant funding for proposed projects. Conducting research and sharing resultant data will also provide guidance and assist with implementing successful restoration and protection methods to help improve water quality. State agency staff will continue 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 North Carolina WPP goals for voluntary restoration and protection include providing guidance and promoting statewide wetland restoration and protection goals (including wetland acres, condition, and functions) and assisting with public outreach and education for North Carolina voluntary restoration efforts.

In addition to the North Carolina WPP goals, this report supports wetland restoration and/or preservation. Restoration efforts should prioritize areas that are strategically located to protect or improve water quality (e.g., headwater or riparian areas), mitigate local flooding issues, have connectivity to existing wetland or upland wildlife habitat, or have deep organic soils. 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.

1.8 Threatened and Endangered Species

The North Carolina Wildlife Action Plan (2015) determined the species of greatest conservation need in the Pasquotank River basin (Table 1-6) and a series of recommendations. Their recommendations include surveys, monitoring, research, management practices, and, conservation programs and partnerships. The complete report is available on the North Carolina Wildlife Resources Commission (WRC) website (link).

Table 1-6 Species of Greatest Conservation Need in the Pasquotank River Basin (Source: NC Wildlife Action Plan 2015).

Taxa Group	Scientific Name	Common Name	Federal/ State Status*
Fish	Acipenser brevirostrum	Shortnose Sturgeon	E/E
	Acipenser oxyrinchus	Atlantic Sturgeon	E/E
	Enneacanthus chaetodon	Blackbanded Sunfish	—
	Enneacanthus obesus	Banded Sunfish	—
	Fundulus cf. diaphanus	Lake Phelps Killifish	FSC/—
	Notropis chalybaeus	Ironcolor Shiner	—

E - Endangered; a taxon which is in danger of extinction throughout all or a significant portion of its range.
FSC - Federal Species of Concern; Those species that appear to be in decline or otherwise in need of conservation and are under consideration for listing or for which there is insufficient information to support listing at this time. Subsumed under the term 'FSC' are all species petitioned by outside parties and other selected focal species identified in USFWS strategic plans, State Wildlife Action Plans, or Natural Heritage Program Lists

The Pasquotank River basin has been recognized as an important spawning area for anadromous fish species including Atlantic and Shortnose Sturgeon, Striped Bass, and River Herring and as such has been designated as an Anadromous Fish Spawning Area (map) in rule by DMF (15A NCAC 03R .0115) and WRC (15A NCAC 10C .0603). River Herring landings in the Albemarle Sound and Chowan River declined sharply in 1986, followed by the implementation of a no-harvest provision in 2007 (NC DMF, 2020). A coastwide stock assessment was completed in 2017. Three stock recovery indicators were used and collectively these indices represent a minimal stock rebuilding goals for the recovery of river herring stocks in the Albemarle Sound and Chowan River. The results of this study found that river herring stocks remain low and at near historic lows coastwide (NC DMF, 2020; ASMFC, 2017). Additional information about fisheries in the Albemarle Sound can be found in the Division of Marine Fisheries website (link).

1.9 Climate Risk and 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 buffer's 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 North Carolina 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 North Carolina'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.

1.9.1 Planning for Sea Level Changes

Sea level rise will adversely impact North Carolina's coastline and specifically the northern coastline because of its underlying geologic structure (Riggs and Ames, 2003). Sea level rise may intensify natural hazards in coastal areas including flooding, storm surge, shoreline erosion, eutrophication, and shoreline recession (Moorman, 2014). There is a predicted acceleration in coastal erosion and an increase in estuarine shoreline erosion if oceanic processes are altered by increased barrier island elevation through natural or human modifications (Riggs and Ames, 2003). Major loss of land is predicted in Currituck, Camden, Dare, Hyde, Tyrrell, Pamlico and Carteret counties if glacial melting rates increase significantly, as projected by the Intergovernmental Panel on Climate Change (Riggs and Ames, 2003; IPCC, 2001). Drowning the North Carolina Coast: Sea-Level Rise and Estuarine Dynamics by S. Riggs and D. Ames (2003) published by North Carolina Sea Grant provides information specifically addressing northeastern North Carolina. This book provides images and figures explaining sea level rise and coastal erosion. This book should be used as a resource for coastal town and municipality planners as new developments, utility infrastructure and other land use decisions are made. Additionally, several universities are researching the impacts of sea level rise on North Carolina's coastal economy and habitat.

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

1. *Rural Coastal Community Resilience: Assessing a Framework in Eastern North Carolina. (link)*
2. *Sea Level Rise Impacts on Rural Coastal Social-Ecological Systems and the Implications for Decision Making. (link)*
3. *Marsh Bird Occupancy Along a Shoreline-to-Forest Gradient as Marshes Migrate from Rising Sea Level. (link)*
4. *Use of Autonomous Recording Units Increased Detection of a Secretive Marsh Bird. (link)*
5. *Bird Community Shifts Associated with Saltwater Exposure in Coastal Forests at the Leading Edge of Rising Sea Level. (link)*
6. *Decadal-Scale Vegetation Change Driven by Salinity at Leading Edge of Rising Sea Level. (link)*
7. *Evaluating the Effects of Land-Use Change and Future Climate Change on Vulnerability of Coastal Landscapes to Saltwater Intrusion. (link)*
8. *'A Commons Before the Sea:' Climate Justice Considerations for Coastal Zone Management. (link)*

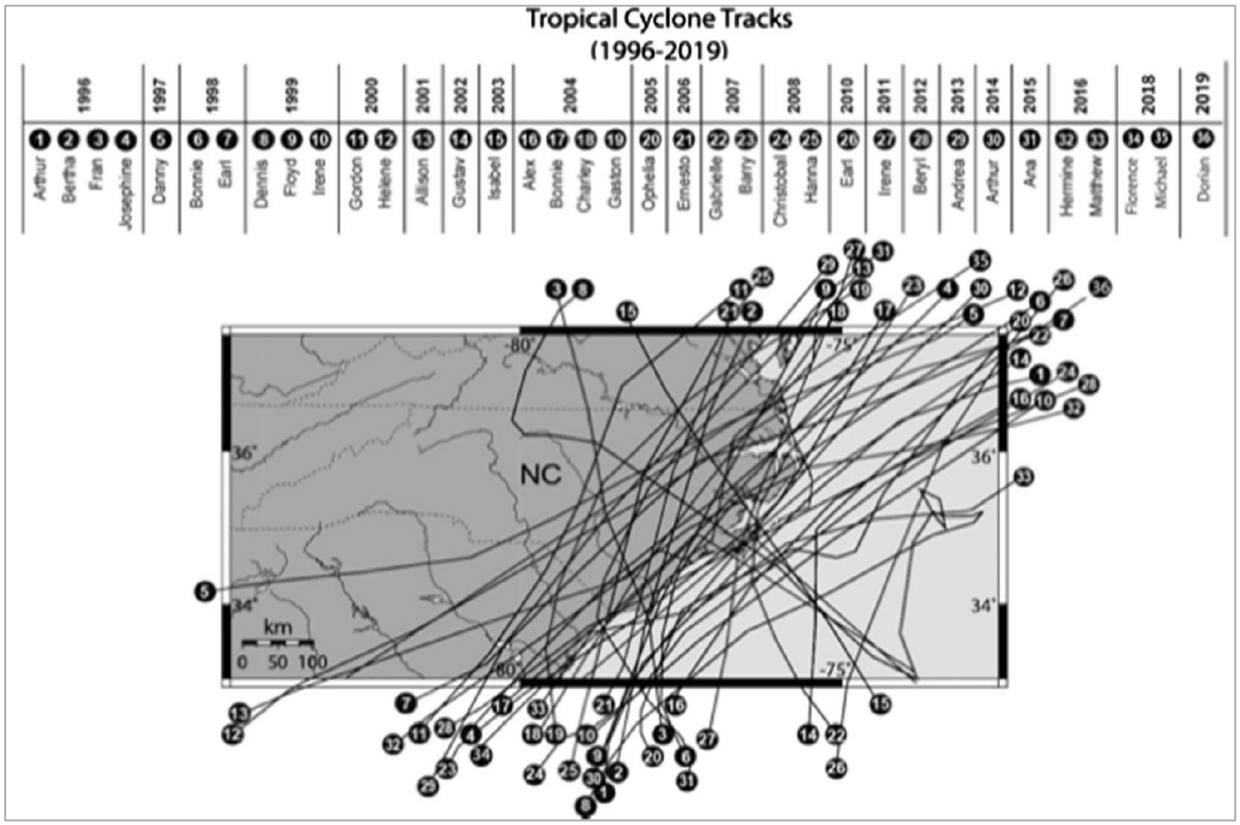
Additionally, researchers from NC State University and Duke University studied the topic of sea level rise and ecological changes in the Alligator River National Wildlife Refuge. Publications include: *Rapid Deforestation of a Coastal Landscape Driven by Sea Level Rise and Extreme Events* (link), *Drivers of Greenhouse Gas Emissions from Standing Dead Trees in Ghost Forests* (link). Duke University also led the Coastal Protection and Blue Carbon: Mid-Atlantic States project (link). This multi-state collaborative project funded by the U.S. Climate Alliance "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 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).

1.9.2 Hurricanes and Flooding

Devastating hurricanes impacted the North Carolina coast and piedmont areas resulting in property damage from storm surge, heavy rains, high winds, tornados, and flooding. The stable environmental conditions between 2004 through 2010 and relatively small size of the watersheds which limits the amount of oxygen-depleted water draining after large rain events appear to have benefitted the Albemarle Sound region (USWRC, 2013). As a result, Hurricane Irene (August 28, 2011) appears to have had little impact on the Pasquotank, Perquimans, Little, Yeopim, and Scuppernong rivers (NCWRC, 2013). Additionally, the oxygen-rich waters of the Albemarle Sound aid in limiting the fish kills in the upper reaches of the smaller coastal rivers (NCWRC, 2013). After Hurricane Irene, the following hurricanes impacted North Carolina: Hurricane Matthew (October 4, 2016 – October 24, 2016), Hurricane Florence (September 7, 2018 – September 29, 2018), Hurricane Michael (October 10, 2018 - October 12, 2018), and Hurricane Dorian (September 1, 2019 - September 9, 2019) (Figure 1-11). The Federal Emergency

Management Agency (FEMA) declared all the counties in the Pasquotank River basin as disaster areas following Hurricane Matthew (map) and Hurricane Dorian (map). Areas of Tyrell, Dare, and Hyde counties were disaster areas following Hurricane Florence (map). Dare and Hyde counties were disaster areas following Hurricane Michael (map). In response to repeated hurricanes, the North Carolina General Assembly appropriated 1.4 billion in State support for disaster recovery efforts (Fiscal Brief).

Figure 1-11 Tropical cyclone paths and time frames of coastal impacts in North Carolina since 1996 (Image Source: Paerl et al., 2020).

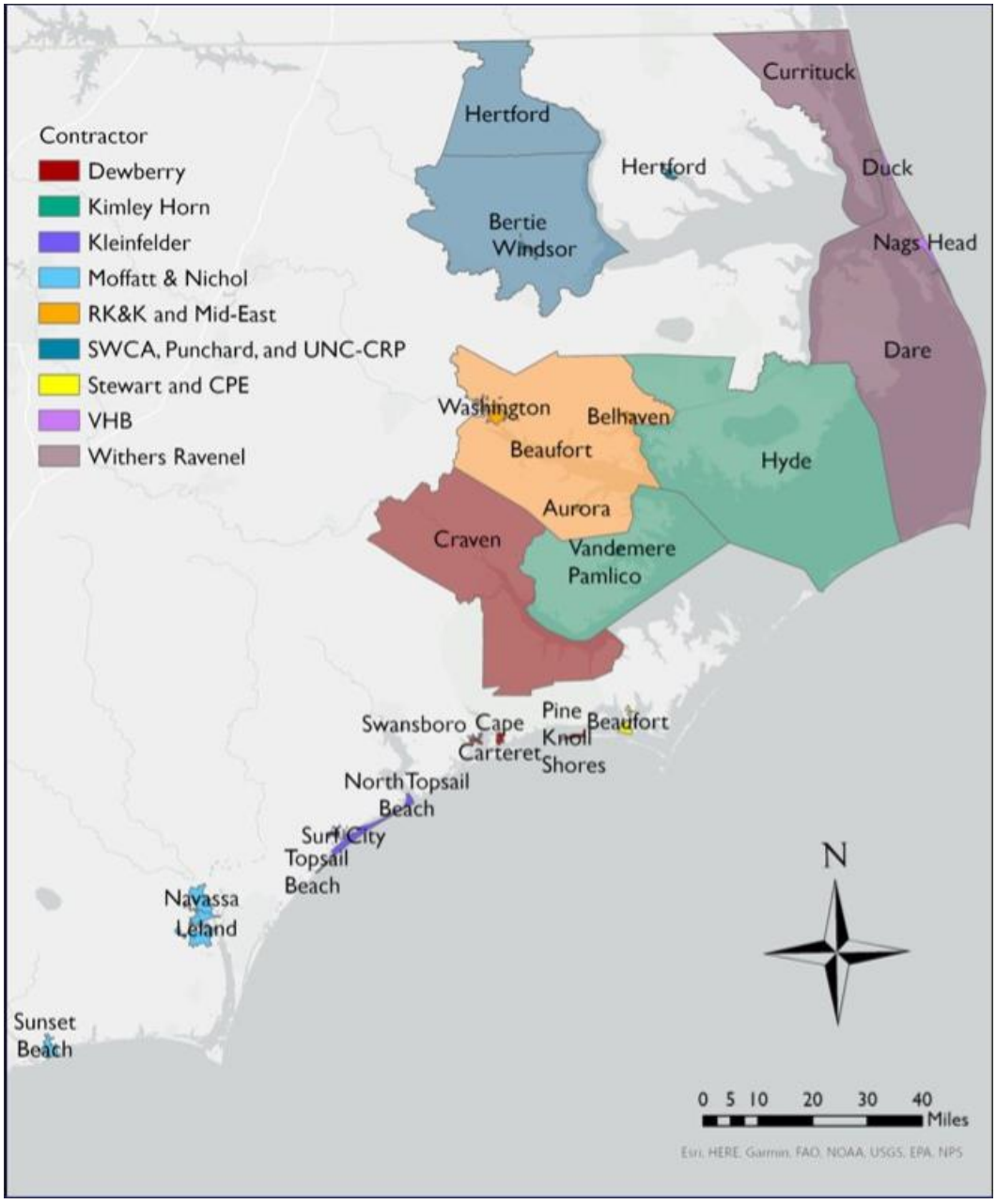


In 2016, the General Assembly established the North Carolina Resilient Redevelopment Planning Program to provide a guide to rebuild communities damaged by the Hurricane Matthews. This program produced Hurricane Matthew Resilient Redevelopment Plans for 50 counties available through North Carolina Office of Recovery and Resiliency (NCORR) (https://www.rebuild.nc.gov/resiliency/hurricane-matthew-resilient-redevelopment-plans). 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 (NCCF, 2021). 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).

From 2016 – 2018, Division of Coastal Management (DCM) developed a pilot program to better understand the needs of communities dealing with natural hazards. Their 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 1-12).

Figure 1-12 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/).

1.10 Contaminants of Emerging Concern

Contaminants of emerging concern (CECs) are increasingly being detected in surface and groundwater across the state. They come from a wide range of sources including pesticides, lawn and agricultural products, disinfection by-products, wood preservatives, pharmaceutical and personal care products (PPCPs), and industrial chemicals as well as their by-products (EPA, 2019). Potential sources include conventional wastewater treatments plants, individual on-site wastewater collection systems, and industrial and chemical manufacturing facilities. GenX and 1,4-dioxane are examples of CECs recently identified in North Carolina surface waters. These compounds often go undetected and untreated because facilities do not have the analytical tools, methods or treatment systems in place that can detect, eliminate or treat them.

While a compound may be unique to a specific source or river basin, many are widespread. The effects of CECs on aquatic ecosystems and on human health are mostly unknown, and the lack of appropriate analytical methods and monitoring techniques makes identification and management a challenge. The uncertainty of whether these emerging compounds are present, their effects on human health and their impacts to aquatic ecosystems is a growing public concern. Because CECs are not fully understood, state agencies and EPA are working on analytical methods to identify the compounds in a variety of media (water, wastewater, biosolids, soils, sediment, agricultural products) and identify treatment options for public water supply systems to provide safe drinking water to the public and ensure that aquatic ecosystems are protected.

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