Hydrogeology & Groundwater in the Tar-Pamlico River Basin

General Description of the Hydrogeologic System

The hydrogeologic system in the Tar-Pamlico River Basin is made up of Holocene through Cretaceous age Coastal Plain sediments east of where the fall line crosses near the Town of Rocky Mount and the Wilson/Nash County line, and mostly older, pre-Cretaceous Piedmont rock units to the west of the fall line. The western most part of the Tar-Pamlico crosses the Triassic Basin north of the town of Durham. East of the fall line, the hydrogeologic system is made up of the surficial, Yorktown, Castle Hayne, Beaufort, Peedee, Black Creek, Upper Cape Fear and Lower Cape Fear Aquifers, all of which are used for water supply in varying amounts from one county to the next. All of the aquifers below the surficial are considered to be confined aquifers that are separated by confining layers.

The surficial, or water table aquifer is the shallowest aquifer in the hydrogeologic system underlying the Tar-Pamlico River Basin. It is the first to receive recharge through infiltration of rainwater, which moves downward from the land surface to the water table. Thus, the water table fluctuates in elevation within the aquifer along with changes in groundwater recharge and storage. Groundwater moves laterally within the surficial aquifer from recharge to discharge areas such as rivers, lakes, swamps, and other surface water bodies. It also moves down gradient in recharge areas into deeper confined aquifers. The surficial aquifer is present throughout the region, and is principally composed of Quaternary age sand, shell and clay beds of marginal marine, lacustrine and fluvial origin. It also is made up of older Pliocene Yorktown deposits in some areas where the confining unit occurs at a lower position in the stratigraphic section.

The Yorktown Aquifer is made up of sands within the Pliocene Yorktown and Miocene Pungo River Formations, and in some areas may include Quaternary age sediments. The Yorktown Formation is principally composed of fine to medium grained shelly, clayey sand, bluish-gray in color, alternating with beds of bluish gray clay. The basal part of the Yorktown Formation often contains medium to coarse sand, including reworked phosphatic sediments from the underlying Pungo River Formation. The Pungo River Formation is generally described as brown phosphatic sand, with gray to green calcareous and diatomaceous clays, dolomitic limestone, and minor gray shell limestone, white chalk and dolomite. Where the aquifer includes sediments of Quaternary age the lithology is made up of fine to coarse grained, gray to tan colored sands and thin clay interbeds.

The Castle Hayne aquifer within the Tar-Pamlico Basin, is the most prolific and high yielding aquifer in the North Carolina Coastal Plain. It is principally composed of the Eocene age Castle Hayne Formation, which consists of very permeable, gray to white molluscan moldic limestones and dolomites. It is interbedded and underlain by fine to medium grained calcareous sands and clays. The lower part of the Castle Hayne Aquifer may include over some parts of the study area, highly glauconitic sands of the uppermost Beaufort Formation of Paleocene age.

The Beaufort Aquifer is principally comprised of highly glauconitic sand and sandy limestone beds present within the Beaufort Formation of Paleocene age.

The Peedee Aquifer within the study area contains alternating beds of sand and clay that primarily make up the Upper Cretaceous Peedee Formation, although the aquifer may contain some sediments from the underlying Black Creek Formation or overlying Beaufort Formation in some areas.

The Black Creek aquifer is made up primarily of the Upper Cretaceous Black Creek Formation, but also includes permeable beds from younger and older formations. The Black Creek aquifer may be described in terms of lithology as alternating beds of gray, sometimes calcareous, glauconitic sand and black to gray clay. The Black Creek Formation is recognized in the subsurface by a high amount of organic material, particularly in the form of lignite. Individual sand bodies are discontinuous in the subsurface as indicated by well log correlations and may be described as lenticular in nature.

The Upper Cape Fear aquifer is made up primarily of the upper part of the Cape Fear Formation of Cretaceous age, which consists of alternating layers of gray to red colored, fine to coarse grained sand and gray to red clay. Gravel beds are also common, and provide a high degree of permeability to the aquifer where present. Sediments of the Cape Fear Formation are interpreted to be non-marine in origin on the basis of a lack of marine fossils and the prevalence of accessory iron oxide minerals. Sands in the aquifer are lenticular in nature as indicated by well-to-well geophysical log correlations over short distances, and are quite variable in thickness, ranging from a few feet to 50 feet. As in the case of the Black Creek, sand bodies are well connected hydraulically, as evidenced by the widespread lateral transmission of drawdown effects in the area.

The Lower Cape Fear aquifer is comprised of the lower part of the Cape Fear Formation of Cretaceous age, and consists of alternating beds of non-marine sand, gravel and clay of similar color and character to the Upper Cape Fear aquifer.

West of the fall line the hydrogeologic system in the Tar-Pamlico River Basin is composed of various igneous and metamorphic rocks and overlying saprolite of the Piedmont Province. Water is contained and produced via fractures and fracture systems present in the bedrock and also within permeable sections of the overlying saprolite. In general these two units are well connected hydraulically and are considered to comprise a single unconfined aquifer.

Groundwater discharge or base flow occurs to the Tar-Pamlico River and its tributaries primarily from the unconfined aquifer, however the river channel is in contact with deeper confined aquifers where they come close to the surface. Thus, the Tertiary and Cretaceous age aquifers contribute some of the base flow as well.

Table 1 shows the historic average, highest and lowest recorded base flow (expressed as a percentage of total flow) at each stream gage station in the Tar-Pamlico River Basin. This is based on a computer model by Arnold and others, 1999. Periods of higher percentage base flow correspond to times of lower rainfall or drought, when the river receives less surface runoff. Conversely, periods of lower percentage base flow correspond to periods of higher rainfall amounts and higher runoff. The amount of development (pavement, building foundations, and road construction) can also have an effect on the rate of recharge to the subsurface by increasing the amount of runoff. This will decrease the percentage of base flow in a river as development progresses over time.

Table 1: Base Load Estimates at Gages

Subbasin	County	Gage	Average Base Flow	Highest Base Flow	Lowest Base Flow
03020101	Granville	Tar River near Tar River NC	0.43	0.58	0.34
03020101	Franklin	Tar River at Louisburg	0.49	0.53	0.45
03020101	Franklin	Tar R at US 401 Louisburg	0.52	0.64	0.42
03020101	Franklin	Cedar Creek near Louisburg	0.64	0.75	0.55
03020101	Franklin	Devils Cradle Crk SR1412	0.56	1.00	0.54
03020101	Nash	Tar River near Nashville	0.59	0.86	0.49
03020101	Nash	Sapony Crk near Nashville	0.55	0.65	0.47
03020101	Nash	Swift Crk at Hilliardston	0.62	0.76	0.41
03020101	Nash	Tar River BL Tar R Reservoir	0.58	0.77	0.45
03020101	Edgecombe	Tar River near Rocky Mount	0.58	0.61	0.54
03020101	Edgecombe	Tar River at NC 97 Rocky Mt	0.57	0.69	0.48
03020102	Halifax	Little Fishing Crk White Oak	0.56	0.71	0.39
03020102	Edgecombe	Fishing Creek near Enfield	0.61	0.76	0.45
03020103	Edgecombe	Tar River at Tarboro NC	0.66	0.78	0.59
03020103	Edgecombe	Conetoe Crk at Conetoe NC	0.59	0.60	0.59
03020103	Edgecombe	Conetoe Crknear Bethel NC	0.60	0.76	0.43
03020103	Pitt	Pete Mitchell Swmp SR 1409	0.67	0.72	0.12
03020103	Pitt	Green Mill RN at Arlington	0.50	0.55	0.46
03020103	Pitt	Juniper Brnch at SR 1766	0.58	0.64	0.50
03020103	Pitt	Tar River at Greenville	0.65	0.74	0.60
03020103	Pitt	Chicod at SR 1760	0.48	0.70	0.33
03020104	Beaufort	Herring Run nr Washington	0.60	0.73	0.52
03020104	Beaufort	Herring Run nr Washington	0.54	0.58	0.49
03020104	Beaufort	Herring Run nr Washington	0.51	0.57	0.41
03020104	Beaufort	Herring Run nr Washington	0.51	0.58	0.42
03020104	Beaufort	Herring Run nr Washington	0.69	0.79	0.55

Central Coastal Plain Capacity Use Area

In 2002, the North Carolina Environmental Management Commission (EMC) enacted the Central Coastal Plain Capacity Use Area (CCPCUA) rules. These regulations were developed to control groundwater use in the Cretaceous Aquifers in response to decreasing groundwater levels and increasing saltwater intrusion. The CCPCUA rules require groundwater users in the impacted areas to reduce their consumption in three phases between 2008 and 2018. The 15 highlighted counties are designated as in the CCPCUA (all but Duplin, Greene, Jones, Lenoir, Onslow, and Wayne, are located in the Tar-Pamlico River Basin) shown on the map. The CCPCUA rules became effective August 1, 2002.

Figure 1: CCPCUA Counties

• Permits are required for groundwater users of more than 100,000 gallons per day.

• Annual registration and reporting of withdrawals is required for surface and groundwater users of more than 10,000 gallons per day

Current and historical summary water use by county, type of use and aquifer along with CCPCUA permit holders and registrants may be viewed at www.ncwater.org/CCPCUA click on the "Query the data" link then summary use tables.

Ground Water Availability

The Ground Water Management Branch of the Division of Water Resources (DWR) (http://ncwater.org/?page=357) provides technical and management support for the development and use of groundwater resources in the State of North Carolina. Groundwater is an essential resource in the state. More than 50% of North Carolina's population receives its drinking water supplies from groundwater. This includes 25% of all drinking water from public water supplies, and 100% of all self-supplied domestic drinking water supplies (as of 2000, about one-third of the state's population, or 2,414,794, received domestic water supplies from private wells). In addition to its use for drinking water, groundwater is withdrawn extensively for irrigation and livestock, mining, and for self-supplied commercial and industrial uses (those that are not served by public water supplies). This Branch also implements the Central Coastal Plain Capacity Use Area permit program.

Table 2: Estimated Water Use in the Tar-Pamlico River Basin (USGS 2010)

County	Groundwater Use mgd	Surface Water Use mgd	Total mgd
Beaufort	88.87	1.01	89.88
Carteret	9.84	0.81	10.65
Craven	21.74	15.60	37.34
Dare	8.63	0.10	8.73
Edgecombe	7.39	7.88	15.27
Franklin	3.24	6.22	9.46
Granville	2.46	5.75	8.21
Halifax	1.86	29.84	31.70
Hyde	1.31	0.50	1.81
Martin	3.38	60.19	63.57
Nash	4.59	16.01	20.60
Pamlico	3.76	0	3.76
Person	2.26	1012.53	1014.79
Pitt	13.25	15.57	28.82
Tyrrell	0.56	0.03	0.59
Vance	2.05	7.77	9.82
Warren	1.01	1.56	2.57
Washington	4.73	1.07	5.80
Wilson	4.18	21.79	25.97
Totals	**175.27**	**1203.42**	**1378.69**

http://water.usgs.gov/watuse/

Groundwater Quality

The DWR Groundwater Planning Branch's (http://portal.ncdenr.org/web/wq/ps/gwp) mission is to support and improve North Carolina's groundwater protection program by identifying needs, applying science to assess the effectiveness of regulations and build knowledge of groundwater quality, and increasing awareness of groundwater quality concerns.

The Groundwater Planning Branch provides science support to DWR's regulatory and classification and standards programs and generates data and analysis to understand and manage the state's groundwater quality. This includes development of a DENR groundwater database.

Ambient Groundwater Quality Monitoring in the Tar-Pamlico River Basin

DWR maintains a substantial network of dedicated groundwater monitoring wells in the Coastal Plain of North Carolina. To date, these wells have been used only to monitor water levels and chloride concentrations. DWR is exploring possibilities for using these wells to expand its ambient groundwater quality monitoring network. A lack of staff resources to conduct this additional monitoring may present an impediment to doing so.

Groundwater Quality Indicators from Private Drinking Water Well Testing

In the absence of routine ambient groundwater quality monitoring, the best available indicators

of groundwater quality in the Tar-Pamlico River Basin come from the routine sampling of newly-constructed private drinking water wells. Under the statewide private well testing program administered by the Department of Health and Human Services (DHHS) and local health departments, all new private drinking water wells are sampled by local health departments and analyzed for a standardized list of chemical constituents by the State Laboratory of Public Health in the DHHS. In addition to their value to individual well users, these samples are the most abundant source of data on groundwater quality in many areas of the state.

Description of the Groundwater Quality Indicators

Nitrate

Naturally occurring background levels of nitrate in groundwater are typically very low. Groundwater nitrate levels above 1 mg/L typically indicate the influence of fertilizer application or human or animal waste disposal. Nitrate concentrations greater than 1 mg/L in groundwater also indicate the possibility that groundwater has been impacted by other pollutants from human activities, such as pesticides or other chemicals. Discharge of groundwater with elevated levels of nitrate to surface waters may also contribute to nutrient overloading in sensitive surface waters. Nitrate levels greater than the state groundwater standard of 10 mg/L in drinking water put infants at serious risk of methemoglobenemia ("blue baby syndrome"), which interferes with the ability of an infant's blood to absorb oxygen. Because nitrate in groundwater can be an indicator at these two different levels, two separate indicators were identified from the nitrate data:

1. The percentage of samples exceeding 1 mg/L nitrate, which serves as an indicator of human impacts to groundwater and potential impacts to surface waters, and

2. The percentage of samples exceeding the state groundwater standard of 10 mg/L, which serves as an indicator of potential health risks to private well users

pH

pH is a measure of the acidity of water. Low pH groundwater can result from natural conditions or human influences, including mining or other land uses. Naturally-occurring low pH is common in North Carolina groundwater. Widespread changes in groundwater pH over time might result from long-term changes in the pH of precipitation (acid rain) as well as long-term changes in the distribution and infiltration of precipitation. While low pH in itself does not constitute a health risk to well users, low pH in groundwater may increase the likelihood of leaching of metals from aquifers, well materials, and plumbing. Groundwater discharge to surface waters can also inhibit or promote acidification in surface waters. For these reasons, the percentage of samples with pH less than 6.5 may be an important indicator to track for human impacts to groundwater, potential health risks to private well users, and potential impacts to surface waters.

Metals: Arsenic and Chromium

Arsenic and chromium may originate from human or natural sources. Arsenic in particular is well-known to occur naturally in North Carolina groundwater in many places, but due to geologic conditions, it is more likely to occur in the central Piedmont. Long-term consumption of groundwater containing these metals above health-based groundwater standards can cause adverse health effects. The percentage of wells exceeding state groundwater standards for arsenic and chromium is a useful indicator for tracking the degree to which private well users might be exposed to these metals.

Metals: Iron & Manganese

Iron and manganese are common in North Carolina soils and rocks and therefore commonly occur naturally in North Carolina groundwater, though they may result from human sources as well. Elevated levels of iron and manganese in groundwater primarily constitute an esthetic concern with color, taste, and staining of plumbing fixtures and laundry. Groundwater monitoring by DWR in central North Carolina also suggests that elevated iron and manganese may reduce the mobility of arsenic in groundwater. Groundwater with high levels of iron and manganese may also contribute to high levels of these metals in surface waters due to natural groundwater discharge. The percentage of samples exceeding the state groundwater standard for each of these metals was identified as an indicator of naturally occurring groundwater quality, and can be used to assess whether human or environmental factors are impacting water quality at a large scale.

2010 Groundwater Quality Indicator Results

For the indicator parameters described above, the results of 2010 private well sample analyses are summarized in Table 2 for each county of the Tar-Pamlico Basin.

Table 3: Private Well Sample Results

County	Number of samples	NO3 > 1 mg/L	NO3 > 10 mg/L	pH < 6.5-	As > 10 ug/L	Cr > 10 ug/L	Fe > 300 ug/L	Mn > 50 ug/L
Beaufort	19	0.0	0.0	0.0	0.0	0.0	36.8	21.1
Edgecombe	12	8.3	0.0	16.7	0.0	0.0	33.3	16.7
Franklin	62	38.7	0.0	27.4	0.0	3.2	16.1	21.0
Granville	77	3.9	0.0	5.2	0.0	6.5	26.0	53.2
Halifax	15	20.0	0.0	13.3	0.0	6.7	20.0	40.0
Hyde	2	0.0	0.0	0.0	0.0	50.0	100.0	100.0
Martin	5	0.0	0.0	0.0	0.0	0.0	40.0	0.0
Nash	125	32.8	0.0	9.6	1.6	0.8	17.6	32.0
Pamlico	6	0.0	0.0	0.0	0.0	0.0	66.7	33.3
Pitt	12	0.0	0.0	0.0	0.0	0.0	50.0	8.3
Vance	17	41.2	0.0	23.5	0.0	0.0	29.4	47.1
Washington	5	0.0	0.0	20.0	0.0	0.0	60.0	20.0
Warren	15	33.3	0.0	13.3	0.0	0.0	26.7	46.7
Wilson	47	28.9	6.7	23.4	2.1	0.0	51.1	59.6

Trends in Groundwater Quality Indicators

Use of the private drinking water well dataset to establish status indicators is a new practice, made possible by the implementation of mandatory testing of all new private drinking water wells in July 2008. No trends can be established at present but DWR will continue to evaluate this dataset for indicator parameters as long as the statewide well testing program remains in place.