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Chapter 8 Water Use and Availability

North Carolina has a diverse array of water users throughout the state including: public and private water supply systems that supply drinking water to their customer base; industries such as food production, pharmaceuticals, wood manufacturing and metal processing; and energy production (hydroelectric and thermoelectric). Water is also used statewide for agricultural, mining, and recreational purposes. The availability and continued use of water by all users is vital to the continued prosperity to the people and communities across the state.

There are several programs within the North Carolina Department of Environmental Quality (DEQ) that provide information about how much water is being used in North Carolina. These include the Water Withdrawal and Transfer Registration (WWATR) Program, the Local Water Supply Planning (LWSP) Program, the Central Coastal Plain Capacity Use Area (CCPCUA), and the Interbasin Transfer (IBT) Certification Program. Several programs are also in place to protect drinking water sources including the Source Water Protection Program (SWAP), the Surface Water Protection Program (SWP) and the Wellhead Protection Program (WHP). Water use information is also collected by the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) and reported in the Agricultural Water Use Survey. More information about the DEQ programs can be found in Chapter 7. More information about the Agricultural Water Use Survey can be found in Section 8.2.4 of this chapter.

In addition to the programs already identified, DEQ also plays a critical role in providing technical and management support for the development and use of groundwater resources and calculating the volume of water moving through a system, while the North Carolina Department of Agriculture & Consumer Services (NCDA&CS) plays a critical role in collecting agricultural water use across the state. The information presented here is based on best available data, and includes information about geology and groundwater, water availability, water use and demand, and stream flow. The chapter concludes with future considerations to better understand statewide water use. Information presented here is not field verified and should not be used for regulatory compliance purposes.

8.1 Geology and Groundwater

Geology of the Chowan River basin consists of interbedded sand, silt, clay and limestone sediments ranging in age from the early Cretaceous (145 million years ago) to the present. These sediments dip and thicken from west to east and overlie considerably older rock consisting primarily of igneous and metamorphic bedrock. Sediment thickness within the basin ranges from ten feet or less in the western portion of the basin to over 1,000 feet in eastern Gates and Chowan counties (Figure 8-1).

Potable groundwater supply is available throughout the Chowan River basin. Salt water, however, is present within some portions of the aquifers, making proper well design a key factor to assuring a sustainable supply of freshwater. Currently, groundwater is the primary source of water supply for communities and private wells in the basin.

8.1.1 Aquifer Systems

Aquifers are layers of water-bearing permeable and semi-permeable rocks and sediments that can store and transmit water through fractures and pore spaces (Hornberger et al., 1998). These fractures and pore

spaces exert physical controls on the storage (porosity) and transport (permeability) of groundwater. Aquifers vary significantly in their porosity and permeability, resulting in varying storage capacity and flow rate. In addition to the natural porosity and permeability of an aquifer, groundwater movement and resource sustainability are affected by the hydrologic cycle, physical forces, and human activities.

Aquifers are categorized into two types: unconfined and confined. An unconfined aquifer is referred to as the water table, or surficial aquifer. Water within an unconfined aquifer occurs at atmospheric pressure and rises and falls seasonally in response to variations in precipitation and air temperature. Confined aquifers are typically sedimentary and are found in the coastal plain. These aquifers consist of thick, water-saturated sand or limestone layers which are confined on the top and the bottom by impermeable beds of clay and silt. Confined aquifers are referred to as artesian when there is enough pressure to allow water to flow to the land surface. This pressure is created by the immense weight of water within the aquifer and the downward force of the overlying sediment. Recharge in confined aquifers occurs by "leakage" from other aquifers or by direct infiltration where the aquifer outcrops. Outcrops occur many tens of miles updip from where the aquifer is being utilized for water supply. Since recharge rates are much lower in confined aquifers, water level monitoring is necessary to assure that dewatering does not occur as a result of overpumping. Dewatering reduces well yield, increases well operating costs, and causes permanent aquifer compaction and land subsidence.

The primary aquifers within the Chowan River basin, from shallowest to deepest, are the surficial, Yorktown, Castle Hayne, Beaufort, Upper Cape Fear, Lower Cape Fear and the Lower Cretaceous aquifers (Figure 8-1). With the exception of the surficial unit, each of these aquifers contains freshwater, transitional, and salt water zones at some depth within the aquifer. In general, these aquifers dip and thicken from west to east. Within the western portion of the basin, where the sedimentary aquifers are thin or absent, groundwater supply is provided by the regolith-bedrock aquifer. A brief description of each aquifer is provided here. More information about North Carolina's aquifers can also be found on the Ground Water Management Branch's (GWMB) website.

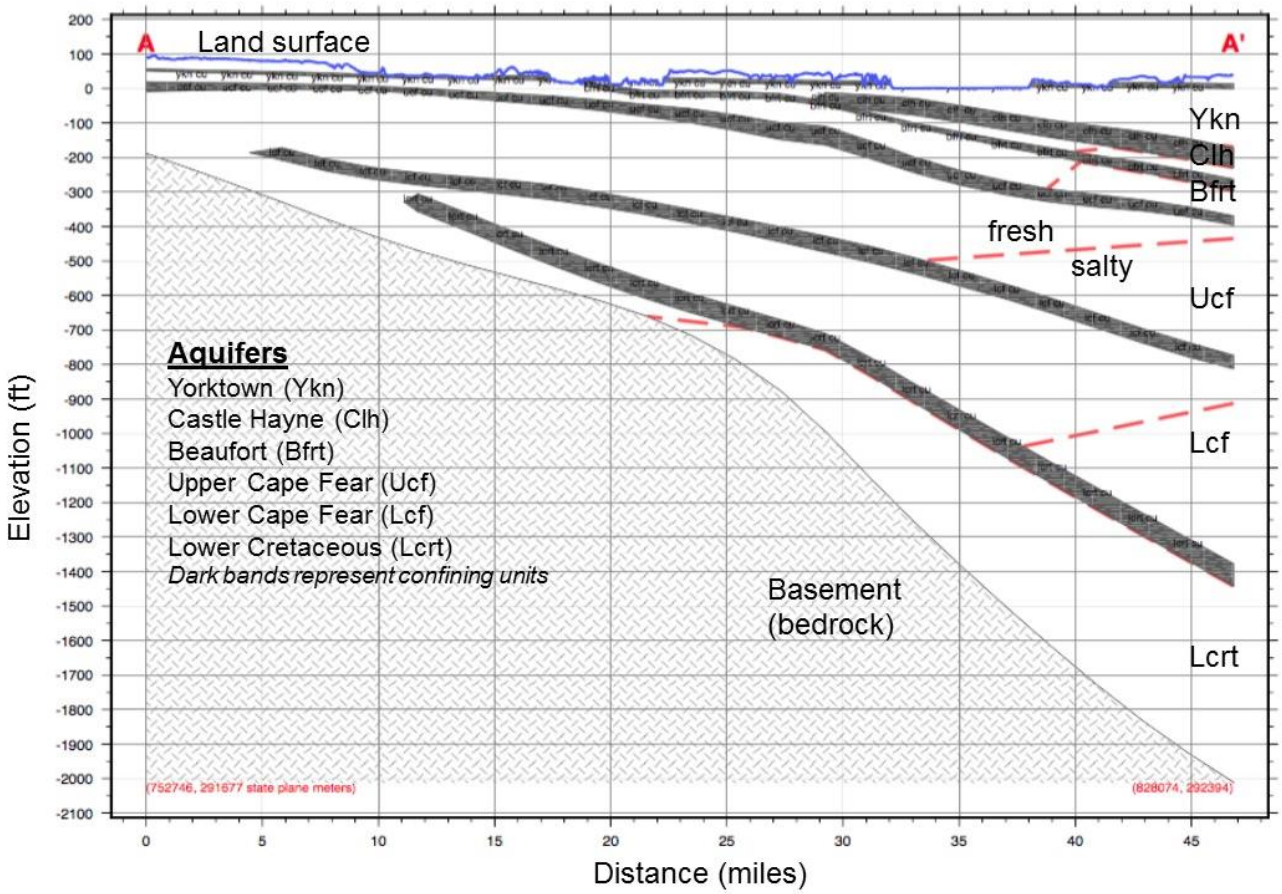
8.1.1.1 Surficial Aquifer

The surficial aquifer, or water table, is continuous throughout the study area and is the uppermost aquifer in the Chowan River basin. In most of the basin, the surficial aquifer is comprised of unconsolidated sediments, but in the western portion of the basin where these sediments thin or pinch out, it includes the regolith-bedrock aquifer. Typically, the surficial aquifer ranges from several feet to over 100 feet in thickness.

Water levels in the surficial aquifer rise and fall throughout the year in direct response to precipitation. Changes in water level may range from several inches to a foot or more during precipitation events and by tens of feet over a period of a year. Sustained well yields from the surficial aquifer range from several gallons per minute to ten or more gallons per minute depending on aquifer thickness, permeability, and other factors.

The surficial aquifer plays an important role in providing potable water from shallow wells where large quantities are not required. It is also essential in providing baseflow to perennial surface waterbodies and, in the coastal plain, recharge to underlying semi-confined and confined aquifers.

Figure 8-1 Geologic Cross-Section through the Chowan River Basin



8.1.1.2 Yorktown Aquifer (Ykn)

The Yorktown aquifer is a fossiliferous, bluish-gray clay with varying amounts of silt and fine-grained sand and shell material. The sandy, shelly portion of the formation is water-bearing and can typically supply enough water to sustain domestic wells. Although usually confined, the Yorktown may behave as a surficial aquifer when present at or near land surface. Groundwater from the aquifer often has high levels of iron.

8.1.1.3 Castle Hayne Aquifer (Clh)

The Castle Hayne limestone aquifer underlies portions of the eastern Chowan River basin but is absent elsewhere. Where present, the Castle Hayne is confined and typically less than 100 feet in thickness within the extent of the basin. Water yields from the aquifer are typically high, but water is generally hard (i.e., calcium and magnesium carbonates) and can sometimes contain high iron concentrations.

8.1.1.4 Beaufort Aquifer (Bfrt)

The Beaufort aquifer underlies portions of the eastern Chowan River basin and is comprised primarily of glauconitic, fossiliferous, clayey sands and intermittent limestones which include sediments from the overlying Castle Hayne formation. Within the basin, the aquifer is confined and typically less than 100 feet thick. Like the Yorktown, the Beaufort can provide potable water where large quantities of water are not required.

8.1.1.5 Upper and Lower Cape Fear Aquifers (Ucf, Lcf)

The Upper and Lower Cape Fear aquifers are the most prolific sources of high-quality groundwater in the basin. Consisting of sands with minor silt and clay interbeds, the upper and lower aquifer units are separated from one another by a thick, low-permeability confining unit comprised of silt and clay.

8.1.1.6 Lower Cretaceous Aquifer (Lcrt)

The Lower Cretaceous aquifer is comprised of interbedded sands and clays which lie uncomformably on crystalline bedrock. The Lower Cretaceous aquifer is seldom used within the Chowan River basin because of the availability of shallower, high quality aquifers. In addition, high chlorides (>250 mg/l) render the water too salty for use as a potable water supply within the eastern half of the basin.

8.1.1.7 Regolith-Bedrock Aquifer

In the western portion of the basin, where coastal plain sediments are thin or non-existent, groundwater is available from the regolith-bedrock aquifer. This aquifer consists of soil, weathered rock, and alluvium, which is referred to as regolith, and the underlying bedrock.

8.1.2 Groundwater Demand and Availability

Groundwater availability is a function of an aquifer's ability to store and transmit water. To be sustainable, groundwater pumping must not exceed the recharge rate of the aquifer. When recharge rates are exceeded, dewatering occurs. Dewatering results in reduced well flow, porosity loss, land subsidence, and in some cases, upward movement of saline water from deeper within the aquifer. The availability of baseflow, which is the continuous supply of groundwater seepage that streams, rivers and wetlands rely on, can also be adversely impacted by groundwater overuse. Stream flow during times of drought is entirely dependent on baseflow.

Precipitation, evapotranspiration, hydrology, geography, land cover and water withdraw all impact baseflow and the amount of water available for human consumption, irrigation, recreation and aquatic habitat. Groundwater and surface water are hydraulically connected, but the interactions are often difficult to measure. A surface waterbody can gain water from groundwater (gaining stream), lose water to groundwater (losing stream), or it can gain and lose depending on the streambed, hydrology and geography of the area. In either instance, the interactions between ground and surface water impact water quality and the availability of both (Winter et al., 1998). Major withdrawals from surface water or groundwater can limit the amount of water available for all uses in the basin.

To estimate groundwater recharge to the surficial aquifer, the Division of Water Resources (DWR) used historical stream flow data available through United States Geological Survey (USGS). Two USGS gaging stations are active in the Chowan River basin and are located on Potecasi Creek (USGS 02053200) and Ahoskie Creek (USGS 02053500). Using historical data from these two stations, the average annual baseflow for the basin was estimated to be 0.037 million gallons per day per square mile (MGD/mi^2).

To estimate groundwater recharge to the basin's confined aquifers, DWR used published estimates. Recent estimates for confined aquifer recharge range from as low as 0.04 in/year (Heath and Spruill, 2003) to 0.5 in/year (Lautier, 2001). These rates are equivalent to about 0.002 and 0.024 MGD/mi^2, respectively.

Groundwater supply estimates for the Chowan River basin are summarized in Table 8-1. DWR calculated low and high ranges of total groundwater availability using the following generalized equations:

- Low range estimate: Groundwater Availability = (surficial recharge rate) + (low range confined aquifer recharge rate)
- High range estimate: Groundwater Availability = (surficial recharge rate) + (high range confined aquifer recharge rate)

These equations take into consideration the estimated fraction of the basin with access to confined aquifers. DWR's low and high range groundwater availability estimates are 50.591 and 78.757 MGD, respectively.

Table 8-1 Estimated Groundwater Available in the Chowan River Basin

County	Low Range Total Estimated Supply (MGD)	High Range Estimated Supply (MGD)	Percent Demand vs. Supply (Low)	Percent Demand vs. Supply (High)
Bertie	8.08	12.638	23%	15%
Chowan	3.703	5.791	59%	38%
Gates	10.798	16.89	19%	12%
Hertford	14.095	22.047	34%	22%
Northampton	13.915	21.391	14%	9%
Total	**50.591**	**78.757**	**25%**	**16%**

Table 8-2 Groundwater Demand for the Chowan River Basin

County	Demand from WWATR (MGD)[2]	Demand from LWSP (MGD)[3]	Demand from Agriculture (MGD)[4]	Demand from Residential Wells (MGD)[5]	Total Demand (MGD)[1]
Bertie	0.055	1.330	0.423	0.043	1.851
Chowan	-	1.420	0.722	0.044	2.187
Gates	-	0.879	1.079	0.071	2.029
Hertford	1.170	1.268	1.983	0.183	4.604
Northampton	0.017	1.007	0.733	0.103	1.861
Total	**1.242**	**5.904**	**4.940**	**0.444**	**12.532**

1. Supply and demand values are for area in county in 2015, unless noted otherwise.
2. DWR Water Withdrawal and Transfer Registration (WWATR) database.
3. DWR Local Water Supply Plan (LWSP) database.
4. Irrigation demand based on data from 2012 USDA Census of Agriculture and 2013 Farm and Ranch Irrigation Survey.
5. Residential well demand assumes DWR's estimate that 10 percent of the basin population uses private wells at a rate of 75 gallons per day per person.

Total groundwater demand for the Chowan River basin was calculated by summing agriculture and residential well demand estimates with demand reported in DWR's Water Withdrawal and Transfer Registration (WWATR) and Local Water Supply Plan (LWSP) databases. Residential well estimates assume 10 percent of the basin population uses private wells at a rate of 75 gallons per person per day. Total

basinwide groundwater demand for 2015 was calculated to be 12.532 MGD (Table 8-2). DWR estimates that total basin demand is currently being met, and that total demand is between 16 and 25 percent of the total available groundwater supply (Table 8-1). Within the Chowan River basin, groundwater is currently the sole source of water supply for all residential and domestic use in the basin.

Based on population projections for the Chowan River basin, DWR estimates that there is adequate water supply from the surficial and confined aquifers to meet current and projected water demands through 2035. Should there be need for additional water supply beyond 2035, the installation of additional wells and expansion of related infrastructure should provide the necessary capacity.

8.1.3 Groundwater Monitoring Network

The DWR Ground Water Management Branch oversees the assessment, monitoring, and management of state groundwater resources with regard to use and availability. Over the past decades, the GWMB has developed a statewide groundwater monitoring network consisting of over 685 wells. Data from these wells are used to:

- Evaluate effects of recharge, discharge, and drought on water supply;
- Monitor well pumping to assure rates are sustainable;
- Regulate the Central Coastal Plain Capacity Use Area (CCPCUA);
- Monitor chlorides for saltwater intrusion; and
- Provide data to an array of agencies, businesses, and the public.

Protecting and optimizing the state's groundwater resources calls for balancing water withdrawals with recharge rates. Using the state groundwater monitoring well network in combination with stream gage data allows DWR to determine if groundwater supplies are adequate and being used sustainably especially in highly developed areas where groundwater use is highest.

Information about the groundwater monitoring well network can be found on the GWMB's website. Information available on the website includes: location, elevation, screen depth and aquifer for each network well; historic groundwater levels; an extensive interactive map interface with over 30 data layers; chloride analyses showing fresh, transitional, and salt water zones within each aquifer; over 3,500 lithologic and geophysical well logs; aquifer analysis tools; potentiometric surface maps for each aquifer; and the state hydrogeologic framework. Currently, DWR has five active multi-aquifer groundwater monitoring stations in the Chowan River basin (Figure 8-2).

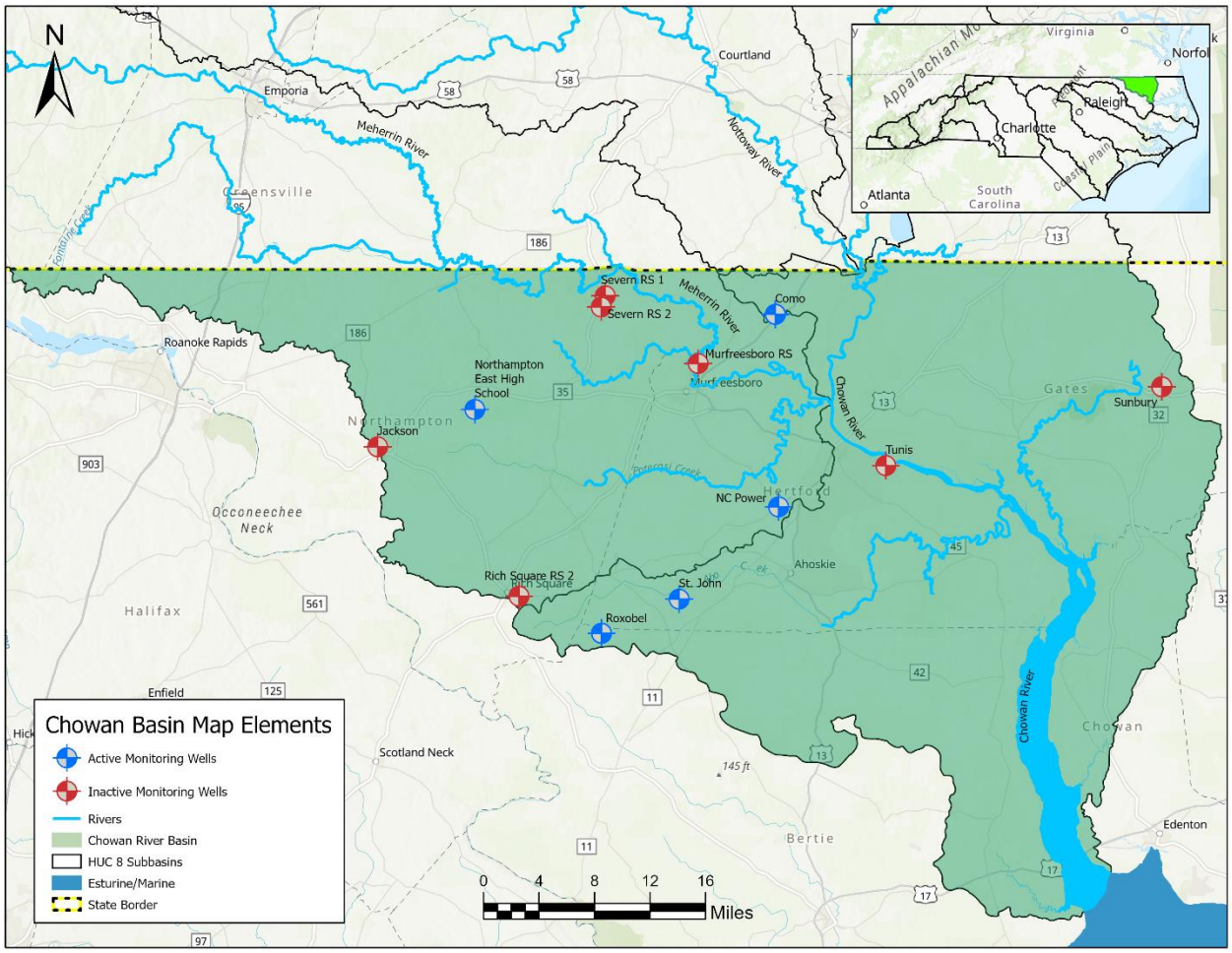
8.2 Water Use Reported in the Chowan River Basin: North Carolina

The information presented in this section quantifies water demand on a basin scale. Data was collected from several programs within DWR. It also includes agricultural water use data collected by the North Carolina Department of Agriculture & Consumer Services (NCDA&CS). For local water supply plans (LWSP), the data includes historic (2015), current (2018) and projected demands in ten-year increments.

The information and data contained within this section is provided by DWR as a service to the public and to stakeholders within the basin. DWR staff does not field verify any data contained within this section. DWR does, however, conduct technical reviews of the LWSPs submitted by the public water supply (PWS) systems to ensure there are no apparent abnormalities in the data. Neither DWR nor any other party involved in the preparation of this data attests that the data is free of errors and/or omissions. Furthermore, data users are cautioned to use the information in this section for planning purposes only

and not regulatory compliance. Questions regarding the accuracy or limitations of using this data should be directed to the individual PWS system, registrant, and/or DWR.

Figure 8-2 Active and Inactive Groundwater Monitoring Wells in the Chowan River Basin



8.2.1 Local Water Supply Plans (LWSP)

In the Chowan River basin, there are 18 PWS systems that submitted a local water supply plan (LWSP) to DWR in 2018 (Table 8-3). Combined, the PWS systems supplied an average of 5.992 MGD to an estimated 66,000 people in 2018. This includes a seasonal population of 1,520 people reported by Murfreesboro. All PWS systems rely on groundwater to meet current and projected water demand.

Table 8-3 Local Water Supply Plans (LWSP) Submitted by Public Water Supply (PWS) in the Chowan River Basin (LWSP, 2018)

HUC	PWS ID	Water System Name	Ownership	Year-Round Population*
03010203	04-46-010	Ahoskie	Municipality	5,479
03010203	04-08-015	Aulander	Municipality	1,438
03010203	04-08-085	Bertie County RWS	County	12,628
03010203	04-21-015	Chowan County	County	10,762
03010203	04-46-030	Cofield	Municipality	413
03010203	04-37-020	Gates Co	County	11,639
03010203	04-46-040	Harrellsville	Municipality	832
03010203	04-08-040	Powellsville	Municipality	265
03010203	04-46-020	Winton	Municipality	756
03010204	04-66-025	Conway	Municipality	749
03010204	04-46-045	Hertford County	County	7,970
03010204	04-46-015	Murfreesboro	Municipality	3,645
03010204	04-66-108	Northampton Co - Milwaukee	County	5,715
03010204	40-66-001	Northampton Co - North Gaston	County	180
03010204	04-66-035	Seaboard	Municipality	602
03010204	04-66-015	Severn	Municipality	350
03010204	04-46-106	Union Utilities Inc.	Non-Profit	350
03010204	04-66-040	Woodland	Municipality	767

* Population reported as year-round. It does not include seasonal population reported by Murfreesboro.

Table 8-4 Water Use Reported in 2018 LWSPs (LWSP, 2018)

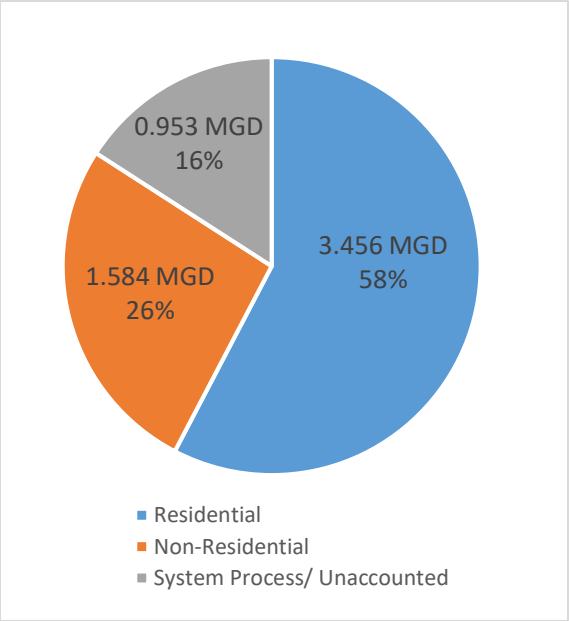
Water Use	Chowan 03010203	Meherrin 03010204	Total 2018
Residential	2.457	0.999	3.456
Commercial	0.409	0.208	0.617
Industrial	0.192	0.240	0.432
Institutional	0.213	0.303	0.516
System Process	0.169	0.048	0.216
Unaccounted-for	0.497	0.240	0.737
Sales	0.019	-	0.019
Total	**3.955**	**2.037**	**5.992**

Based on information provided in the LWSPs, residential demand accounted for 58 percent of the total water use in 2018. Non-residential demand accounted for 26 percent. The remaining 16 percent was used for system processing (cleaning and flushing waterlines, backwash, etc.) or is unaccounted-for (Table 8-4; Figure 8-3). By 2060, a slight increase in total water demand is expected. Combined, the water systems will supply a projected annual average of 6.558 MGD to almost 70,400 people in 2060 (Table 8-5; Figure 8-4).

Table 8-5 Total Average Daily Demand (MGD) and Population Projections (LWSP, 2018)

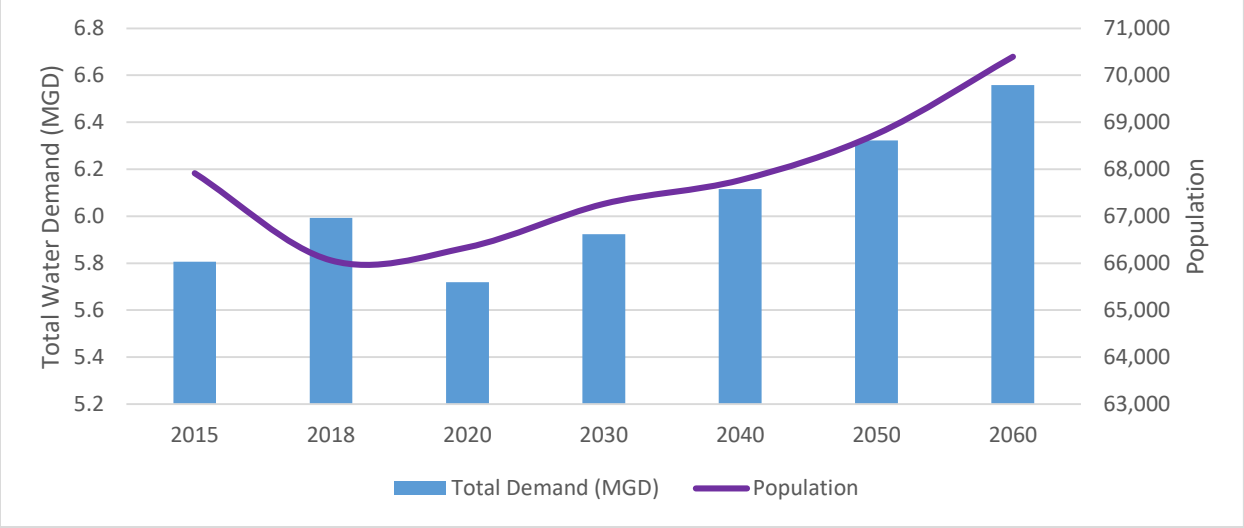
Year	Total Demand (MGD)	Population	Total Demand (MGD)	Population	Total Demand (MGD)	Population
	Chowan 03010203		Meherrin 03010204		Basin Totals	
2015	3.803	48,465	2.003	19,452	5.806	67,917
2018	3.955	44,212	2.037	21,848	5.992	66,060
2020	3.786	44,507	1.933	21,831	5.719	66,338
2030	3.873	44,861	2.051	22,403	5.924	67,264
2040	4.005	45,099	2.111	22,670	6.116	67,769
2050	4.169	45,648	2.153	23,102	6.323	68,750
2060	4.349	46,913	2.209	23,484	6.558	70,397

Figure 8-3 Water Use Reported in 2018 LWSPs



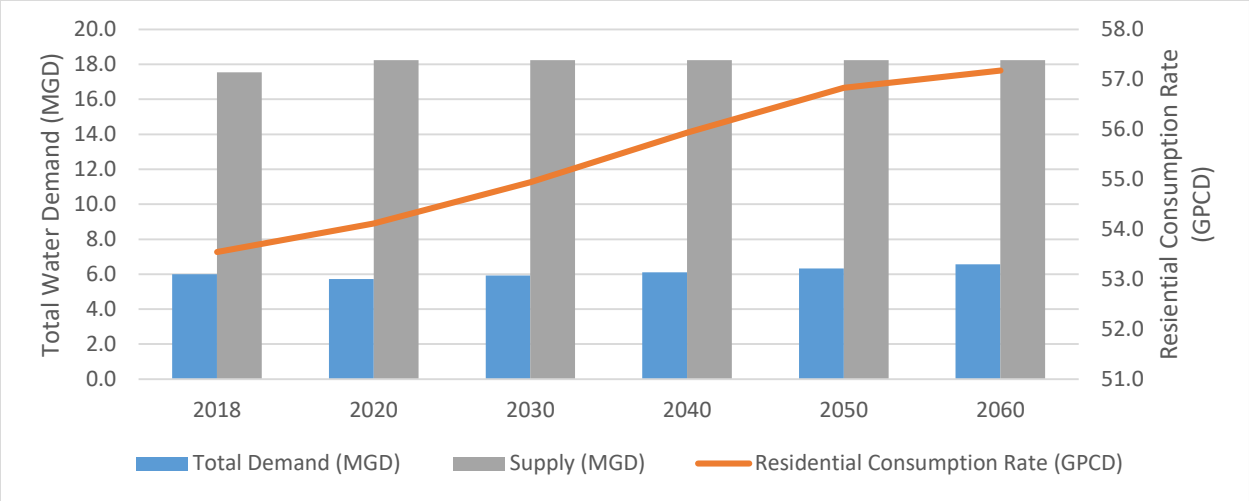
Water systems are advised to maintain adequate water supplies and manage water demands to ensure that the average daily use does not exceed 80 percent of the available supply. Collectively, water systems in the Chowan River basin are expected to have adequate water supplies to meet current and future demands. Individually, 16 of the 18 systems are below the 80 percent threshold, indicating that they are able to meet current (2018) and projected demands (through 2060). Water supply systems for Powellsville (PWSID 04-08-040) and Northampton County – North Gaston (PWSID 40-66-001), however, are over the 80 percent threshold. Information presented in the LWSPs indicates that Powellsville is planning to establish a new interconnection to increase their future supply to meet projected demand. The future supply was not, however, accounted for or reported in the 2018 LWSP. Northampton County purchases water from Roanoke Rapids Sanitary District (PWSID 04-42-010) and allocates the water to Gaston (PWSID 04-66-113), Lake Gaston (04-66-110) and North Gaston systems as needed. The net demand for the three systems is 78 percent of the available supply. Future planning should allow more water to be distributed or allocated to North Gaston in order to meet projected demands. If necessary, the contract with Roanoke Rapids Sanitary District should be increased.

Figure 8-4 Total Average Daily Demand (MGD) and Population Projections (LWSP, 2018)



Residential consumption rate is measured in gallons of water per capita per day (GPCD) and is calculated by the total residential demand divided by the service area population (total) reported in the LWSPs. Collectively, residential consumption rate is expected to remain relatively stable increasing from an estimated 53.547 GPCD in 2018 to an estimated 57.175 GPCD by 2060 (Figure 8-5).

Figure 8-5 Total Average Daily Demand (MGD), Available Supply (MGD) and Residential Consumption Rate (GPCD) (LWSP, 2018)



8.2.2 Private Groundwater Wells

To estimate the population served by private groundwater wells, county population numbers reported by the North Carolina Office of State Budget and Management (OSBM) in 2015 were used. These numbers are multiplied by the percent of the county within the basin to get the estimated population living in the basin. These numbers are calculated on the assumption that the population is evenly distributed throughout the county. Based on these calculations, DWR assumes that private wells supply an estimated ten percent of persons living within the Chowan River basin. Water demand from residential wells was calculated based on a per capita water use value of 75 gallons per person per day and a basin population in 2015 of 59,226 persons. Within the basin, residential wells supply water from either the surficial or

confined aquifers. It is estimated that the average daily demand for private groundwater wells is 0.444 MGD (Table 8-6) (DWR, 2017).

Table 8-6 Estimation of Private Groundwater Wells based off Population (OSBM, 2015; DWR, 2017)

County	% of County in Basin	Population 2015 (OSBM)	Estimated Population in the Basin 2015	Demand from Residential Wells (MGD)
Bertie	28	20,533	5,749	0.043
Chowan	41	14,541	5,962	0.044
Gates	80	11,739	9,391	0.071
Hertford	100	24,426	24,426	0.183
Northampton	65	21,073	13,697	0.103
Total		**92,312**	**59,226**	**0.444**

8.2.3 Water Withdrawal & Transfer Registration (WWATR) Program

In 2018, 23 facilities withdrew a combined annual average of 3.241 MGD with the majority being used for row-crop farming and research (Table 8-7). The estimated average annual amount of surface water withdrawn (ponds, streams, canals, rivers) by facilities registered with WWATR is 1.760 MGD. Another 1.481 MGD is withdrawn from groundwater sources (Table 8-7).

Table 8-7 Total Water Use of Registered Water Users (WWATR, 2018)

Use Type	Number of Facilities	Ground Water (MGD)*	Surface Water (MGD)*	Total	% Ground Water	% Surface Water	% of Total
Agriculture (Row-Crop Farming/Research)	19	0.275	1.753	2.029	14%	86%	63%
Industrial (Animal Processing)	1	0.471	0.000	0.471	100%	0%	15%
Industrial (Metal/Plastic/Fiberglass Manufacturing)	1	0.735	0.004	0.739	99%	1%	23%
Mining (Mineral Extraction)	2	0.000	0.003	0.003	0%	100%	0%
Total	23	1.481	1.760	3.241	46%	54%	100%

* Annual average ground or surface water used (MGD). Calculated based on the average daily amount and the number of days reported in 2018. Surface water includes canals, ponds, rivers and streams.

8.2.4 Agricultural Water Use

Under legislation enacted in 2008 (Session Law 2008-0143), the North Carolina Department of Agriculture and Consumer Services (NCDA&CS), Agriculture Statistics Division, is required to collect information biennially from farmers who withdraw more than 10,000 gallons of water on any given day (NCGS § 106-

24, 2015). Individual responses remain confidential and are only used in combination with other reports, including produce and livestock totals. Operations that withdraw more than 1.0 million gallons per day (MGD) are required to register and report water use to DWR through the WWATR program. The unique number of operations, annual average daily use of ground and surface water, and daily withdrawal capacity is published by county and by hydrologic unit code (HUC). The capacity represents the sum of capacities for all reporting operations in that county or HUC. Water is not withdrawn every day of the year. Instead, water use is dependent upon soil moisture, precipitation, and crop. If there were less than three operations in any category, or if one report included more than 60 percent of the total, data was not disclosed (NCDA&CS, 2018).

According to the 2018 NCDA&CS Agricultural Water Use Survey, 1,025 farms statewide withdrew at least 10,000 gpd. Collectively, these farms had an average daily water use of 60.2 MGD and an annual withdrawal capacity that totaled 1.2 billion gallons of water per day (NCDA&CS, 2018). In the Chowan River basin, data is available for three of the five counties located partially or entirely within the basin (Table 8-8). Water use is also reported on the HUC scale for both the Chowan (HUC 03010203) and Meherrin (HUC 03010204) (Table 8-9) (NCDA&CS, 2018). Using values as presented on the HUC scale, 36 operations used 2.613 MGD from a combination of ground and surface water sources. The total withdrawal capacity is reported to be 49.189 MGD. Due to federal and state confidentiality laws surrounding agricultural production, surface water use was not disclosed by NCDA&CS for HUC 03010204 or for Bertie or Chowan counties.

Table 8-8 Water Use County Summary (NCDA&CS, 2018)

County	Number of Unique Operations[1]	Annual Average Daily Ground (MGD)[2]	Annual Average Daily Surface (MGD)[2]	Daily Withdrawal Capacity (Ground and Surface) (MGD)[3]
Gates	9	*	0.295	*
Hertford	12	0.148	*	*
Northampton	19	0.254	*	20.677

* one operation is greater than 60% of the total or less than 3 operations reported
[1] represents the unique number of operations with withdrew surface or groundwater
[2] represents the average across all days of the year
[3] includes ground and surface water

Table 8-9 Water Use Hydrologic Unit Code (HUC) Summary (NCDA&CS, 2018)

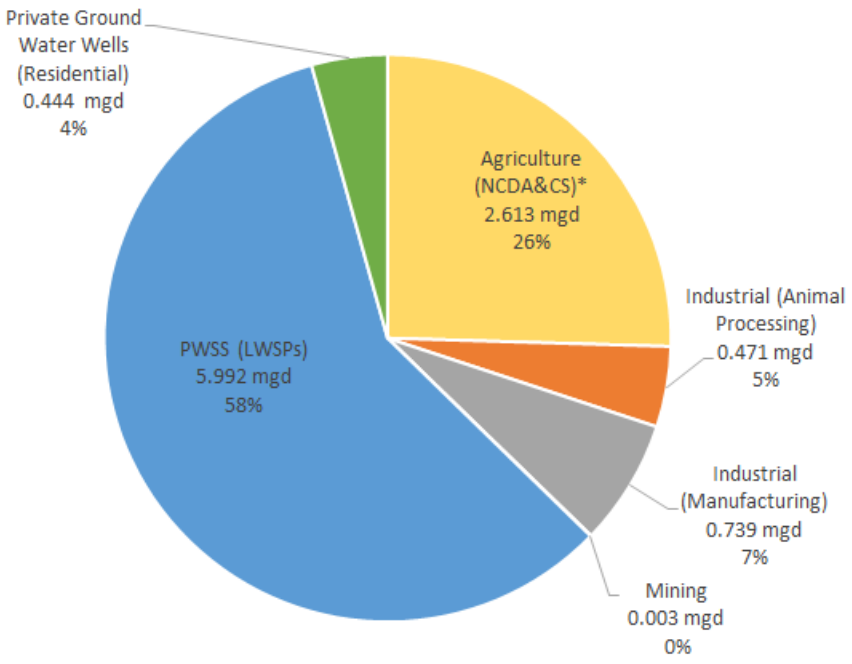
HUC	Number of Unique Operations[1]	Annual Average Daily Ground (MGD)[2]	Annual Average Daily Surface (MGD)[2]	Daily Withdrawal Capacity (Ground and Surface) (MGD)[3]
03010203	26	0.343	2.164	40.915
03010204	10	0.107	*	8.275
Total	36	0.449	*	49.189

* one operation is greater than 60% of the total or less than 3 operations reported
[1] represents the unique number of operations with withdrew surface or groundwater
[2] represents the average across all days of the year
[3] includes ground and surface water

8.2.5 Water Use Summary

Based on information provided in the 2018 LWSPs, estimated water use for private groundwater wells (2017), 2018 WWATR, and the Agricultural Water Use Survey conducted by NCDA&CS, it is estimated that 10.262 MGD is used in the Chowan River basin (Figure 8-6). Water use for agriculture (row crop farming/research) reported to WWATR was not included in this total. Instead, numbers reported by NCDA&CS on the HUC scale were used. Because information is not reported for HUC 03010204 (Meherrin), however, the total water use by agricultural operations is likely underestimated. Understanding the total amount of water being used for agricultural activities is critical for helping agricultural producers, manufactures and utilities plan for the future while also maintaining or protecting water quality and the ecological integrity of waterbodies throughout the region.

Figure 8-6 Total Estimated Water Use in the Chowan River Basin 2018



* NCDA&CS Agriculture Water Use Survey 2018 did not report all water used in HUC 03010204.

8.3 Surface Water Use and Demand: Virginia

The City of Norfolk has raw-water intakes on both the Blackwater and Nottoway rivers in Virginia. The Blackwater River intake has a drainage area of 617 mi^2 upstream of the USGS gage, Blackwater River near Franklin, Virginia (USGS 02049500). This intake also has a weir associated with it that can be used to impound water. The intake on the Nottoway River has a drainage area of 1,577 mi^2. Both intakes are reported by the Virginia Department of Environmental Quality (DEQ) under the Virginia Water Protection (VWP) Permit Program to have a combined average daily withdrawal of 130 MGD (201 cfs). These withdrawals discharge into Lake Prince (Chesapeake Bay basin) and supplement the City of Norfolk's overall water supply. The water is withdrawn from Lake Prince and treated for public consumption for the City of Norfolk and bulk water sales to the City of Chesapeake, the City of Virginia Beach, the City of

Portsmouth, and the United States Navy. Neither intake has a permitted limit on the amount that can be withdrawn from either river. The water intakes and the pump stations predate state regulations governing surface water withdrawals (BNRP, 2012).

To understand how changes in flow may be impacting aquatic life, an ecosystem assessment study for the Albemarle-Pamlico region was conducted by the Albemarle-Pamlico National Estuary Partnership (APNEP). The study reported that no statistically significant long-term trends were detected for mean annual flow (MAF) at the gage on the Blackwater River near Franklin, Virginia (USGS 02049500) for the period of 1945 to 2010. This suggests that no major changes in water use, water management, rainfall or rainfall-runoff relationships occurred in the river upstream of the gage during the period of record (Carpenter and Dubbs, 2012). The authors recognized, however, that additional analyzes, such as a narrower timeframe or other components of the flow regime, could produce different results. Understanding long-term flow trends is important for resource sustainability and forecasting availability but is difficult to model because of short-term climatic conditions, anthropogenic impacts and the availability of long-term data.

Greensville County Water and Sewer Authority (GCWASA) has a 12-MGD (18.5 cfs) intake on the Nottoway River. The drainage area is 535 mi^2 north of the City of Emporia. GCWASA also constructed an associated one-billion-gallon, off-steam reservoir for storage. The intake supplements the water supply for Emporia, a 210-acre reservoir on the Meherrin River.

Because much of the Chowan River basin is located in Virginia, the amount of water that is withdrawn can impact downstream uses in North Carolina. Changes in flow can impact waste assimilative capacity, engineering designs, navigation, nutrient and sediment loads, flood forecasting, aquifer recharge, water supply and reservoir management, and environmental management. Adequate flow is also needed to provide a suitable environment for organisms and their life-sustaining prey, support water quality classifications, provide wetland and floodplain connectivity, and benefit the economy through recreational opportunities and commerce. A list of currently active surface water withdrawal permits can be found on VADEQ's Surface Water Withdrawal Permitting and Fees website.

8.4 Stream Flow

Stream flow varies hourly, daily, seasonally, and annually based on changes to its source, including precipitation, groundwater level, snowpack and melt, and upstream uses. For a planning and water management perspective, it is important to understand such variability and trends. Trend analysis is useful to detect and attribute long-term flow patterns of a stream to natural climate variability and human interference. Hence, stream flow records remain a key indicator for long-term, hydro-climatic variability and changes associated with it. Equally, the length of period over which a stream-flow record is used to estimate the current and future dynamics of the stream system affects the accuracy of calculating estimates and has direct implication on the growing and competing priorities of water uses and management.

Insight into the flow characteristics of a stream is aided by the presence of USGS gaging stations with a record of flow measurements that spans multiple years or decades. Established gages and long-term flow records can be used to assist in early flood warning, help in the revision of floodplain maps, monitor drought conditions, inform recreational boaters, determine assimilative capacity of a waterbody receiving a permitted discharge, and support decisions on water withdrawal and allocation for drinking water,

irrigation, and industry. Long-term flow records also help resource agencies understand environmental changes associated with a changing climate, aid in establishing flow requirements, and assist in monitoring compliance with established flow requirements. Flow statistics are not static but may change over time.

8.4.1 Low-Flow Statistics (7Q10)

Flow (Q) is measured in terms of volume of water per unit of time, usually cubic feet per second (cfs). Minimum flows are intended to be occasional short-term events that maintain stream conditions. One example is the 7Q10 statistic. It is the lowest flow that occurs for seven consecutive days with the probability of occurring once every 10 years. The 7Q10 is a low-flow statistic and is used to determine many flow related questions.

The Mann-Kendall test was used to perform trend analysis on 7Q10 flow statistics for selected USGS stations in the Chowan River basin (Table 8-10; Table 8-11). The Mann-Kendall test is a statistical test widely used for the analysis of trend in hydrologic time series. The trend test was performed using the USGS Computer Program for the Kendall Family of Trend Tests. The 7Q10 statistics used for the analysis were estimated using the Water Resources Information, Storage, Analysis, and Retrieval System (WRISARS), hosted by the Division of Water Resources (DWR). The 7Q10 values were computed for a 10-year (Table 8-10) and 30-year (Table 8-11) window. These values represent the first year of the forward-looking window where N=10 and N=30. More than a 10-year or 30-year window was required to capture the respective number of years with complete records for some stations.

The results of the trend test on the statistics from the selected USGS gages are given in Table 8-10 and Table 8-11 and Appendix VIII. Significantly increasing trends in the 10-yr 7Q10 were observed for Ahoskie Creek, but significantly decreasing trends for Potecasi Creek and Blackwater River. The 10-yr 7Q10 trend for Nottoway and Meherrin rivers were not significant (Table 8-10). For the 30-yr 7Q10, significantly increasing trends were observed for Ahoskie Creek and Nottoway River, but decreasing trends were observed for Potecasi Creek and Blackwater River. The trend for Meherrin River was not significant (Table 8-11).

Table 8-10 Trends in the Annual 7Q10 Streamflow for Selected Waterbodies in the Chowan Basin (10-year 7Q10)

Station	USGS Gage	Period of Record	Kendall's Tau	Mann-Kendall Statistic (S)	Slope (cfs/year)	Trend*
Ahoskie Creek at Ahoskie, NC	02053500	1950-2019	0.212	303	0.01423	Increasing
Potecasi Creek near Union, NC	02053200	1958-2019	-0.603	-570	-0.0333	Decreasing
Nottoway River near Sebrell, VA	02047000	1941-2019	-0.055	-108	-0.0308	No Significant Trend
Meherrin River at Emporia, VA	02052000	1951-2019	-0.106	-130	-0.11	No Significant Trend
Blackwater River near Franklin, VA	02049500	1944-2019	-0.592	-1013	-0.03115	Decreasing
*A threshold significance level of 0.05 (α=0.05) was used; a p-value of less than 0.05 means that the trend is considered significant						

Table 8-11 Trends in the Annual 7Q10 Streamflow for Selected Waterbodies in the Chowan Basin (30-year 7Q10)

Station	USGS Gage	Period of Record	Kendall's Tau	Mann-Kendall Statistic (S)	Slope (cfs/year)	Trend*
Ahoskie Creek at Ahoskie, NC	02053500	1950-2019	0.406	228	0.02	Increasing
Potecasi Creek near Union, NC	02053200	1958-2019	-0.699	-193	-0.0714	Decreasing
Nottoway River near Sebrell, VA	02047000	1941-2019	0.264	238	0.04864	Increasing
Meherrin River at Emporia, VA	02052000	1951-2019	-0.239	-104	-0.1775	No Significant Trend
Blackwater River near Franklin, VA	02049500	1944-2019	-0.934	-693	-0.04091	Decreasing
*A threshold significance level of 0.05 (α=0.05) was used; a p-value of less than 0.05 means that the trend is considered significant						

In addition to the trend test for the 7Q10 statistic, trends in the water year (Oct. through Sep.) daily minimum flow, 7-day minimum flow, daily median flow, daily mean flow, and daily maximum flow were performed for the period of record at the selected stations to explore the nature and extent of the streamflow changes in the Chowan River basin using the EGRET software (Hirsch and De Cicco, 2015) (Table 8-12). Significantly upward trends were observed in minimum day and 7-day minimum flow for Ahoskie Creek and significant downward trends were observed for the Nottoway and Blackwater rivers. The maximum day flow increased significantly for the Blackwater River, which was the only significant trend for the three higher flow categories for any of the five gages. Potecasi Creek and Meherrin River showed no trends for any of the flow categories.

Table 8-12 Trends in Selected flow Statistics for Selected Waterbodies in the Chowan Basin

Station (USGS Gage)	Minimum (per year)	7-day Minimum (per year)	Median (per year)	Mean (per year)	Maximum (per year)
Ahoskie Creek at Ahoskie, NC (02053500)	Increasing (2.9%)*	Increasing (2.5%)	No trend (0.11)	No trend (-0.076)	No trend (0.58%)
Potecasi Creek near Union, NC (02053200)	No trend (-0.25%)	No trend (0.021%)	No trend (-0.32%)	No trend (-0.021%)	No trend (0.68%)
Nottoway River near Sebrell, VA (02047000)	Decreasing (-0.8%)	Decreasing (-0.87%)	No Trend (-0.2%)	No Trend (-0.012%)	No Trend (0.071%)
Meherrin River at Emporia, VA (02052000)	No trend (0.39%)	No trend (-0.32%)	No trend (-0.38%)	No trend (-0.21%)	No trend (0.26%)
Blackwater River near Franklin, VA (02049500)	Decreasing (-2%)	Decreasing (-2.2%)	No Trend (0.09%)	No Trend (0.18%)	Increasing (0.81%)

* Slope in % per year is shown in parenthesis

8.4.2 Ecological Flow

While calculating minimum flow is important when considering wasteload assimilative capacity for new or existing point source discharges and estimating the amount of water available for withdrawals, it is not designed to protect the ecological integrity of the stream for sustained periods of time. Minimum flows do not take into consideration monthly and seasonal demands or annual climatic variability. To protect ecological integrity, critical characteristics of a flow regime (magnitude, frequency, duration, timing, and rate of change) need to be considered (Poff et al., 1997). The magnitude refers to a particular amount, or height of water, within the range of low to high flows at a moment in time at a particular location within a stream channel. The frequency is how often a particular magnitude occurs during a designated period of time within a period of recorded flows. The duration refers to the length of time that a particular magnitude is sustained during an episode. The timing refers to the predictability of a particular magnitude over a period of record, and the rate of change refers to the deviation above or below a particular magnitude within a given amount of time.

The term "instream flow" is often used to describe a flow requirement, but it is sometimes used in a more general sense to refer to the amount of water flowing in a stream without providing any established level of protection. A flow regime that protects ecological integrity is often referred to as an “ecological flow”. Ecological integrity is defined in North Carolina General Statute (NCGS) 143-355(o) and means “the ability of an aquatic system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to prevailing ecological conditions and, when subject to disruption, to recover and continue to provide the natural goods and services that normally accrue from the system” (NCGS, 2017).

Like other aquatic systems, maintaining coastal ecological flows (i.e., approximating the spectrum of low, medium and high flows of a stream’s natural hydrograph) is important for many functions, including: aquifer recharge; triggering biological cues; assimilating wastewater discharges; supporting water quality classifications; transporting nutrients, detritus, sediment, eggs and larvae; wetland and flood plain connectivity; and benefits to the economy through recreation and commerce.

Assessing ecological flows in coastal basins like the Chowan, however, is a challenge because of the complexity of the fresh and brackish ecosystems and the associated complexity of the hydrology, or the movement of water through the system. The complexity is due in part to the interplay of a location’s slope, the proximity to fresh and saline sources, the amount of the source inflow, the percent of salinity in the water column, and the timing and extent of tides.

One challenge when assessing ecological flows is the lack of knowledge regarding a stream’s flow characteristics. The absence of gages in the basin collecting decades of flow values in different streams at different drainage areas produces a data gap. Currently, there are only two active surface-water gages in the North Carolina portion of the basin, Potecasi Creek (USGS 02053200) and Ahoskie Creek (USGS 02053500). There are 15 active gages in Virginia, monitoring the Blackwater, Meherrin and Nottoway rivers and some of their tributaries (USGS, 2020).

In coastal waters, gages typically collect stage, or water depth, rather than flow values. This is largely due to the difficulty of obtaining accurate flow values in circulating, bidirectional tidal waters and the width of some channels. Water stage may be a suitable surrogate for flow in coastal waters given the importance of flood forecasting, daily wetland inundation patterns associated with tides, the difficulty of measuring

flow and understanding sea-level rise. The National Weather Service (NWS) maintains a gage (Chowan River near Waterfront Park at Edenton NC, EWPN7) to monitor water elevation and to forecast flood events.

The stream flow data gap and the tidal influence in coastal waters complicates efforts to model stream flow. Typical hydrologic models do not adequately represent reality when water can move both upstream and downstream simultaneously in the channel. In the absence of actual flow data, a pseudo-flow record would need to be created from historical flow records in conjunction with precipitation data and runoff models. New and innovative modeling approaches are required in coastal watersheds to adequately replicate the interactions of surface and groundwater withdrawals, modified land use and drainage patterns, climate change and stage-flow relationships

The apparent lack of anthropological, or human-induced, flow alterations may call into question the necessity of considering ecological flows in coastal watersheds. It is a reasonable assumption that watersheds will be largely unimpacted that have no, or limited, land-cover modification or population growth that often results in additional ground- or surface-water withdrawals. However, given the unknowns associated with groundwater extraction and spatial impacts within a watershed, or adjoining watersheds, potential surface water demands (such as freshwater purification from brackish waters), and sea-level rise, future impacts are a reasonable expectation. Therefore, the need exists for long-range water availability planning and the consideration of these impacts.

Adequate freshwater flow regimes are necessary to maintain a suitable environment for organisms, their life-sustaining prey and other nutritional requirements, their various life stages, and their habitats. The consideration of flow regimes should encompass both flow (as it relates to the freshwater environment and the management of the position of the downstream saltwater wedge) and the mixing of the two (freshwater and salt water) to produce a range of sustaining brackish-water concentrations. Mobile organism can relocate in search of suitable water conditions and other less-mobile organisms can tolerate temporary deviations until suitable parameters are re-established, but other less-tolerant species may perish.

Given the low slope of coastal stream channels, low- or drought-flow conditions may not necessarily dewater critical aquatic habitat as is seen in Piedmont streams with steeper slopes. However, coastal streams that become stagnant can lead to warmer temperatures, dissolved oxygen depletion, algal blooms and repositioning of the saltwater wedge and the intervening brackish-water concentrations. The warmer months are when off-stream demands for water are greatest and evaporation and transpiration rates are highest, which can additionally contribute to these deleterious impacts to baseflows, water quality and aquatic habitat. Stagnant or reduced baseflow waters can also hinder the downstream transport of developing fish eggs and larvae and concentrate fish in deep-water refuges where denser populations can increase predation pressures.

8.4.3 Impacts from Changes in Flow Regime

The cumulative alterations to flow in coastal streams from surface water and groundwater withdrawals for irrigation and public water supply, agricultural ditching and drainage networks, and stormwater runoff can impact aquatic habitat. Channel scouring and bank erosion from higher, storm-related discharges can deposit sediment loads that cannot be readily transported downstream, blanketing preferred habitat and sessile organisms.

Some of the greatest impacts to water quality are usually associated with high-flow storm events that contribute stormwater runoff, which often increase fecal concentrations, which then typically result in the closure of shellfish waters and swimming areas. Hurricane-related, catastrophic floods can also inundate municipal wastewater and industrial infrastructure and lagoons associated with animal feeding operations (AFOs). Any of these have the potential to release tremendous amounts of untreated waste and chemicals to public waters, contributing to human health risks and the disruption of daily activities. Extended flooding also depletes dissolved oxygen in the stagnant water due to increased biological oxygen demand, and massive fish kills may result from the rapid recession of these flood waters back into river channels.

Concerns related to water supply, on the other hand, are often associated with drought conditions. Drought and low-flow conditions can have a significant impact on how much water is available for consumptive use. Since groundwater is the primary source of potable water in the Chowan River basin, this impact is limited, but it may result in reduced baseflow which can then have significant impacts on downstream water quality as waste assimilative capacity is reduced.

8.4.4 Impoundments

Under the Division of Energy, Mineral and Land Resources (DEMLR) Dam Safety Program, there are 22 dams reported in the Chowan River basin (NCDEMLR, 2020). Forty percent of the impoundments are used for irrigation and are listed as exempt from jurisdiction. Four dams are considered jurisdictional and impounding: one on Bennetts Creek (Merchants Millpond) and three on College Branch. The Merchants Millpond dam has a minimum flow requirement of 0.2 cfs, but no records are available to indicate there are flow requirements for the dams located on College Branch. Other impoundments in the basin do not fall under DEMLR's Dam Safety Program's jurisdiction. In addition, there are also other flow-control structures (such as tidal or flood gates, weirs and road culverts) that block access to upstream habitat and alter flows.

Study results reported in the 2016 Coastal Habitat Protection Plan (CHPP) mapped more than 90 dams and culverts. Both are impediments to fish movement in the basin (NCDEQ, 2016). The CHPP reported that 38 percent of streams in the basin were dam-obstructed, blocking fish passage. Road culverts that are improperly installed or not maintained can also hinder upstream fish migration by increasing flow volumes above suitable swimming speeds or the water depth is too shallow to traverse. Culverts can also cause erosion and become elevated above the downstream channel ("perched"), making them unnavigable for fish. Culverts may also be installed without consideration to the amount of transported woody debris, which can lead to eventual clogging and require stream debris removal (USACE, 2013). Some fish species may also resist moving through dark road culverts during daytime migration (Moser and Patrick, 2000).

A few dam modifications have been completed in the Chowan River basin to encourage fish passage, notably at the Emporia Dam on the Meherrin River and Merchants Millpond Dam on Bennetts Creek. Sampling and monitoring are required to ascertain the effectiveness of these structures to allow for the passage of the various migratory fish species. Guidance is also available for new or replaced culverts to make them more suitable for the passage of anadromous fish (USACE, 2013).

The removal of structures that impede the movement of migratory fishes can be difficult given the essential uses of these structures, the limited amount of funding, and landowner cooperation.

Prioritization tools have become available to identify those structures that would provide the most suitable habitat for the most fish species (SARP, 2020). The development of a prioritization tool requires the input of resource experts to identify, rate and map habitat for target species, to identify impediments in the basin, and an assessment of either the miles of stream network or the area of habitat made available to migrating fish by removal or modification of each structure. Some of the other considerations associated with a dam removal proposal is the amount of accumulated sediment stored behind the dam, the amount, value and potential impact to established wetlands that may surround the impoundment and the potential expansion of the range of any existing exotic species in the basin.

8.5 Management Under Drought Conditions

Droughts are unpredictable, but their occurrence is inevitable. A drought plan, or water shortage response plan (WSRP), can help reduce the impacts to water resources and minimize disruptions to water withdraws. A WSRP establishes authority for declaring a water shortage, defines different stages of water shortage severity and outlines appropriate responses for each stage. All public and privately-owned water systems subject to General Statute 143-355 (l) are required to prepare and submit a WSRP as part of their LWSP. WSRPs are updated every five years but can be updated more often to address changes to population, water sources and/or additional demands. The plans can also be updated to address any issues that may have been identified when implementing or evaluating the effectiveness of the plan.

The North Carolina Drought Management Advisory Council (NCDMAC) has been monitoring drought conditions weekly since 2000 and was given official statutory status and assigned the responsibility for issuing drought advisories in 2003. The NCDMAC assesses drought conditions based on several indices including stream flow, groundwater levels, rainfall, reservoir levels and soil moisture and issues advisories on a county by county basis. The council provides consistent and accurate information as it relates to drought and includes representative experts from ground and surface water hydrology, meteorology, water system operation and management, reservoir management, emergency response as well as local governments, agriculture and agribusiness, forestry, manufacturing and water utilities.

Five drought designations, or classifications, were established by the NCDMAC. A statewide drought assessment is published on a weekly basis. A drought classification is applied to a county when at least 25 percent of the land area of the county is impacted. The drought monitor history (Figure 8-7 and Figure 8-8) provides a graphical representation of the drought designation, and the length of time the basin was in a specific designation. During the ten-year assessment period (September 2005 - August 2015), the Chowan River basin experienced extreme weather conditions that included above average rainfall due to several hurricanes and four levels of drought (2000-2008). The designation of Severe to Extreme Drought can first be seen from November 2001 through October 2002 and then again for another year from September 2007 through August 2008. The last severe drought recorded for the basin was the summer of 2010.

Drought Classification
D0 - Abnormally Dry
D1 - Moderate Drought
D2 - Severe Drought
D3 - Extreme Drought
D4 - Exceptional Drought

Figure 8-7 Drought Monitor History for Chowan River Basin (January 2000 – February 2019)

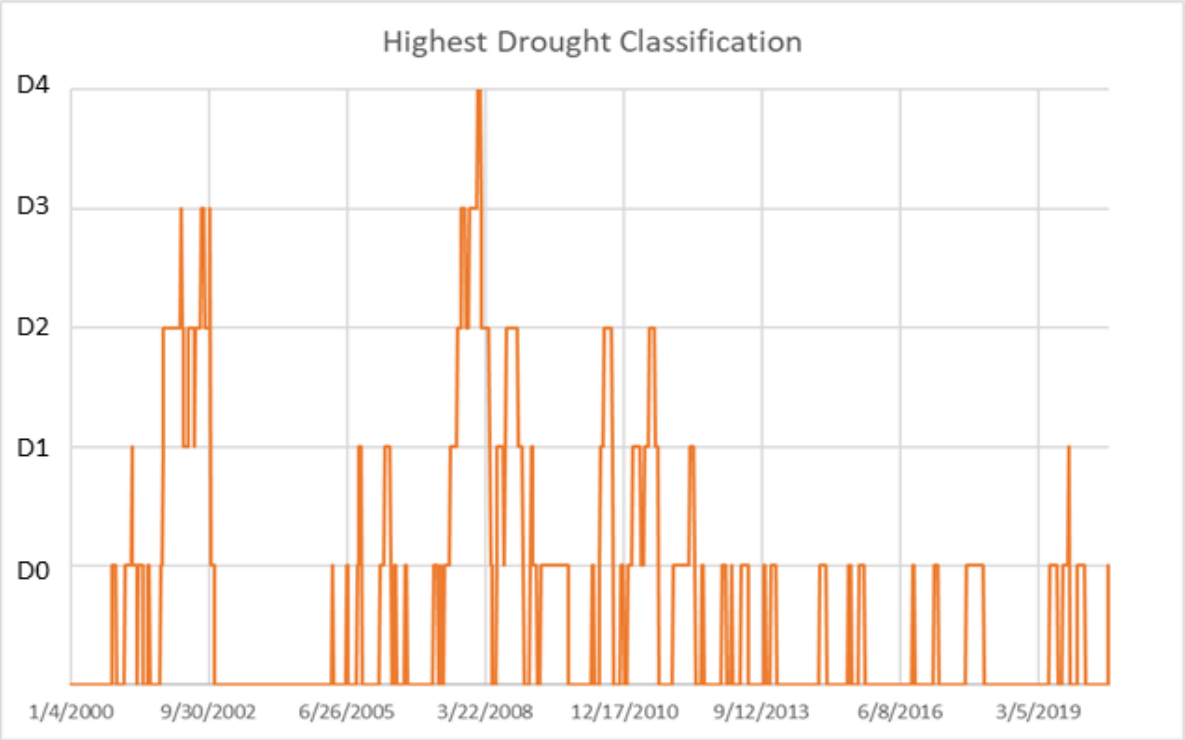
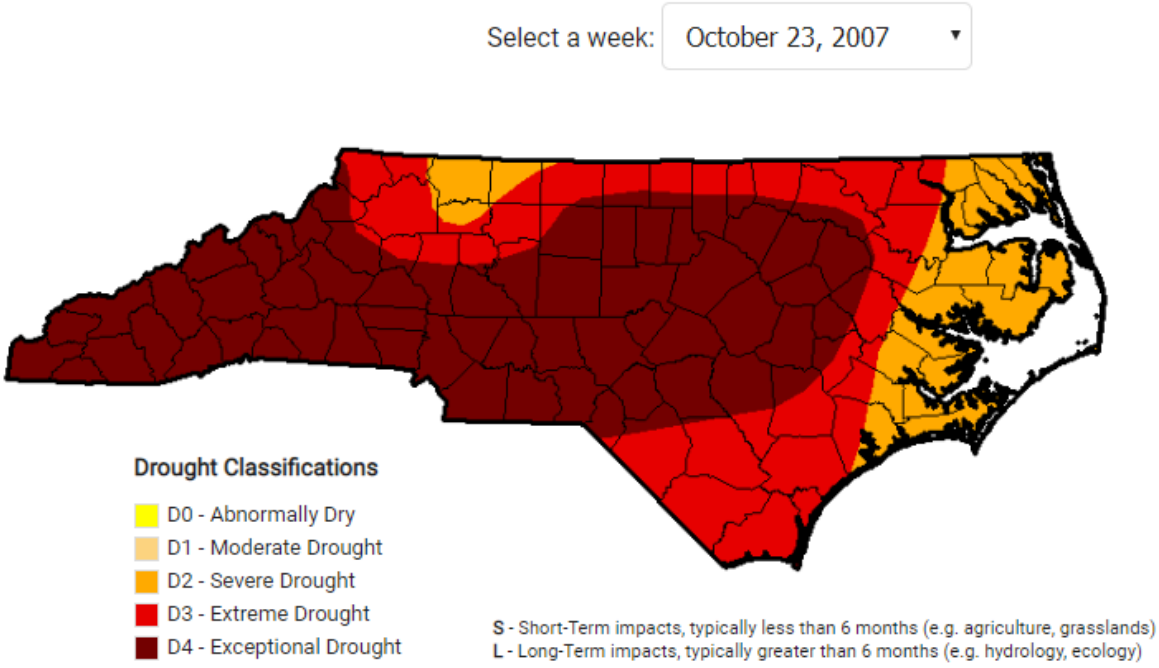
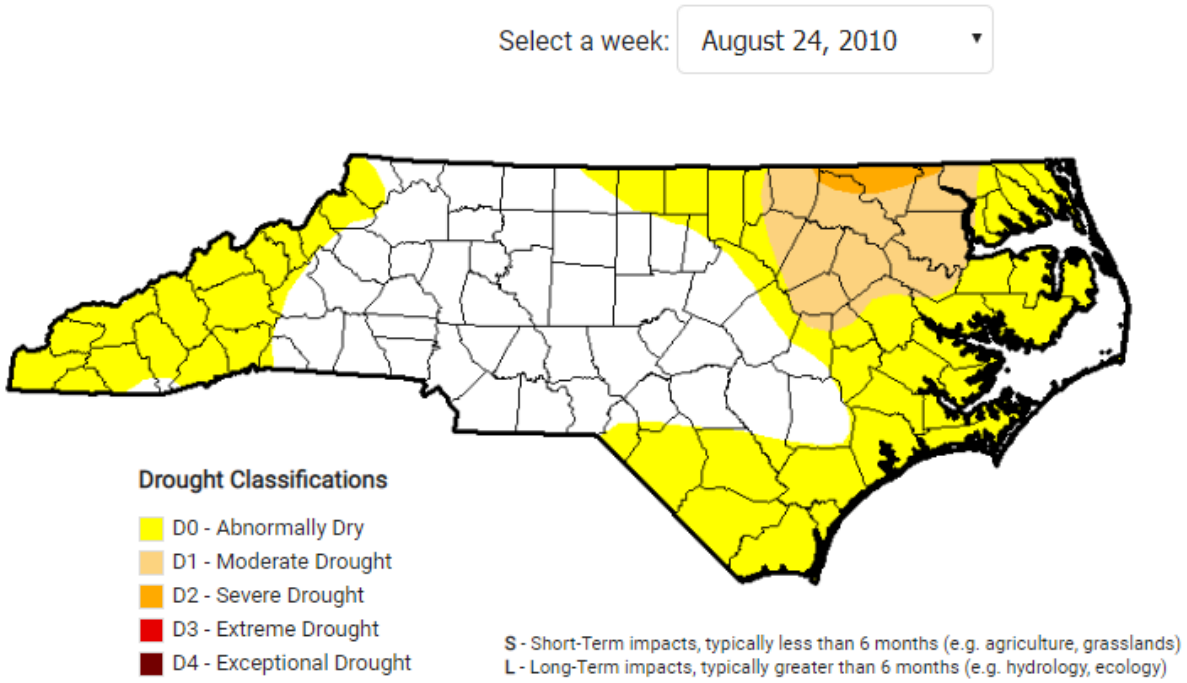


Figure 8-8 North Carolina Drought Monitor Map (October 2007; August 2010)





8.6 Future Considerations

While compliance with existing, statewide programs dealing with water resources management is reasonably effective at capturing major water withdraws and uses for most sectors, there are still data gaps that make it difficult for DWR to provide assistance across the state and ensure the long-term sustainability of water resources for all users. Understanding the amount and quality of surface and groundwater, long-term river and reservoir gages, and long-term stream flow calculations are all critical to understanding how water is being used and how it can be sustained into the future. The following identifies topics for state leaders to consider when answering questions about water resources management.

8.6.1 Groundwater Availability and Trends

North Carolina places considerable demands on its groundwater resources, including domestic drinking-water supplies (i.e., self-supplied private wells), numerous PWS systems, irrigation, livestock management, mining, and self-supplied commercial and industrial uses. Groundwater is a finite resource, and it will continue to be stressed to meet the demands of a growing population.

A key element of properly managing any regional groundwater system is quantifying just how much water can be extracted from contributing aquifers without inducing adverse effects. **Adverse effects can include aquifer dewatering, saltwater intrusion, water quality degradation, and/or impacts to stream flow and ecological integrity.** Groundwater needs to be properly managed to ensure that present withdrawals are sustainable and that ever-increasing projected future demands can be met. For these reasons, it is crucial that North Carolina continue to develop its statewide groundwater monitoring program. Groundwater data collected from a comprehensive groundwater monitoring network can be used to help water

resource managers better plan for future water uses to meet current and future demands. It is recommended that each unit of local government and large community water system certify by testing, evaluating or by other means acceptable to DEQ, the available raw water supply at least once by 2030.

8.6.2 Agricultural Water Use Data

Agriculture is a major user of ground and surface water in the United States. According to the 2018 Agricultural Water Use Survey published by the NCDA&CS, water use in the Chowan River basin averages approximately 2.613 MGD with a withdrawal capacity that totals 49.189 MGD (NCDA&CS, 2018).

In the Chowan River basin, agricultural water use data is reported by county and watershed (HUC 8) in the 2018 Agriculture Water Use Survey. Data is available for three of the five counties located partially or entirely within the basin, but annual average daily groundwater withdrawn is not reported for one of the counties and annual average daily surface water withdrawn is not reported for two (Table 8-8). Similarly, annual average daily groundwater use is reported for both the Chowan (HUC 03010203) and Meherrin (HUC 03010204), but annual average daily surface water use is only reported for the Chowan (Table 8-9). Due to federal and state confidentiality laws surrounding agricultural production, the data submitted as part of the Agriculture Water Use Survey is often aggregated. While aggregated data can be used to potentially answer statewide questions about the amount of water withdrawn, it is difficult to use in models to assess water use and availability or resolve impacts on water resources when new or additional withdrawals are made. To answer questions regarding water availability, consumptive rates, crop irrigation, and drinking water supplies, complete data sets by either county are watershed can help plan for future growth, long-term sustainability, and allow for better management during drought conditions.

8.6.3 Stream Flow Gages

Accurately measuring stream flows and reservoir levels is critical to understanding long-term water availability as well as determining real-time instream and lake/impoundment level conditions. Federal and state funding has decreased over time while the demand for gages and the cost of gages capable of monitoring multiple water quality and quantity parameters has increased. Funds are also needed for maintenance to maintain functionality.

The USGS's present network of real-time, surface-water gages in North Carolina is located primarily in non-tidal rivers, the Piedmont and the Piedmont's urban areas. A more diverse gage network would aid federal, state and local agencies in understanding flow characteristics of such diverse locations as headwater streams and tidally influenced creeks. A more diverse gage network would also help water resource managers and planners understand the interactions between surface to groundwater, long-term changes in weather patterns, climatic conditions and sea-level rise, determining ecological flows for long-range planning, establishing instream flow regimes for projects requiring state action, and the role of land use on flow patterns. As water resources face greater pressures from multiple demands, a more extensive gage network is needed.

8.6.4 Update Long-Term Stream Flow Calculations

Many federal and state permitting programs and agency policies rely on flow statistics. The most common flow statistic is the 7Q10, the 7-day lowest average flow in a 10-year period. The last statewide assessment of 7Q10 values were conducted in the early 1990's by the USGS (Giese and Mason, 1993). The most recently conducted assessment of 7Q10 values by USGS in North Carolina focused on select sites in 2015 (Weaver, 2016). The resulting document suggests that 7Q10 values across North Carolina have been

declining, some significantly, over time. As a result, streams may have lower baseflows. Lower baseflows directly impact the assimilative capacity for point and nonpoint discharges and the estimated available yield for water systems. In addition, the potential inaccuracy of these older estimates makes it difficult to calculate an accurate 7Q10 for streams that do not have a gage.

8.6.5 Identifying Data Gaps

North Carolina General Statute §143-355 requires DWR to assure the availability of adequate supplies of water to protect public health and support economic growth. Water supply planning and management requires a basic understanding of both the available water resources and all the demands being placed on those resources. Strides have been made with existing statewide programs to capture water withdrawal from all classes of water users, but data gaps exist. Consequently, these data gaps do not allow DWR to accurately report the amount of water being withdrawn statewide.

Collecting water use information from water users in all sectors is needed to fill in data gaps and allow DWR the ability to identify conflicts or problems that need to be resolved. Complete data sets are also needed to effectively plan, monitor, and manage water resources in North Carolina to ensure future water supply needs can be met. Working collaboratively across all state and federal agencies that have an interest in water resources could help identify and fill in some of the data gaps and identify regional concerns and challenges. Being able to report more completely about water use in the state would add value and more certainty in answering questions about water availability, giving businesses, industries, and citizens more assurance that water needs can be met now and in the future.

8.6.6 Ecological Flow

A critical component of water supply planning and management is not only the amount of water needed and available to supply existing and future water demands but also determining how much flow is needed to support the ecological integrity of the aquatic life present in the region's rivers, streams, and adjacent floodplains. Referred to as ecological flow or instream flow requirements, it is the amount of water (measured by volume) needed to adequately provide for downstream ecological uses occurring within the stream channel.

Given the increasing off-stream demands on surface waters and the associated flow-altering infrastructure (e.g., intakes and dams), it is unlikely that 100 percent of the natural flow will remain in the stream channel. The challenge is how much can be removed from surface waters without significantly impacting the ecological integrity downstream. Without additional studies, ecological flow remains a largely unknown portion of the overall water demand. It should be considered in any water demand versus available supply analysis and is key to the sustainability of North Carolina's water resources for multiple uses.

In 2010, the General Assembly directed the creation of an Ecological Flows Science Advisory Board (EFSAB) to assist DEQ in characterizing the ecology of the state's river basins and identifying the flows necessary to maintain ecological integrity. When it presented its recommendations to DEQ, the EFSAB requested the use of adaptive management to protect the ecological integrity of North Carolina streams. The request was based on the realization that the supporting science behind ecological flow advances as more research examines the flow-ecology relationship at various spatial and temporal scales. An adaptive management approach would allow natural resource managers and planners to factor in changes in the state's climate, land-cover, precipitation, and runoff patterns, as well as potential shifts in air and water

temperature statistics. Additionally, with time and lessons learned, the flow and biological criteria recommendations will need to be reevaluated to assess their efficacy.

To address data gaps, the EFSAB suggested the following steps:

- Collect additional hydrologic and biologic data in the headwater creeks, the coastal plain and the large, non-wadeable rivers that are underrepresented in DWR datasets. This data will help determine if these waterbodies fit with existing models and assumptions.
- Adopt, design, and develop strategies that:
  - Validate the efficacy of ecological thresholds and adjust these thresholds as necessary based on new data and research.
  - Track the impacts of flow changes when and where they occur.
  - Modify characterizations, target flows and thresholds based on new data and changing conditions like land cover, precipitation, and hydrology.
  - Georeference the hydrologic model nodes to facilitate analysis

The recommendations of the EFSAB represent a starting point for developing ecological flows that protect the integrity of North Carolina streams. By adopting an adaptive management approach, DENR can ensure that ecological integrity is protected through the refinement and improvement of the recommendations of the EFSAB over time. As data gaps associated with hydrology and biology in the headwater creeks, the coastal plain, and the large, non-wadable rivers are addressed, a more complete representation of flow effects on biological integrity within the state will be available (EFSAB, 2013).

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