Section 3 – Potential infrastructure impacts

A. Water supply

This analysis of water availability focuses on the areas around the geologically defined Dan River Triassic Basin and the Deep River Triassic Basin. The use of the terms "basin" and "sub-basin" in geologic terms is inconsistent with how these terms are used in reference to water resources. Therefore, when the geologically defined areas are being discussed they will be denoted as Triassic or geologic basins and when the hydrologically defined areas are discussed they will be denoted as hydrologic basins. Maintaining this distinction is important because water use and water availability data are compiled, evaluated and summarized by hydrologically defined boundaries.

Data on water availability are typically collected and summarized using a nested hierarchy of surface water drainage areas adopted by the United States Geological Survey (USGS) and the Natural Resources Conservation Service of the U.S. Department of Agriculture. This system, shown in Table 3-1, designates the Upper Dan River sub-basin as hydrologic unit 03010103 and the Deep River sub-basin as hydrologic unit 03030003.[19] These geographic areas are further subdivided into smaller watersheds designated by 10 digit labels and subwatersheds designated by 12 digit labels.

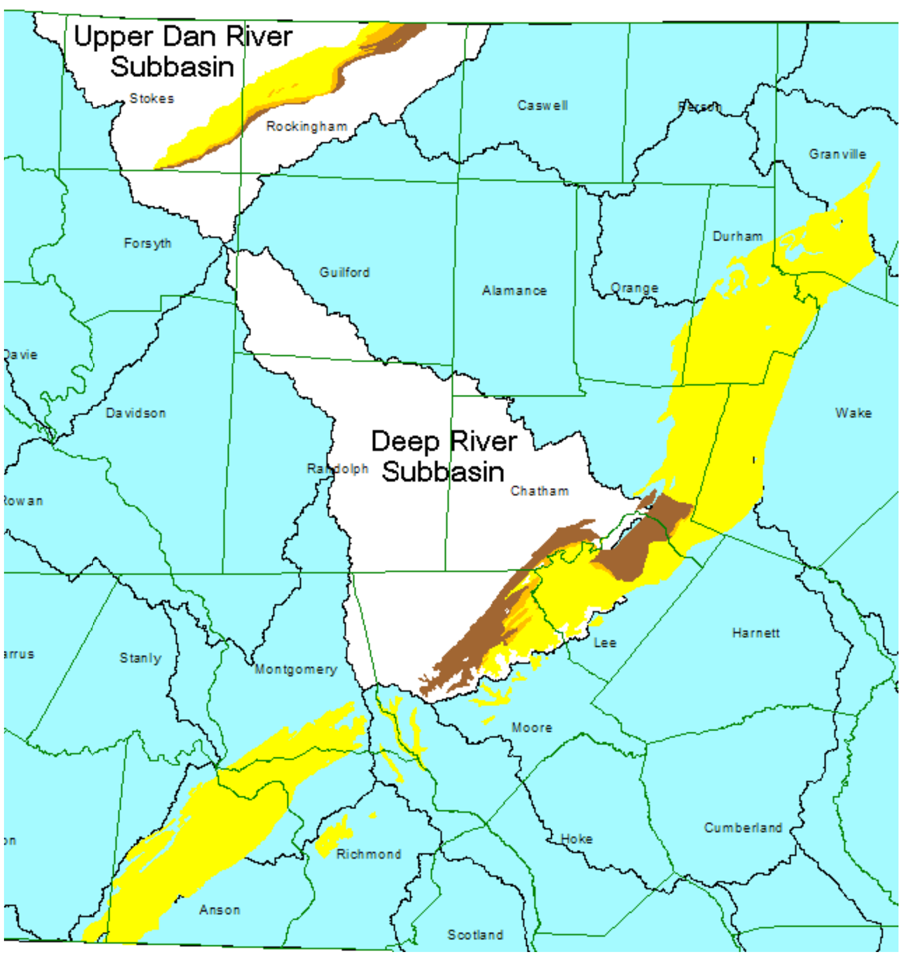
Figure 3-1 shows the Triassic Basins with the extent of the component formations shown in yellow, orange, and brown in relation to the Upper Dan River and the Deep River hydrologic sub-basins shown in white. Study areas are delineated by groupings of hydrologically defined subwatersheds. The groupings of subwatersheds encompassing the Triassic Basins and defining the study areas for water resource evaluations are delineated by the black lines in Figure 3-2.

[19] U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service, 2011, Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (2d ed.) U.S. Geological Survey Techniques and Methods 11-A3, 62p. Available on the World Wide Web at http://pubs.usgs.gov/tm/tm11a3/

Table 3-1. USGS Drainage Area Nomenclature[20]

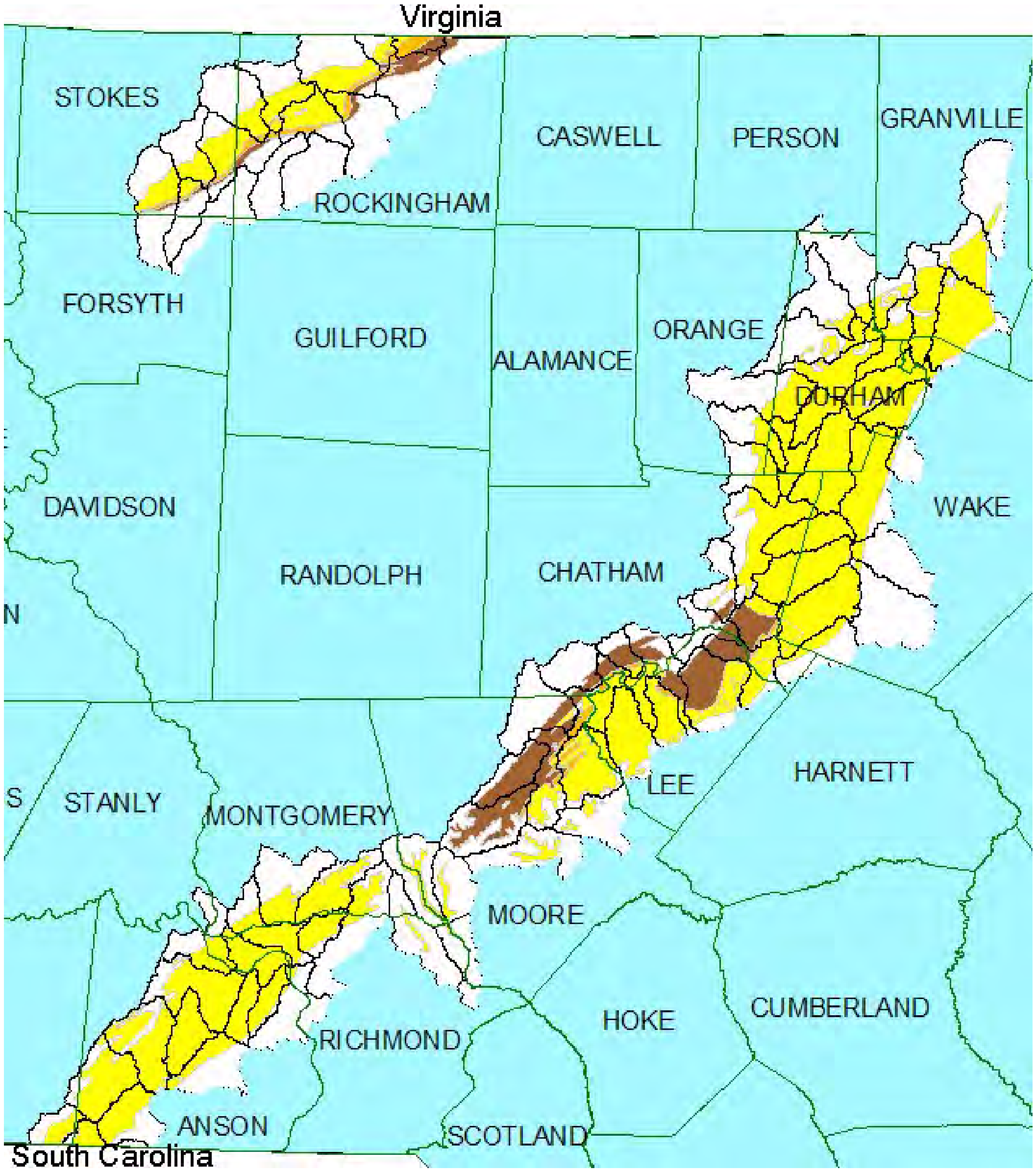
Current numerical name	Digits in hydrologic unit code	Common name	Hydrologic unit level	Average size (square miles)	Approximate number of hydrologic units
2 digit	2	Region	1	177,560	21 (actual)
4 digit	4	Sugregion	2	16,800	222
6 digit	6	Basin	3	10,596	370
8 digit	8	Sub-basin	4	700	2,270
10 digit	10	Watershed	5	227 (40,000-250,000 acres)	20,000
12 digit	12	Subwatershed	6	40 (10,000-40,000 acres)	100,000
14 digit	14	(None)	7	Open	Open
16 digit	16	(None)	8	Open	Open

Figure 3-1. Triassic Basins and Upper Dan River and Deep River Sub-basins



[20] United States Geological Survey Techniques and Methods 11-A3.

Figure 3-2. Triassic Basins and Subwatersheds Used in this Analysis



Data sources

State law requires some water withdrawers to register their water use with the Department of Environment and Natural Resources. Owners of non-agricultural facilities that withdraw 100,000 gallons or more of water on any day and owners of agricultural operations that withdraw 1 million gallons or more of water on any day are required to register their withdrawals.[21] These registrations document water sources and current water usage. Some community water systems meet the registration requirement by submitting a local water

[21] N.C. General Statute 143-215.22H.

supply plan to the Division of Water Resources. All units of local government that supply water to the public and other large community water systems are required by General Statute 143-355(l) to prepare and submit a local water supply plan. The local plans describe the characteristics of the water system, such as water sources, number of connections, population served and projections of future water supply needs. Details of the water supply plan requirements and the local water supply data can be found on the division's web site at www.ncwater.org. Data from these plans were used to estimate current and future water needs for existing water users for this analysis.

Water withdrawal locations and water use figures were analyzed using data collected and compiled by the Source Water Assessment Program, the Water Withdrawal and Transfer Registration Program and the Local Water Supply Planning Program, all of which are administered by the Division of Water Resources. The study areas for the Triassic Basins were defined by sets of subwatersheds that provide close geographic consistency with the Triassic Basins.

Water use and potential supply

Deep River Triassic Basin

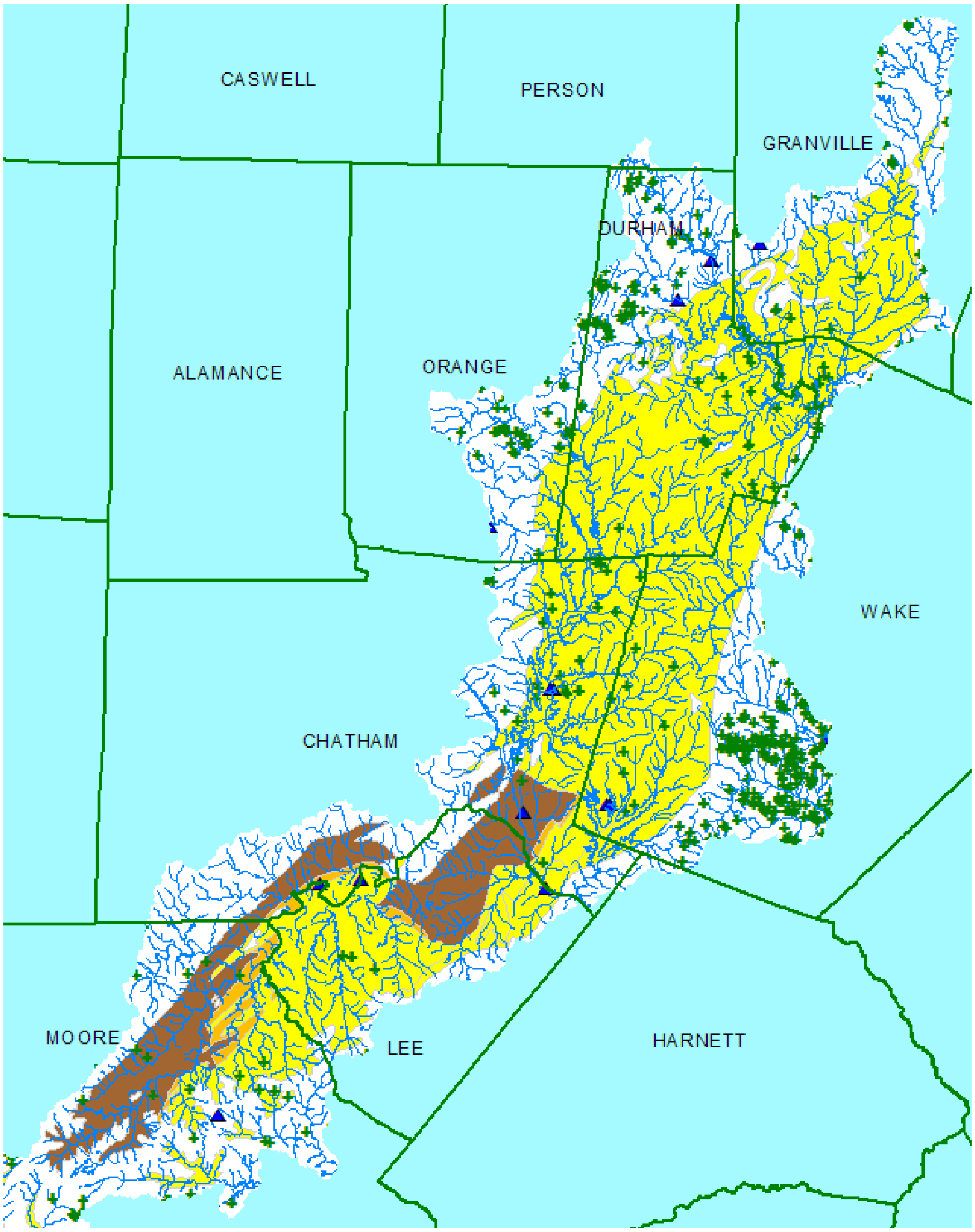
The geologic formations in the Deep River Triassic Basin are comprised of materials deposited millions of years ago and now found in a "northeast-trending, trough-shaped downfaulted block of Triassic rocks near the east edge of the Piedmont plateau."[22] The Deep River Triassic Basin extends from the boundaries of Union and Anson counties at the South Carolina state line northeasterly into the southern portion of Granville County. Along this path the component formations underlie portions of several major surface water drainage areas including the Upper Pee Dee, Lower Pee Dee, Lumber, Deep, Upper Cape Fear, Haw, Upper Neuse and Upper Tar sub-basins. A natural break in the geologic formations near the boundary of Moore County and Montgomery County creates a convenient analytical divide in the geologic basin. The Sanford and Durham geologic sub-basins lie north of the divide within Chatham, Durham, Granville, Lee, Moore, Orange and Wake counties. South of the divide, the Wadesboro geologic sub-basin lies within Anson, Montgomery, and Richmond counties.

Sanford and Durham Sub-basins of the Deep River Triassic Basins

The areas encompassing the Sanford and Durham Sub-basins of the Deep River Triassic Basin are shown in Figure 3-3 in yellow, orange and brown within the water resource study area. Public water supply systems' water sources are shown on this figure with surface water intakes indicated by blue triangles and groundwater wells indicated by the green crosses. It is noteworthy that there are few public water system wells within the Triassic Basins. This may be an indication of the low yields produced by these formations, especially when compared to the proliferation of wells seen just outside of the Triassic basin boundaries in Durham, Orange and Wake counties.

[22] Reinemund, J.A. "Geology of the Deep River Coal Field North Carolina: U.S. Geological Survey Professional Paper 246." U.S. Geological Survey, 1955, page 9.

Figure 3-3. Sanford and Durham Sub-basins and Study Area



In the Sanford and Durham geologic sub-basins the Deep River and the Haw River merge to form the Cape Fear River; the surface waters flowing out of these drainage areas flow through the Sanford and Durham geologic sub-basins. The lower 30 miles of the Deep River flow along the western boundary of the Triassic Basin. Low flows in the Deep River are supplemented by releases of stored water from several upstream reservoirs. Above the confluence, in the Haw River drainage, Jordan Lake lies inside the western boundary of the Triassic Basin in Chatham County. This reservoir, built and operated by the U.S. Army Corps of Engineers, stores water as a regional water supply source, provides flood control storage and provides water to augment downstream flows in the Cape Fear River.

In the Durham sub-basin of the Deep River Triassic Basin waters from the Eno, Little and Flat rivers flow into Falls Lake. This reservoir serves as the main water supply for the city of Raleigh's public water system and provides flood control storage and water for flow augmentation downstream in the Neuse River.

Interest in the gas-producing potential of the Triassic Basins has focused on the Sanford geologic sub-basin because historically this area has produced coal, and because existing exploratory wells indicate the presence of natural gas. Within the Sanford study area there are four local government water systems: the city of Sanford, Goldston-Gulf Sanitary District, Moore County Public Utilities – Seven Lakes, and the town of Carthage.

The city of Sanford and the Goldston-Gulf Sanitary District are supplied by water withdrawn from the Cape Fear River through a water treatment plant operated by Sanford. The Moore County Public Utilities-Seven Lakes water system distributes groundwater withdrawn from a subwatershed outside of the Triassic Basin to its customers, some of whom reside in the Triassic Basin. The town of Carthage withdraws surface water from Nicks Creek, a tributary of the Little River that is outside of the study area and the Deep River sub-basin. Overall in the Sanford geologic sub-basin study area 45 groundwater and surface water sources supply public water systems. Twenty-four of these sources tap waters within the Triassic Basin.

Within Lee County, the city of Sanford also provides water from the Cape Fear River to the Carolina Trace Water System and the town of Broadway. In 2010, these three systems provided water to almost 47,000 of the 58,059 county residents (81 percent). Residents not supplied by the network of water utilities supplied by the city of Sanford depend on private wells or other groundwater-based community water systems. At least one community water system uses water from wells in the Triassic Basin.

Until recently, the Goldston-Gulf Sanitary District in the Chatham County portion of the Sanford study area withdrew and treated water from the Deep River. In 2010, the district provided water treated by the city of Sanford to 1,250 of the 11,160 residents of the Indian Creek, Smith Creek, and Cedar Creek subwatersheds. The rest of the residents in these subwatersheds depend on private wells, some of which likely draw water from Triassic Basins. In addition to the community water systems noted, two registered water withdrawers use surface water from the Deep River in southern Chatham County; one agricultural operation and one industrial facility. There may be additional self-supplied agricultural or industrial operations that use water from the Deep River, but do not meet the threshold of use that requires them to register their water withdrawals.

Nine subwatersheds within the Sanford study area lie within Moore County. The town of Carthage supplied water from outside the study area to 2,414 county residents in 2010. Moore County Public Utilities-Seven Lakes provides water to an undetermined number of customers in several of the subwatersheds within the study area. Some of the water comes from wells outside of the Triassic Basin and some water comes from Drowning Creek, in the Lumber River sub-basin, through other public water systems in the county. In addition, the Foxfire Village water system provides water from groundwater sources to customers in southwestern Moore County. In 2010 the estimated population in the nine study area subwatersheds in Moore

County was about 22,000. Residents of this area that do not receive water from the town of Carthage, Moore County Public Utilities-Seven Lakes or the Foxfire Village water systems are dependent on other groundwater sources within the study area. An unknown number of these wells are located in the Triassic Basin.

Characterizing water use within the study area is complicated by the inconsistency of the boundaries used to collect and summarize data. Water use data needed for this analysis may be organized by politically defined county boundaries, hydrologically defined surface water drainage areas or the geologically defined Triassic Basins. The boundaries of those different units are not correlated and have different geographic extents.

The Office of State Budget and Management provides population data and projections of population changes through 2030 for counties in the state. County population figures used in this report were extracted from the Office of State Budget and Management website on Jan. 6, 2012, which showed figures that were updated on Sept. 1, 2011. Table 3-2 shows historic and projected population data for the counties encompassing the Sanford and Durham sub-basins of the Deep River Triassic Basin. Table 3-3 shows the expected population to be served by public water systems in these counties that submit a local water supply plan to DWR. The expected levels of water use associated with the anticipated levels of service are shown in Table 3-4. These water utilities anticipate continuing to serve more than half of the current and future residents of these counties.

Table 3-2. Sanford and Durham Sub-basins - County Population

Sanford-Durham Sub-units of Deep River Triassic formations			
County Population	Population 2010	Population 2020	Population 2030
Chatham County	63,870	78,237	92,604
Durham County	268,925	323,474	378,024
Granville County	60,547	69,359	78,167
Lee County	58,059	65,857	73,658
Moore County	88,594	101,324	112,189
Orange County	134,325	155,442	176,559
Wake County	907,314	1,160,823	1,414,333
Total	1,581,634	1,954,516	2,325,534
(from OSBM website on January 6, 2012)			

Table 3-3. Sanford and Durham Sub-basin - Population Served by a Local Water Supply Plan (LWSP) Water System

Sanford-Durham Sub-units of Deep River Triassic formations			
LWSP Service Population	Population	Population	Population
	2010	2020	2030
Chatham County	30,853	32,886	35,266
Durham County	241,543	286,419	329,421
Granville County	31,262	36,046	44,822
Lee County	46,820	64,088	84,615
Moore County	51,101	60,112	69,474
Orange County	103,604	121,366	139,325
Wake County	688,004	964,088	1,224,617
Total	1,193,187	1,565,005	1,927,540

Table 3-4. Sanford and Durham Sub-unit - Water Demands from Local Water Supply Plans

Sanford-Durham Sub-units of Deep River Triassic formations			
LWSP Service Area Demand	MGD	MGD	MGD
	2010	2020	2030
Chatham County	5.1	6.3	7.6
Durham County	28.1	29.4	34.1
Granville County	5.7	7.8	9.7
Lee County	9.4	14.8	22.0
Moore County	8.0	9.1	10.5
Orange County	8.9	11.2	13.1
Wake County	84.5	108.1	133.7
Total	149.7	186.8	230.6

Table 3-5. Sanford and Durham Sub-basins - Population and Water Demands of County Residents Not Served by a LWSP System

Sanford-Durham Sub-units of Deep River Triassic formations			
Non-LWSP Population/Demand			
Estimated @ 75 gals/person/day	2010	2020	2030
Chatham County	33,017	45,351	57,338
Durham County	27,382	37,055	48,603
Granville County	29,285	33,313	33,345
Lee County	11,239	1,769	0
Moore County	37,493	41,212	42,715
Orange County	30,721	34,076	37,234
Wake County	219,310	196,735	189,716
Total	388,447	389,511	408,951
Estimated water needs (mgd)	29.1	29.2	30.7
zero values indicate predicted service population exceeded predicted county population			

The data in Table 3-2 and Table 3-3 suggest that, over the next couple of decades, a significant number of county residents will continue to be dependent on private wells or very small well-based community water systems. Table 3-5 estimates the number of county residents that will likely be dependent on groundwater from household or community wells, including estimates of the cumulative amount of water needed to meet those demands assuming each person uses 75 gallons of water per day.

Table 3-6. Sanford and Durham Sub-basins Agricultural Water Use

Sanford-Durham Sub-units of Deep River Triassic formations				
2010 Daily Agricultural Use	Unique	Ave. Daily	Ave. Daily	Daily
Use in million gallons per day	Operations	Ground Water	Surface Water	Capacity
Chatham County	12	0.091	*	0.956
Durham County	6	*	0.040	0.938
Granville County	19	0.425	0.346	17.876
Lee County	20	0.062	0.216	13.539
Moore County	33	*	0.537	22.508
Orange County	10	*	0.074	5.424
Wake County	41	0.143	1.477	28.822
Total	141			90.1
Data from Dept. Agriculture & Consumer Services-Agricultural Statistics Division - Water Use Survey				
* data not released -one operation is greater than 60% of total or less than 3 operations				

In addition to the registered water withdrawals and the estimated usage by individual households and small systems, at least 141 agricultural operations in these counties each withdrew 10,000 gallons of water or more on at least one day during 2010 (see Table 3-6). According to the annual survey of agricultural water users conducted by the Agricultural Statistics Division of the N.C. Department of Agriculture and Consumer Services, these agricultural operations have the combined capacity to withdraw 90 million gallons per day from unspecified locations and sources in these counties.[23] Agricultural water use varies by the type of operation and hydrologic conditions during the growing season. In many cases, agricultural operations only apply water when precipitation is inadequate to support crop development. The lack of information about these and other unregistered withdrawals makes it difficult to predict withdrawal needs and identify potential conflicts among water users.

Wadesboro Sub-basin of the Deep River Triassic Basin

Figure 3-4 shows the extent of the Triassic Basins in yellow and delineates the cluster of subwatersheds used as the study area for the Wadesboro sub-basin of the Deep River Triassic Basin. Public water system surface water sources are shown as blue triangles and groundwater sources as green crosses. This area of geologic interest extends from the southeastern corner of Union County, at the South Carolina state line, northeasterly through Anson and Richmond counties and into southern Montgomery County. The Pee Dee River, flowing south out of Lake

[23] The 2010 Agricultural Water Use Survey Report is available at: http://www.ncagr.gov/stats/environmental/WU2010.pdf

Tillery, is the major hydrologic feature within this geologic sub-basin. Lake Tillery collects runoff from 4,600 square miles of central North Carolina. Just upstream of the Wadesboro Triassic sub-basin the Pee Dee River is joined by the Rocky River, which drains an additional 1,400 square miles of Anson, Cabarrus, Mecklenburg, Stanly and Union counties. The Wadesboro Sub-basin underlies the Pee Dee River between Lake Tillery and Blewett Falls Lake. These two reservoirs are owned by Progress Energy and managed under a license issued by the Federal Energy Regulatory Commission (FERC). These reservoirs serve as the major water sources for three county water systems. East of the river, Richmond County has an intake on Blewett Falls Lake to supply its public water system. To the north, Montgomery County gets water from Lake Tillery and then distributes it throughout the county including at least one public water system in northwestern Moore County. West of the river, Anson County withdraws water from Blewett Falls Lake and distributes drinking water throughout the county to municipal water systems and county residents, many of whom reside within the boundaries of the Wadesboro Triassic sub-basin. The Anson County water system also supplies water to communities in Union County.[24]

Figure 3-4. Wadesboro Triassic Sub-basin and Study Area

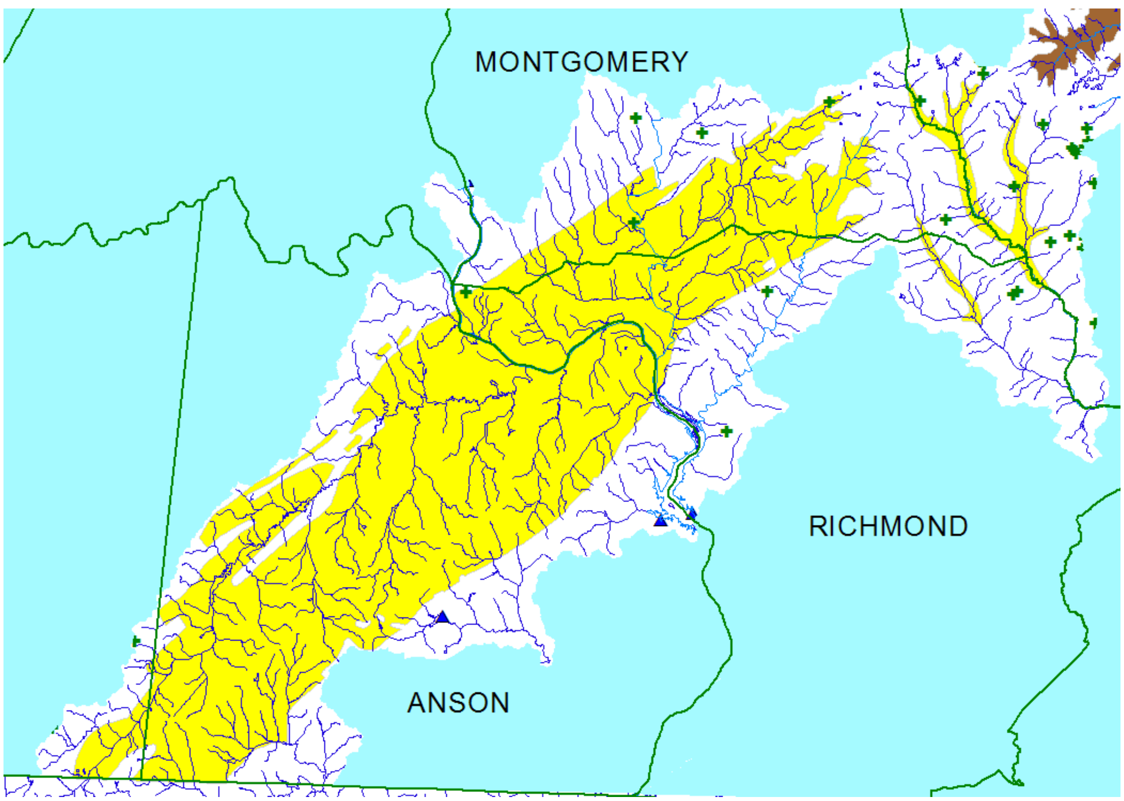


Table 3-7 shows the current population and the estimated population changes for the counties in this area based on North Carolina Office of State Budget and Management data. Seventeen

[24] Details on the communities supplied by the Anson County water system are available in their local water supply plan available on the Division of Water Resources' website at: http://www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/

local government or large community water systems serve most of the residents of these counties. Estimates of current and future service populations for these systems are presented in Table 3-8 followed by estimated future water demand in Table 3-9.

Table 3-7. Wadesboro Triassic Sub-basin County Population

Wadesboro Sub-unit of Deep River Triassic formations			
County Population	Population	Population	Population
	2010	2020	2030
Anson County	26,973	27,454	27,941
Montgomery County	27,992	30,256	32,159
Richmond County	46,600	46,431	46,430
Total	101,565	104,141	106,530
(from OSBM website on January 6, 2012)			

Table 3-8. Wadesboro Triassic Sub-basin Local Water Supply Plan Service Population

Wadesboro Sub-unit of Deep River Triassic formations			
LWSP Service Population	Population	Population	Population
	2010	2020	2030
Anson County	26,183	26,561	26,918
Montgomery County	23,420	24,760	26,250
Richmond County	42,752	47,750	52,600
Total	92,355	99,071	105,768

Table 3-9. Wadesboro Triassic Sub-basin Local Water Supply Plan Water Use

Wadesboro Sub-unit of Deep River Triassic formations			
LWSP Service Area Demand	MGD	MGD	MGD
	2010	2020	2030
Anson County	4.253	4.67	4.602
Montgomery County	2.806	2.938	3.043
Richmond County	13.367	19.103	21.275
Total	20.426	26.711	28.92

County residents that are not supplied by a local government or large community water system depend on groundwater supplied by household wells or small community water systems. Table 3-10 calculates the number of residents dependent on private wells or well-based small community systems and estimates their daily average water needs, assuming that each person uses 75 gallons of water per day.

Table 3-10. Wadesboro Triassic Sub-basin Water Demands - Non-LWSP residents

Wadesboro Sub-unit of Deep River Triassic formations			
Non-LWSP Population/Demand			
Estimated @ 75 gals/person/day	2010	2020	2030
Anson County	790	893	1,023
Montgomery County	4,572	5,496	5,909
Richmond County	3,848	0	0
Total	9,210	6,389	6,932
Estimated water needs (mgd)	0.7	0.5	0.5
zero values indicate predicted service population exceeded predicted county population			

In addition to the registered water withdrawals and the estimated usage by individual households and small water systems, at least 44 agricultural operations in these counties each withdrew 10,000 gallons of water or more on at least one day during 2010. According to data from the annual survey of agricultural water users conducted by the Agricultural Statistics Division of the N.C. Department of Agriculture and Consumer Services[25] shown in Table 3-11, these facilities have the combined capacity to withdraw 31 million gallons per day from unspecified locations and sources in these counties. The lack of information on these and other unregistered water withdrawals makes it difficult to predict withdrawal needs and identify potential conflicts among water users.

Table 3-11. Wadesboro Sub-basin Agricultural Water Use

Wadesboro Sub-unit of Deep River Triassic formations				
2010 Daily Agricultural Use	Unique	Ave. Daily	Ave. Daily	Daily
Use in million gallons per day	Operations	Ground Water	Surface Water	Capacity
Anson County	9	0.073	*	2.103
Montgomery County	18	0.065	*	13.993
Richmond County	17	0.158	0.238	14.770
Total	44.0			30.9
Data from Dept. Agriculture & Consumer Services-Agricultural Statistics Division - Water Use Survey				
* data not released -one operation is greater than 60% of total or less than 3 operations				

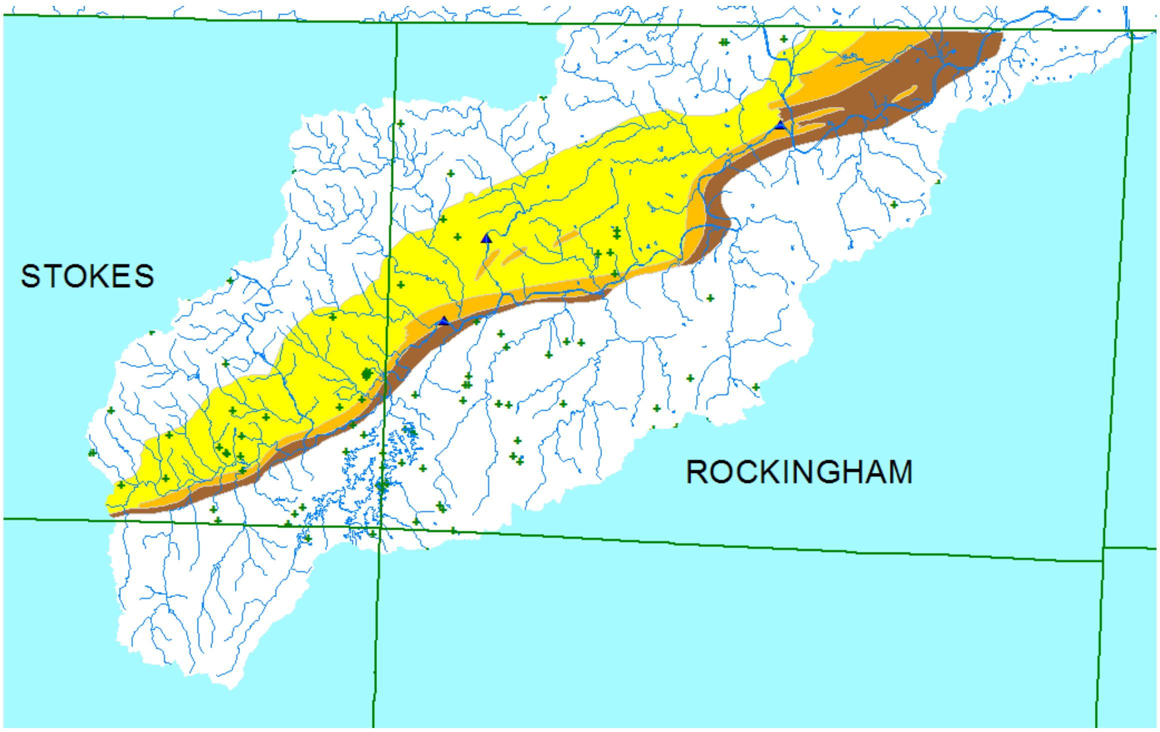
Dan River Triassic Basin

The Dan River Triassic Basin is located along the southern boundary of the much larger hydrologically defined Upper Dan River sub-basin that encompasses 2,054 square miles in North Carolina and Virginia. The Dan River flows southeasterly from western Stokes County where it enters North Carolina. In the vicinity of the town of Walnut Cove, the river turns and begins flowing northeasterly, following the Triassic Basin and collecting the flows from the Mayo and Smith Rivers before flowing back into Virginia in eastern Rockingham County. The study area is defined by 16 subwatersheds that overlay the Triassic Basin. In 2010, almost 75,000 persons resided in the more than 500 square miles of this study area.

[25] The 2010 Agricultural Water Use Survey Report is available at: http://www.ncagr.gov/stats/environmental/WU2010.pdf

Six local government or large community water systems are found within this study area. Three of these systems withdraw surface water to supply their customers. Two of the remaining water systems purchase all of their water from one of the surface-water supplied systems. The sixth water system withdraws groundwater from seven wells within the Triassic Basin. Figure 3-5 shows the study area for the Dan River Triassic Basin with the geologic formations highlighted in yellow, orange and brown. The triangles in Figure 3-5 show the locations of the municipal surface water intakes and the crosses indicate the locations of community and non-community public water system wells.

Figure 3-5. Dan River Triassic Basin Study Area with Wells and Surface Water Intakes



The Dan River Triassic Basin in North Carolina lies within Stokes and Rockingham counties. Table 3-12 shows the estimated populations for Stokes and Rockingham counties according to the Office of State Budget and Management, including the changes expected through 2030. As shown in Table 3-13, the local government and large community water systems serve more than half of the residents in these counties and expect to increase that proportion over the next two decades. The growth in service population will be accompanied by increases in water demands. Table 3-14 shows the current and expected future water needs for these systems. Projections of future water demands are not available for water withdrawers or public water systems that do not prepare a local water supply plan.

Table 3-12. Dan River Triassic Basin - County Population

Dan River Triassic Formation			
County Population	Population	Population	Population
	2010	2020	2030
Rockingham County	93,764	98,664	103,563
Stokes County	47,478	49,802	51,033
Total	141,242	148,466	154,596
(from OSBM website on January 6, 2012)			

Table 3-13. Dan River Triassic Basin - Population Served by a Local Water Supply Plan Water System

Dan River Triassic Formation			
LWSP Service Population	Population	Population	Population
	2010	2020	2030
Rockingham County	51,441	53,407	55,699
Stokes County	22,395	26,735	31,890
Total	73,836	80,142	87,589

Table 3-14. Dan River Triassic Basin - Water Demands from Local Water Supply Plans

Dan River Triassic Formation			
LWSP Service Area Demand	MGD	MGD	MGD
	2010	2020	2030
Rockingham County	13.852	14.599	15.437
Stokes County	2.724	4.129	5.413
Total	16.576	18.728	20.85

County residents who are not supplied with water by a local government or large community water system depend on local groundwater resources for their water supply. Some will receive water from a small well-based community water system; others will rely on individual household wells. Table 3-15 summarizes the number of residents in these categories and estimates current and future water needs. Each person is assumed to use 75 gallons of water per day. An undeterminable number of these residents will receive water from wells in the Triassic Basin, as do the current residents of the town of Walnut Cove.

Table 3-15. Dan River Triassic Basin - Population and Water Demands of County Residents Not Served by a LWSP System

Dan River Triassic Formation			
Non-LWSP Population/Demand			
Estimated @ 75 gals/person/day	2010	2020	2030
Rockingham County	42,323	45,257	47,864
Stokes County	25,083	23,067	19,143
Total	67,406	68,324	67,007
Estimated water needs (mgd)	5.1	5.1	5.0

Six registered water withdrawers are found in the study area: Aqua North Carolina (which operates two groundwater-based community water systems); two golf courses that withdraw water from ponds on golf course property; and the Dan River and Belews Creek steam stations operated by Duke Energy. The two steam stations use surface water to cool thermoelectric generation facilities. Data submitted to DWR indicate that more than 98 percent of the amount withdrawn by these facilities for electricity generation is returned to the source.

Table 3-16. Dan River Triassic Basin - Agricultural Water Use

Dan River Triassic Formation				
2010 Daily Agricultural Use Use in million gallons per day	Unique Operations	Ave. Daily Ground Water	Ave. Daily Surface Water	Daily Capacity
Rockingham County	32	0.162	0.476	30.065
Stokes County	5	*	0.033	4.927
Total	37			35.0
Data from Dept. Agriculture & Consumer Services-Agricultural Statistics Division - Water Use Survey				
* data not released -one operation is greater than 60% of total or less than 3 operations				

In addition to the registered water withdrawals and estimated usage by individual households and small community systems, at least 37 agricultural operations in these counties each withdrew 10,000 gallons or more of water for at least one day during 2010 (see Table 3-16). According to the annual survey of agricultural water users conducted by the Agricultural Statistics Division of the N.C. Department of Agriculture and Consumer Services, these facilities have the combined capacity to withdraw 35 million gallons of water per day from unspecified locations within Stokes and Rockingham counties. The lack of information on these and other unregistered withdrawals makes it difficult to predict withdrawal needs and identify potential conflicts among water users.

Water availability

North Carolina has traditionally been considered a relatively water-rich state. In certain hydrologic conditions, however, the demands of regional water withdrawal and in-stream needs put stress on available water resources in some parts of the state. North Carolina faced serious droughts from 1998 to 2002 and again in 2007 to 2008. Many communities across the state were forced to deal with serious water shortages, including some in the counties surrounding the Sanford and Durham sub-basins. The town of Siler City gets it water from the Rocky River, a tributary of the Deep River. Several times during the last few decades the town of Siler City has faced drought-induced water shortages. To prevent disruption of work at the town's major employers during these droughts, the town was forced to truck and pipe water from emergency sources to the town's reservoir. In August 2002, the N.C. Division of Emergency Management provided an emergency supply of 5,800 gallons of bottled water to the town of Vass in Moore County. Also in 2002, the town of Carthage developed an emergency connection with the Pinehurst water system to supply water to Carthage during the drought. Partially because of their experiences during droughts, the town of Robbins now purchases its drinking water from the Montgomery County water system, which get its water from Lake Tillery in the Yadkin River basin.

In general, permits are not required for water withdrawals in North Carolina.[26] Under the common law reasonable use doctrine, groundwater use on the overlying property is considered a reasonable use and landowners along natural waterways have equal rights to reasonable use of the surface water. Regulatory review of a proposed water withdrawal generally happens only in the context of a state or federal permit review triggered by other project impacts. For example, the impacts of a withdrawal may be reviewed in the course of issuing a Safe Drinking Water Act permit for infrastructure to treat and distribute large amounts of water. When a proposed withdrawal from a free-flowing stream or river is reviewed as part of a broader permit application, the impacts are evaluated based on the relationship between the amount of water to be withdrawn and the amount of water available during low-flow periods. The goal is to identify the amount of water that can be withdrawn while still maintaining sufficient water in the stream to support aquatic life, ensure good water quality and protect the rights of downstream landowners to also make beneficial use of the waters. To find this balance between a proposed withdrawal and other stream uses, the estimated 7Q10 flow in the vicinity of the withdrawal is used to characterize low-flow conditions.

The 7Q10 flow is a statistical estimate, based on available flow records, of the lowest flows that would be expected to occur for seven continuous days once in 10 years. There is a 10 percent chance that this level of flows could occur in any particular year. Except for special situations such as trout streams, the state has generally assumed that individual or cumulative withdrawals from a stream or river should be limited to an instantaneous withdrawal of less than 20 percent of the 7Q10 in the absence of an in-depth environmental review. This threshold is used in rules implementing the N. C. Environmental Policy Act as one of several limits that define for the class of construction activities that can be permitted without first preparing an environmental impact statement.[27] The 7Q10 flow is also cited in case of a dispute under the Right of Withdrawal of Impounded Waters Act as the presumed underlying flow that would be in a watercourse if the impoundment did not exist.[28] The General Assembly has recognized the importance of maintaining the ecological integrity of the state's water resources by requiring an evaluation of the magnitude and timing of flows required to avoid unrecoverable impacts to aquatic habitats. The Ecological Flows Science Advisory Board established by Session Law 2010-143 is in the process of evaluating the natural ecology of North Carolina streams for purposes of identifying the streamflows required to maintain ecological integrity. Ecological flows, based on the board's recommendations and public input, will be integrated into the river basin hydrologic models for the major river basins in North Carolina. With the addition of an ecological flow component, the river basin hydrologic models will provide an even more refined tool for assessing the cumulative effects of surface water

[26] The one exception is in the Central Coastal Plain Capacity Use Area, which does not intersect with the Triassic Basins. Also, parties wishing to use water from a hydropower project licensed by the Federal Energy Regulatory Commission must obtain permission from the licensee and from the FERC if the withdrawal is greater than one million gallons per day.

[27] 15A N.C.A.C. 01C .0408 (2)(b)(i)

[28] G.S. § 143-215.48(a). Retrieved April 18, 2012 from http://www.ncga.state.nc.us/EnactedLegislation/Statutes/HTML/BySection/Chapter_143/GS_143-215.48.html.

withdrawals and for anticipating a river basin's ability to meet water demands across a range of hydrologic conditions.

Currently, proposed projects requiring withdrawals that would raise the instantaneous withdrawals in a particular river reach to greater than 20 percent of the 7Q10 may be acceptable if a site-specific in-stream flow study indicates the desired level of withdrawal will maintain sufficient water to support aquatic life, ensure good water quality and protect the rights of other users. DENR recommends that the same principle should be applied to new surface water withdrawals for gas well development. Making that principle enforceable will likely require development of rules specific to those types of withdrawals, since it is unlikely that water withdrawal for purposes of hydraulic fracturing would trigger review under existing state permitting programs. New withdrawals may also be possible from existing reservoirs. However, access to water from a legally constructed surface water impoundment is controlled by the owners of the impoundment.[29]

If new surface water withdrawals for gas well development are to be limited to a percentage of the 7Q10 flow in the vicinity of a proposed withdrawal it will be useful to elaborate on the possible range of 7Q10 flow values to be expected in the Triassic Basins. The USGS conducts Water-Resources Investigations using nationally standardized methodologies that evaluate low-flow characteristics of river basins in North Carolina. Several of these studies provide useful information to describe low-flow conditions in the vicinity of the Triassic Basins.[30] Low-flow conditions, frequently referred to as base flow, occur during extended periods of time between rainfall events and represent the level of surface water flow that can be supported by groundwater discharges into the surface water channel. Groundwater discharges are influenced by a variety of geologic characteristics including typography and aquifer composition. The rock and sediment composition of the Triassic Basins are noted for having a limited ability to transmit water, and therefore areas in the Triassic Basin typically exhibit very low base flow conditions.

The USGS publication "Low-Flow Characteristics of Streams in North Carolina"[31] provides some general guidelines for estimating low-flow values for hydrologically grouped areas in the state. The authors sub-divided the state into 10 distinct hydrologic areas based on available base flow data and published a set of coefficients to allow estimation of several low-flow statistics based on the square miles of drainage area contributing runoff to a point of interest. The authors include estimates of the drainage area likely to be needed to produce a 7Q10 flow estimate

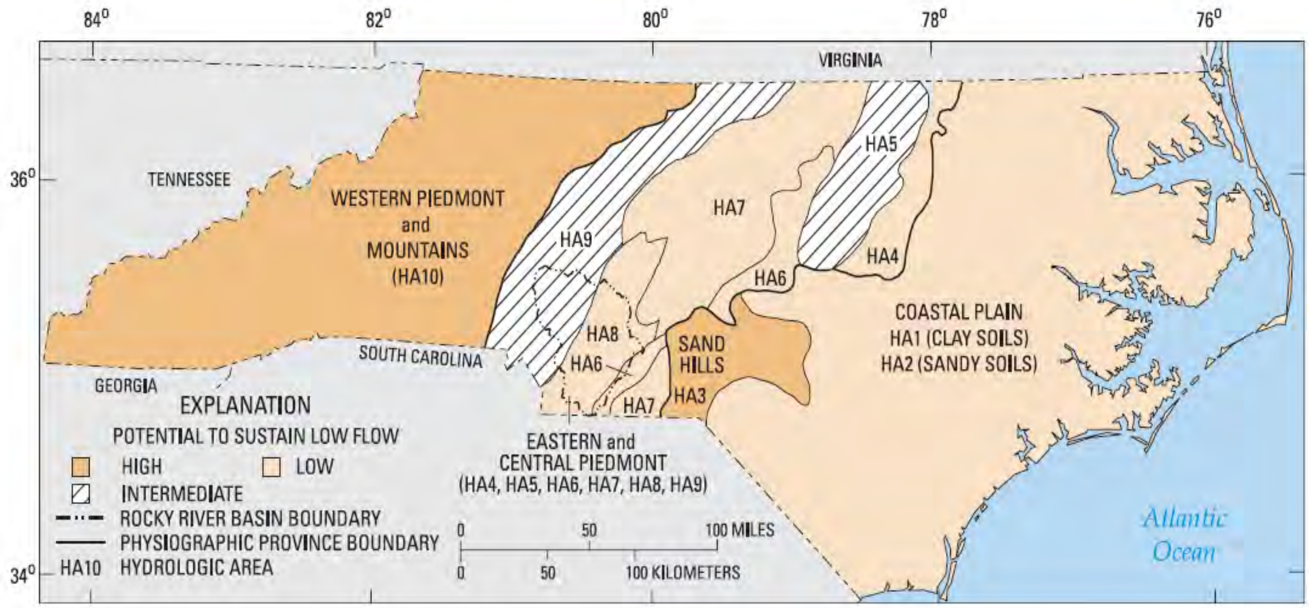
[29] General Statute § 143-215.44 et.seq. Right of Withdrawal of Impounded Waters

[30] Weaver, J. C. "Low-flow Characteristics and Profiles for Selected Streams in the Roanoke River Basin, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 96-4154." USGS, 1996.
Weaver, J. C. "Low-Flow Characteristics and Profiles for the Deep River in the Cape Fear River Basin, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 97-4128." USGS, 1997.
Weaver, J. C., and B.F. Pope. "Low-flow Characteristics and Discharge Profiles for Selected Streams in the Cape Fear River Basin, North Carolina, through 1998: U.S. Geological Survey Water-Resources Investigations Report 01-4094." USGS, 2001.

[31] Giese, G.L., and R.R. Mason, Jr. "Low-flow characteristics of streams in North Carolina: U.S. Geological Survey Water-Supply Paper 2403." USGS, 1993.

greater than zero. Data from this report were used to estimate the potential ranges of low-flows that could occur in parts of the two study areas. These estimates provide guidance as to the possible magnitudes of surface water withdrawals possible under the presumption that 20 percent of the 7Q10 flow would be available without site-specific environmental evaluations. Figure 3-6 shows the delineations of the hydrologic areas established for North Carolina.

Figure 3-6. Hydrologic Areas of Similar Potential to Sustain Low Flows in North Carolina



Study areas were defined by the sets of subwatersheds encompassing the Deep River Triassic Basin and the Dan River Triassic Basin. The study areas are shown in Figure 3-7 with the units of the Triassic Basins highlighted in yellow, orange, and brown. Figure 3-8 and Figure 3-9 show more detailed views of the study areas, showing the boundaries of the USGS-defined hydrologic areas relevant for each of the sub-basins of the Deep River Triassic Basin.

Figure 3-7. Sanford Triassic Sub-basin Study Area

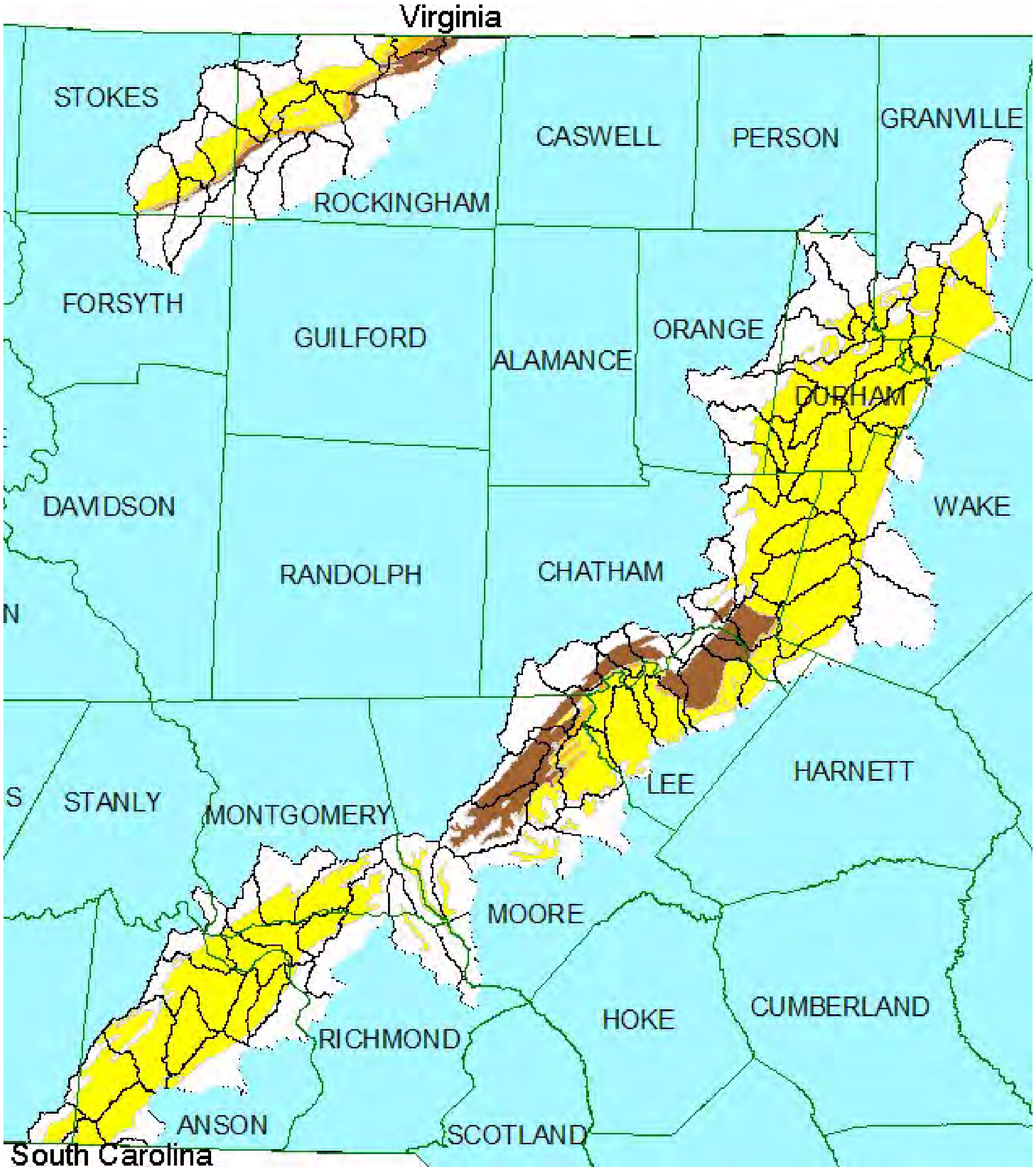
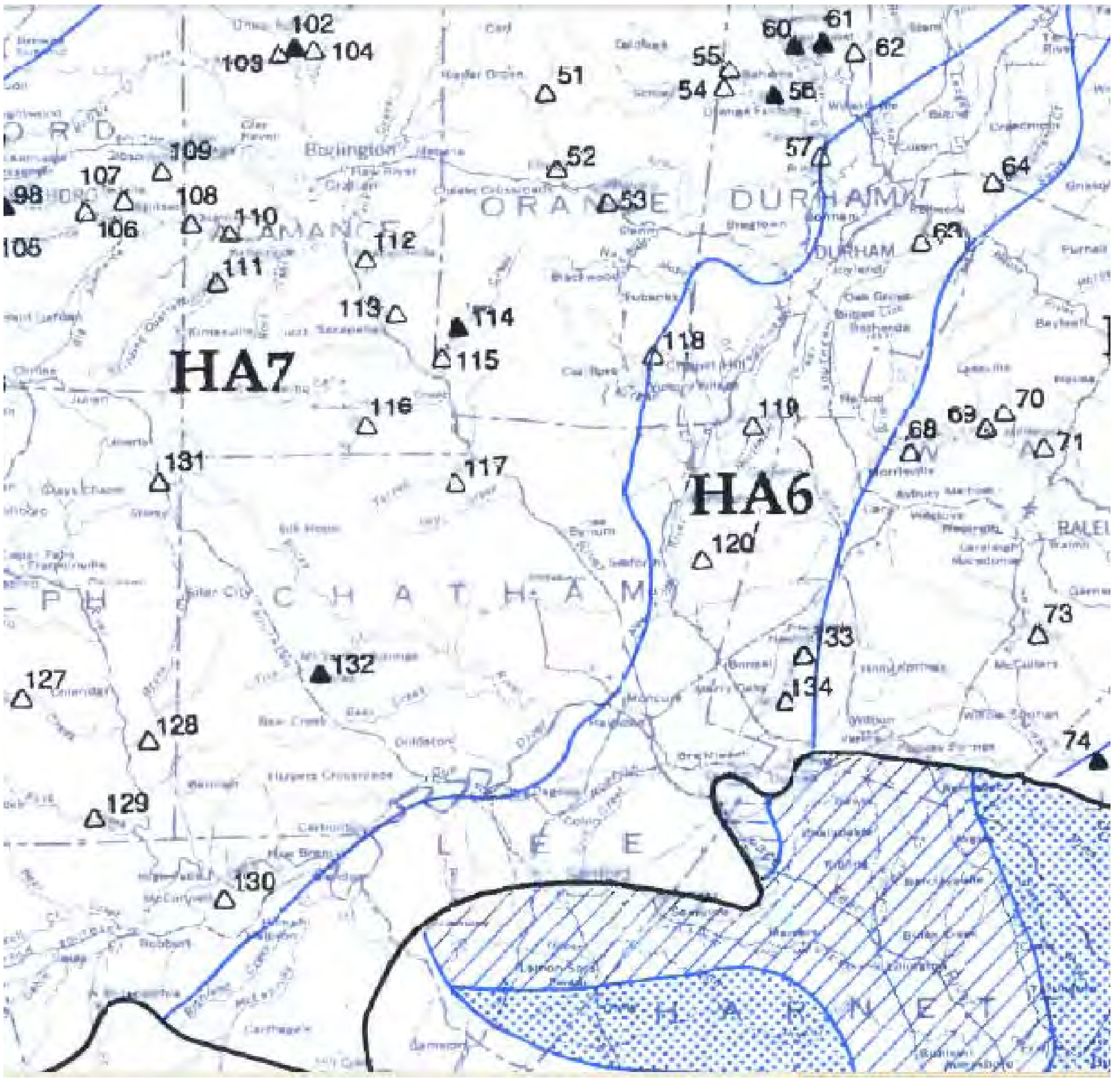


Figure 3-8. Hydrologic Areas – Sanford and Durham Sub-basins of Deep River Triassic Basin



The study area for the Sanford and Durham Triassic Sub-basins is defined by a group of subwatersheds that fall within Hydrologic Area 6 (Triassic Basin) and Hydrologic Area 7 (Carolina Slate Belt). The USGS report estimates the range of 7Q10 flows for drainage areas designated as HA6 between zero and 0.004 cubic feet per second (cfs) per square mile; with the additional caveat that 7Q10 flows greater than zero would only be likely in drainage areas greater than 45 square miles. The range of values for drainage areas designated as HA7 is from zero to 0.131 cfs per square mile with the likelihood of seeing 7Q10 flows greater than zero from drainage areas as small as three square miles. Given these parameters, the range of 7Q10 flows from a hypothetical 60 square mile drainage area could be from zero to 0.024 cfs in the HA6 areas and from zero to 7.86 cfs in the HA7 areas.

The Deep River flows through the northern part of the Sanford Triassic sub-basin carrying water collected from more than 1,434 square miles of drainage area and sustained by minimum releases from several reservoirs upstream of the study area. The 7Q10 flow at the USGS stream gage in Moncure near the mouth of the river has been estimated at 24 cfs. The area upstream of the Triassic Basins contributes most of this flow. For example, above the confluence with Bear Creek a drainage area of 621 square miles produced an estimated 7Q10 flow in the Deep River of 18 cfs.[32] The remaining 813 square miles of drainage between Bear Creek and Moncure only contributes 6 cfs out of the total 7Q10 flow of 24 cfs at Moncure.

At the northern limit of the Sanford Triassic Sub-basin, the dominant water source is the Cape Fear River. Water from the Haw River flows through Jordan Lake, a reservoir operated by the U.S. Army Corps of Engineers, and joins with water from the Deep River to form the Cape Fear River. Almost all of the water flowing over the Triassic Basin in the Cape Fear River originates to the north of the geologic basin in the Deep River and Haw River drainage areas. Flows in the Cape Fear River are augmented by releases from Jordan Lake with a goal of maintaining flows of 600 cubic feet per second in the river at the Lillington stream gage. These releases are made to maintain artificially higher low flows in the river for water quality purposes, which also reduces the uncertainty of water availability for downstream water withdrawers. The city of Sanford withdraws water several miles downstream of the confluence of the Deep and Haw rivers, above the Lillington stream gage. Sanford's 2010 local water supply plan indicates they have 12.6 million gallons per day available at the intake location and the city uses between 5.5 and 9 mgd.

In the Durham Triassic sub-basin surface water availability is dominated by Jordan Lake and Falls Lake. The water supply storage in Jordan Lake is estimated to be able to supply 100 mgd. Allocations of water supply storage are made by the Environmental Management Commission to units of local government based on demonstrated need. Currently 63 percent of the storage is allocated to eight entities.[33] Water supply storage in Falls Lake is reserved for the city of Raleigh.

While proximity to the Deep or the Cape Fear River may increase access to and the reliability of surface water supplies and allow for larger water withdrawals, oil and gas projects not in the immediate vicinity of these sources will face more uncertainty with regards to surface water availability in the tributary streams. The smaller drainage areas of tributary streams produce more variable flow conditions and lower low-flow conditions and therefore lower 7Q10 values. The volume of water that can be withdrawn without degrading water quality or affecting other users may not be enough to support gas well development.[34]

Also, consideration has to be given to the potential water use conflicts that could arise during drought conditions. If drilling operations and intermittent agricultural users decide to withdraw water at the same time, neither may be able to get the volume of water desired. Without a

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[32] Weaver, J.C. "Low-Flow Characteristics and Profiles for the Deep River in the Cape Fear River Basin, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 97-4128." USGS, 1997.

[33] Details on current allocations and the allocation process are available on the DWR website at: http://www.ncwater.org/Permits_and_Registration/Jordan_Lake_Water_Supply_Allocation/

[34] In areas where withdrawals greater than two million gallons per day are possible, state law on interbasin transfers may apply if the water will be withdrawn from one river basin and used in another. Familiarity with the interbasin transfer basin boundaries map could avoid delays in accessing productive water sources.

regulatory regime that clearly defines allowable withdrawals, resolution of the conflicts must be reached by negotiated agreements between the parties or in the courts.

Except in the Central Coastal Plain Capacity Use Area, water withdrawal permits are not required to extract groundwater under an individual's property. In general, wells in the Triassic Basins are not prolific. Depending on the subsurface formations, well yields vary considerably. Table 18 at the end of this section presents yield estimates for public water supply wells located in the Triassic Basins evaluated in this analysis. Proximity to fractures in the underlying rock or vertical intrusions that can aid in the vertical movement of water between horizontal rock layers are critical factors in determining well yield. For example, one small community water system in Lee County is supplied by three wells in the Triassic Basin that have yields of five, 25 and 76 gallons per minute.

As an alternative to operating independent water withdrawals, new projects may choose to get water from existing local government water systems. Local water utilities with unused capacity may welcome the opportunity to sell water, on a time-limited basis, to drilling operations within or bordering the footprints of their distribution systems.

The Wadesboro Triassic sub-basin lies within the USGS-designated Hydrologic Areas HA6 and HA7, like the Sanford and Durham Triassic sub-basins. Therefore estimates of potential low-flows in the area would be similar to those discussed earlier. As noted in the description of this area, the Triassic Basin is transected by the Pee-Dee River in which flows are regulated by hydroelectric power operations and federal license requirements. Three county water systems withdraw water from Lake Tillery and Blewett Falls Lake and distribute drinking water throughout major portions of the Wadesboro Triassic sub-basin.

Figure 3-9. Hydrologic Areas - Wadesboro Sub-unit

Figure 3-10. Dan River Triassic Basins Study Area

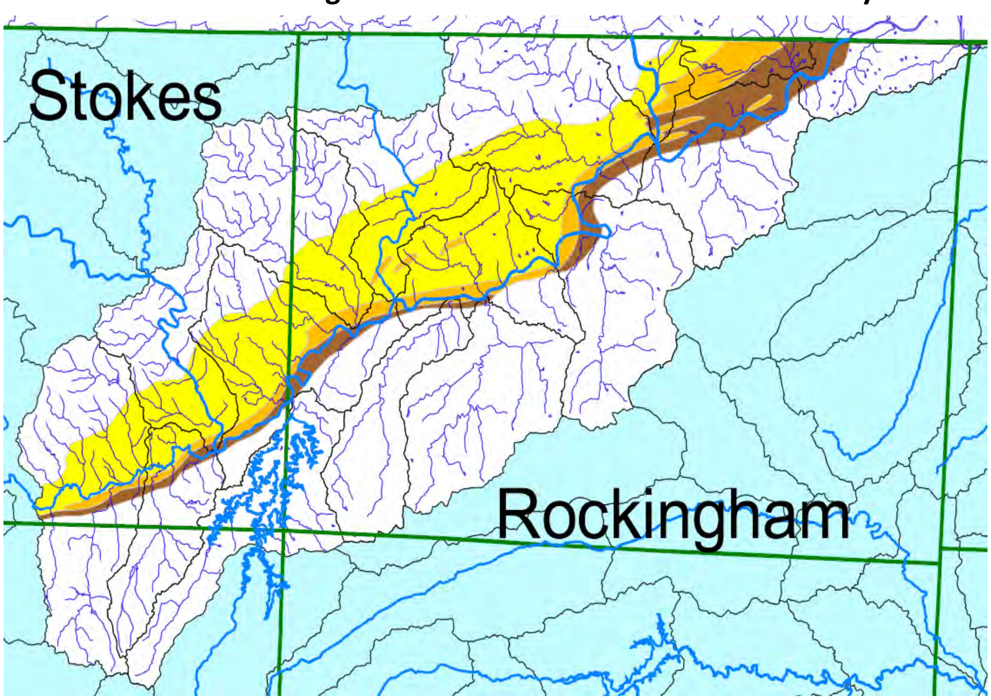
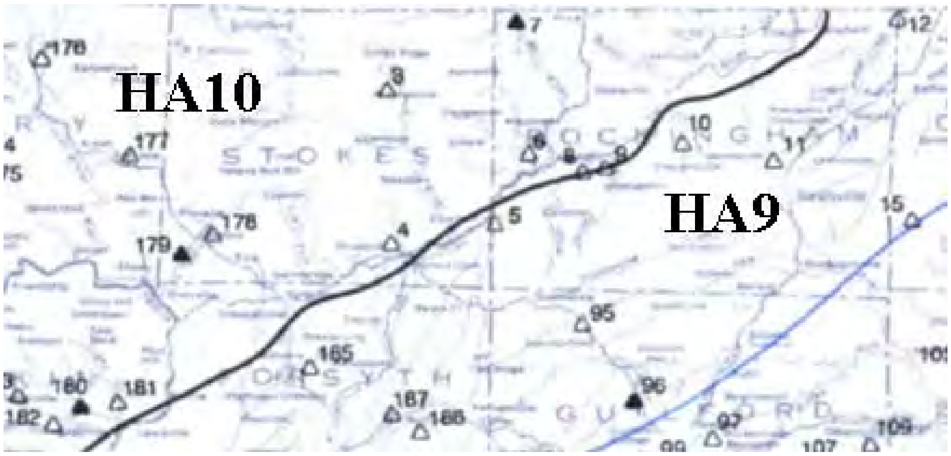


Figure 3-11. Hydrologic Areas - Dan River Triassic Basins



The Dan River Triassic Basin study area is defined by 16 hydrologic subwatersheds. The drainage areas south of the Dan River are designated as Hydrologic Area HA9 (Charlotte Belt and Milton Belt) and areas north of the river are designated as HA10 (Western Piedmont and mountains). Estimates for 7Q10 flows for the HA9 areas range from zero to 0.16 cfs per square mile with drainage areas larger than one square mile likely needed to produce 7Q10 flow estimates greater than zero. Estimated low flows for the HA10 are predicted to vary from zero to 1.062 cfs per square mile with 7Q10 flows greater than zero likely from drainages larger than half of a square mile. Using these parameters a hypothetical 60 square mile drainage area in the HA9 area may produce 7Q10 flows from zero to 2.67 cfs with 7Q10 estimates from zero to 63.72 cfs in the HA10 area.

The Dan River Triassic Basin lies along the lower boundary of the Upper Dan River hydrologic sub-basin. The majority of the sub-basin drainage area lies north of the river where the geologic formations support higher baseflow conditions. The Dan River near Pine Hall, N.C., before its confluence with the Mayo or Smith Rivers, has an estimated 7Q10 flow of 80 cfs. After its merger with the Mayo River, the 7Q10 flow near Wentworth increases to 175 cfs. The Smith River joins the Dan River further downstream. Flows in the Smith River are influenced by releases from Philpott Reservoir upstream in Virginia. After merging with the Smith River, the 7Q10 estimate for the Dan River increases to 375 cfs. Within the study area, the major tributaries of the Dan River flow southerly, transecting the Triassic Basin, before merging with the main river channel that parallels the Triassic formation close to its southern boundary. The ability of the geologic formations in the areas north of the Triassic Basins to support relatively high low-flow conditions reduces the uncertainty associated with using streams in these areas as water sources for gas well development.

The town of Walnut Cove relies on seven wells drilled in the Dan River Triassic Basin in Stokes County. The wells range in depth from 130 to 1,230 feet and reported yields for the various wells range from 35 to 140 gallons per minute. In Rockingham County, public water systems with wells in the Triassic Basins produce yields of six to 22 gallons per minute. As noted earlier, groundwater availability in the Triassic Basins varies considerably, which limits the ability to accurately estimate well yields prior to well completion. The amount of water available to wells drilled in the Triassic Basins is influenced by the nature of fractures occurring in the source rock in the vicinity of the well. Given the highly variable nature of fracture networks, it is difficult to predict impacts to neighboring wells before pumping of new wells actually begins.

Under current state law, a property owner can make reasonable use of the groundwater under their property. If a well used to supply water for hydraulic fracturing is located on the same property as a drinking water well, the owner of the drinking water well would have little or no ability to recover damages for loss of water supply because of the increased pumping. The driller's use of the groundwater would be assumed to be reasonable.

As in the vicinity of the Sanford Triassic Basins, the possibility of accessing the unused capacity of existing community water systems may provide a reasonable option for projects in this area. There are several municipal water utilities that currently produce and distribute treated surface water to customers in the study area.

Existing regulatory structure for water withdrawals for shale gas exploration and production

As noted above, North Carolina law does not currently require a water withdrawal permit for either surface or groundwater withdrawals outside the 15-county Central Coastal Plain Capacity Use Area (which does not overlap with the Triassic Basins). North Carolina is be one of only a handful of states (perhaps as few as two to four) without a statewide water withdrawal permitting requirement.[35] Most of the major oil and gas producing states require permits for large water withdrawals.

Currently, the ability to put conditions on a proposed water withdrawal associated with hydraulic fracturing would be dependent on the operator's need for a permit that triggered a review of potential impacts. The developer of an oil or gas well must apply for a drilling permit from the Division of Land Resources, but the permit review required under the state Oil and Gas Conservation Act does not appear to cover off-site water withdrawals and construction of water storage structures.[36]

Under existing law, the state's ability to influence surface water withdrawals associated with hydraulic fracturing would be limited to situations where some other project impact triggered a permit review broad enough in scope to also include the effects of the water withdrawal. For the most part, that happens only if the withdrawal is associated with infrastructure (such as a water treatment plant) or in-stream activities (such as construction of an impoundment or in-stream water intake structure) that trigger review under state and federal water quality laws.

Some types of water intake structures and other activities associated with surface water withdrawals, for example, require a permit from the U.S. Army Corps of Engineers under either Section 404 of the federal Clean Water Act[37] (for deposition of fill material in waters and wetlands) or under Section 10 of the Rivers and Harbors Act of 1899 (for structures in navigable

[35] Email from Richard Whisnant, UNC School of Government.
[36] N.C.G.S. 113-396; 15A NCAC 05D .0105
[37] 33 U.S.C. § 1344 (2010)

waters). If a Section 404 permit is required, the project would also need a certification from DENR's Division of Water Quality that the project would be consistent with state water quality standards.[38] This certification, called a Section 401 Certification (referring to the Clean Water Act section) can look broadly at water quality impacts. The Section 401 Certification review can clearly extend to review of the water quality impacts of a large individual water withdrawal. The 401 Certification does not, however, provide a good tool for protecting other water users who may be affected by the volume of a new withdrawal.

In any case, these environmental reviews will only occur if the method used to withdraw water involves deposition of fill material, disturbance of the stream bottom, placement of a structure in navigable waters or some other activity that would require a permit. Use of a simple in-stream pump may not require review under either federal or state law.

Public infrastructure projects involving large water withdrawals may require an environmental assessment or environmental impact statement (EIS) under the state Environmental Policy Act (SEPA), G.S. 113A-1, et seq. In those cases, the SEPA document addresses all project impacts, including the surface or groundwater withdrawal. Since SEPA only applies to projects that involve the expenditure of public funds or the use of public lands, a SEPA review would not be required for a water withdrawal associated with commercial natural gas production unless public funds – such as an economic incentive grant – were involved.

Because of highly variable yields from wells in the Triassic Basins, groundwater would be a less reliable source of water for hydraulic fracturing than surface water. While many areas in the Triassic Basins have surface water sources capable of providing adequate water supply there are many other areas where nearby streams do not have enough water to supply well development needs while protecting water quality and the rights of other users. In some areas, the groundwater most often used for drinking water supplies has limited yield and may not be adequate to quickly generate the volumes required for fracturing. Without the ability to condition a permit for drilling oil or gas wells, the source of water for hydraulic fracturing would not be subject to review to maintain sufficient water in streams to support aquatic life, ensure good quality water and protect the rights of other landowners to also make beneficial use of the waters. Under current state law, a new well used to supply water for drilling operations would be treated as a private water supply well and only required to meet well construction standards. No review of the potential impact of the well(s) on other public or private water supply wells, groundwater levels or stream flow would take place.

In short, it is clear that in most cases DENR will not have sufficient authority to limit or manage the timing of water withdrawals in connection with hydraulic fracturing. DENR would only have the opportunity to put conditions on surface water withdrawals for hydraulic fracturing if the drilling operation had other impacts requiring environmental review. In those circumstances, management of water withdrawals associated with hydraulic fracturing would be sporadic and inconsistent. Aside from being inadequate to protect streams and downstream water users,

[38] 33 U.S.C. §1341 (2010)

such a fragmented approach makes it difficult for the industry to predict how it will be regulated.

If there are no permit limitations on water withdrawals, the proximity of the water source and transportation constraints (such as whether the water is piped or trucked to the well pad) will likely determine the timing and magnitude of withdrawals. As noted in the New York Draft Generic Environmental Impact Statement,

> "Without proper controls on the rate, timing and location of such withdrawals, modifications to groundwater levels, surface water levels, and stream flow could result in adverse impacts to aquatic ecosystems, downstream flow levels, drinking water assured yields, wetlands, and aquifer recharge."[39]

When large scale hydraulic fracturing for natural gas began in Pennsylvania in 2005, that state's rules did not require any permit for the associated water withdrawals. Some streams went completely dry for a time because the industry withdrew large amounts of water over a very short period of time during low flow periods.[40]

A number of states with active shale gas extraction activities have regulatory systems in place to monitor groundwater and surface water withdrawals for hydraulic fracturing. In Pennsylvania and New York, the Delaware River Basin Commission (DRBC) and the Susquehanna River Basin Commission (SRBC) use a permit system and approval process to regulate existing water usage. Operators must provide a comprehensive project description, including site location, water source(s), location of withdrawals, proposed timing and rate of water withdrawal and the anticipated project duration. In addition, operators must identify the amount of consumptive use and any import or export of water to or from the hydrologic basin. Once the project is approved, operators must meter withdrawals and submit quarterly reports to the DRBC or the SRBC.[41]

The Pennsylvania Department of Environmental Protection (DEP) has similar requirements for areas of the state outside the Delaware and Susquehanna River Basins. The 2002 Water Resources Planning Act requires entities withdrawing more than 300,000 gallons of water over a 30-day period to register their water withdrawal, allowing DEP to monitor water withdrawals outside the jurisdiction of the river basin commissions. As a result of problems experienced in the early years of hydraulic fracturing, the Pennsylvania Bureau of Oil and Gas Management amended its rules in 2008 to require operators to submit a water management plan that identifies water withdrawal locations and volumes. In reviewing those plans, the Pennsylvania agency applies water withdrawal guidance developed by the Susquehanna River Basin Commission. [42] These regulatory changes caused the industry to alter its water withdrawal

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[39] NYSDEC, p. 6.2.
[40] WTAE. "Pa. Streams Drained Dry by Drillers." November 17, 2008. Retrieved March 6, 2012 from http://www.wtae.com/r/17973811/detail.html.
[41] NYSDEC, p. 6-8.
[42] STRONGER. *Pennsylvania Hydraulic Fracturing State Review*. September 2010. Retrieved March 4, 2012 from http://www.shalegas.energy.gov/resources/071311_stronger_pa_hf_review.pdf.

practices; operators now stockpile water for hydraulic fracturing over a period of time, stored in impoundments near the drilling site, to avoid extreme impacts on stream flows.

In New York, the Water Resources Law extends the Department of Environmental Conservation's authority to regulate all water withdrawals of more than 100,000 gallons per day throughout the state of New York. The law applies to water used for hydraulic fracturing. The New York Draft Generic Environmental Impact Statement states that future withdrawal permits issued pursuant to the regulations implementing the Water Resources Law "would include conditions to allow the Department to monitor and enforce water quality and quantity standards, and requirements." NYSDEC is currently developing these regulations, but notes that the requirements may include "passby flow; fish impingement and entrainment protections; protections for aquatic life; reasonable use; water conservation practices; and evaluation of cumulative impacts on other water withdrawals."[43]

The water withdrawal registration statute requires registration of large withdrawals within two months of initiating the withdrawal.[44] This would identify the location and amount of withdrawals after the fact. However, since North Carolina does not have a permitting system for water withdrawals, no clear tool exists for monitoring the location, volume or rate of water withdrawals for hydraulic fracturing. Without the ability to manage the volume and timing of those withdrawals, North Carolina could problems similar to those experienced in Pennsylvania, including damage to streams and adverse impacts to other water users.

Estimated water needs for gas well development

To estimate potential water needs for gas well drilling and hydraulic fracturing, a set of assumptions were developed to capture the range of possible water needs. The assumptions were based on information about water use options employed in other natural gas exploration areas, discussions with industry representatives, and the best professional judgment of DENR staff.

Many variables influence the amount of water that will actually be needed to drill and develop gas extraction wells in North Carolina. To develop a plausible estimate of an upper limit on water use, the scenarios used for this analysis do not consider the potential withdrawal reductions that could be realized by recycling water within drilling operations, nor do they consider the possibility of re-fracturing of wells. The ability to recycle used water may not exist until after the potential for gas production has been determined and several wells have been hydraulically fractured, making it practical to invest in a recycling operation. If gas well development becomes a reality in North Carolina then water management practices implemented to meet new regulatory requirements and control costs may reduce water usage below the estimates presented in this analysis.[45]

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[43] NYSDEC, p. 6-8.
[44] N.C.G.S. § 143-215.22H. Retrieved April 18, 2012 from http://www.ncga.state.nc.us/EnactedLegislation/Statutes/HTML/BySection/Chapter_143/GS_143-215.22H.html.
[45] The New York State Department of Environmental Conservation reports that in Pennsylvania, "Current practice is to use 80% - 90% fresh water and 10% - 20% recycled flowback water for high-volume hydraulic fracturing." NYSDEC, p. 6-10.

Based on available information from other parts of the country, total water use for each successful production well, including hydraulic fracturing, is likely to be between three and five million gallons. In comparison to other water users, the total amount of water needed for hydraulic fracturing of natural gas wells is a modest amount. There are many communities across the state that use an average of five million gallons and more of water per day throughout each year. Based on information from the 2010 local water supply plans, five million gallons is approximately the volume of water that communities like Lenoir, Lincolnton, Monroe, Roxboro, Spruce Pine, and Statesville use on an average daily basis to meet their customers' water demands. Slightly larger communities like Burlington, Hickory, and High Point used over twice that amount on a daily average basis in 2010. Of the 552 water systems that submitted a local water supply plan for 2010, 47 systems used five million gallons per day or more on average, 341 used 0.25 mgd or more on average, and 391 use 0.145 mgd or more on average each day to meet their customers' demands.

A variable percentage of the water used for hydraulic fracturing is recovered shortly after the process is finished. This recovered water is called flowback. The volume of flowback reported in the Marcellus shale in northern Pennsylvania ranges from 9 to 35 percent of the fluid pumped into a well for hydraulic fracturing.[46] Most of the water used in the hydraulic fracturing operation remains trapped in the geologic formations. In some cases flowback can be mixed with water from other sources and additional hydraulic fracturing additives to reduce the quantity of new water needed for hydraulic fracturing of subsequent nearby wells.

Hydraulic fracturing is undertaken after a well has been drilled. By this point in the process activities at the drilling site have been ongoing for some time. A site had to be chosen, permits acquired, well pad prepared, equipment moved into place, and the well drilled. The time needed for these activities will vary but is assumed to require 38 to 56 days.[47]

Industry Terms

Produced water: A naturally occurring by-product of natural gas and oil extraction that travels from the producing formation through the wellbore to the surface with natural gas and oil during completion and production operations. Produced water generally contains various salts, sand, silt and naturally occurring radioactive materials (NORM).

Flowback water: The mixture of hydraulic fracturing fluids, proppant, and produced water that flows up through the wellbore to the surface after hydraulic fracturing is completed and the direction of fluid flow reverses.

Flowback: The process of flowback water returning up the wellbore to the surface.

In other states drilling operations often accumulate the necessary volume of water over a period of time and store the water either onsite or at a surface water impoundment within

[46] NYSDEC, p. 5-99.
[47] NYSDEC, p. 6-298.

close proximity so it is available when needed. The time needed to accumulate the desired volume of water depends on permit withdrawal limits, water source availability, proximity to the well site and transport requirements. Water is either moved by overland pipe or truck directly from the source water to the well pad, or it is piped from the source water to the surface water impoundment. From the surface water impoundment, the water is either piped or trucked to the well pad.

The magnitude, timing and source of water withdrawals are strongly influenced by laws regulating water withdrawals. Most oil- and gas-producing states have water withdrawal permitting requirements; many are relatively water-poor western states that have long regulated withdrawals. If the state permit does not include withdrawal restrictions, the timing and rate of withdrawal is completely up to the operator. Under current North Carolina law, the Division of Land Resources does not have the authority to regulate water withdrawals as a condition of a drilling permit. Since North Carolina does not have a statewide water withdrawal permitting system, withdrawal decisions would generally be up to the operator.

It is technically feasible for an operator to withdraw three to five million gallons of water within a two to four day pumping period. [48] To address this possibility, DENR's analysis includes a scenario involving water withdrawals made within a three-day pumping period. An average of one million gallons per day could be pumped over three days to supply three million gallons to a well site. If the goal was to accumulate five million gallons, then daily withdrawals would average 1.667 million gallons.

The American Petroleum Institute encourages contractors undertaking hydraulic fracturing operations to coordinate water withdrawals to minimize effects on aquatic life and other users, especially public water systems. [49] However, the API guidance is not mandatory. The language of the guidance document implies that each state will impose limitations on drilling operations to protect resources the state chooses to protect.

In states where water withdrawals are regulated through the drilling permit or a separate water withdrawal permit, operators may pump smaller amounts for a period of days or weeks to accumulate the amount needed to fracture. DENR has analyzed two alternative scenarios for water withdrawal: 1. Pumping the necessary amount over a three-day period; and 2. Pumping the necessary amount over a period of three weeks (21 days). If the operator pumps water over a period of 21 days to accumulate water onsite for fracturing, then withdrawals of about 143,000 gallons (0.22 cubic feet per second) per day would be adequate to accumulate three million gallons. If five million gallons of water were needed, then daily withdrawals of about 238,000 gallons (0.37 cubic feet per second) per day over a period of 21 days would be

[48] The two to four day estimate for total withdrawal time was provided in a phone conversation with DENR staff by David Miller of the American Petroleum Institute. This number is based on the use of a typical centrifugal pump. The time needed to withdraw this water depends on permit requirements, stream flow, and equipment.

[49] American Petroleum Institute; 2010; API Guidance Document HF2-Water Management Associated with Hydraulic Fracturing. http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/api_hf2_water_management.aspx

adequate. Longer withdrawal times that allow smaller daily withdrawals may also make it possible to use smaller water sources.

From the perspective of water resource management and the potential impacts to water resources and other water users, the total volume of water needed is less critical than the withdrawal rate and the timing of water withdrawals. Stream flows vary throughout the year and withdrawals made when flows are low would have more impacts on aquatic habitats, water quality and downstream users than the same level of withdrawal made when flows are higher. Taking 1.667 mgd of water from a stream for three days would have different impacts than withdrawing 0.5 mgd from the same location for 10 days or 0.25 mgd for 20 days. Each approach would withdraw five million gallons in total.

Being able to get the water needed by withdrawing smaller volumes over a longer period of time provides the ability to get water from more locations while maintaining sufficient water to support aquatic life, ensure good water quality, and protect the rights of landowners to also make beneficial use of the waters. The state has more water sources capable of supporting a 0.24 mgd (0.37 cfs) withdrawal than water sources capable of supporting a 1.667 mgd (2.58 cfs) withdrawal. However, without the authority to regulate the location, timing and magnitude of withdrawals, the potential exists for withdrawals to reduce stream flows to levels that would produce unrecoverable ecosystem impacts or limit water available for other landowners' beneficial uses.

Overall, water usage will also be influenced by the number of gas wells that are developed. Since we do not know how much production will occur in North Carolina, DENR estimated the number of wells that could be developed in the Deep River and Dan River Triassic Basins. Not all formations of the Triassic Basins show the potential to produce hydrocarbons in the form of natural gas. Because of its lack of potential to produce hydrocarbons, the areas of the Pekin Formation in the Deep River Triassic Basin were subtracted from the total area of the Triassic Basins to arrive at a working estimate of about 785,000 acres of potential area for gas well development.

Consistent with other sections of this report, the analysis presented here assumes a well spacing of one well on 160 acres. North Carolina law does not currently address well spacing; 160 per well is used in several other states. Given the working estimate of 785,000 acres available for development with a spacing of 160 acres per well the maximum number of wells possible would be 4,904. If the state chose a different well spacing unit (such as one well on 60 acres), the number of potential wells and the amount of water required would increase proportionately.

Complete development of the gas production potential of North Carolina's Triassic Basins would happen over an indeterminate time span. In other parts of the country, shale plays are in the middle of production and it is unknown how long those areas will remain productive. Some estimate that shale gas plays will last 20 to 40 years. If well development were evenly distributed over 30 years in North Carolina, then 164 wells could be drilled each year across both Triassic Basins (at 160 acres per well).

For this analysis the actual drilling, hydraulic fracturing, and completion of a well was assumed to take three months. This results in an estimated 41 wells being developed within each three-month period.

At five million gallons per well and a three-day pumping time, 68 million gallons per day would be withdrawn to supply 41 wells. For the same number of wells, daily withdrawals would drop to 10 million gallons per day if the water was pumped and stored over a 21-day period. At three million gallons per well, pumping rates range from 41 million gallons per day over three days to six million gallons per day over 21 days.

Assuming that all the 785,000 acres will actually be able to produce recoverable natural gas is likely too optimistic. Gas operators may not be able to obtain leases for all areas within the Triassic Basins, particularly in urban areas where parcel sizes are small and agreements have to be negotiated with multiple parties to assemble leases covering sufficient contiguous acreage to allow drilling. In addition, not all areas within the Triassic Basins may be suitable for drilling.

Assuming only half of the estimated maximum number of wells are installed over the same 30-year time horizon reduces the number of wells drilled annually to between 82 and 218, depending on spacing. The amount of water needed for each well may not change but the total withdrawals needed to support this level of gas well development would likely decrease by half. Similarly if only one quarter of the estimated maximum numbers of wells were developed total water withdrawals for each pumping day would be reduced by about three quarters from the estimates above. The details of the 160-acre per well alternative scenarios are summarized in Table 3-17.

Table 3-17. Analysis Scenario Descriptions

Assumptions				
Well spacing (acres per well)	160	160	160	160
Pumping days	3	21	3	21
Water per well (million gallons)	3	3	5	5
Development cycles per year	4	4	4	4
Years of development	30	30	30	30
Triassic Basins' estimated acreage	785,000	785,000	785,000	785,000
Estimations				
Maximum number of wells for spacing	4,906	4,906	4,906	4,906
Wells per year if maximum number	164	164	164	164
Wells per quarter if maximum number	41	41	41	41
Water per well per pumping day (mgd)	1.000	0.143	1.667	0
Total water per pumping day (mgd)	41	6	68	10
Total water per pumping day @ 50% development (mgd)	20	3	34	5
Total water per pumping day @ 25% development (mgd)	10	1	17	2
Water per well per pumping day (cfs)	1.547	0.221	2.579	0.368
mgd = million gallons per day cfs = cubic feet per second				

This analysis presents one set of potential scenarios using assumptions based on experiences in other gas producing areas of the country. By focusing on withdrawing water over a three-day period this analysis estimates the upper limits of the volumes of water that could be withdrawn daily. Analyzing withdrawals over a period of 21 days describes a lower limit of withdrawals that could supply the volumes of water needed to support gas well development. These approaches also can be used to identify water sources capable of supplying water for hydraulic fracturing under a managed withdrawal. If a particular drilling site is located near a watercourse with flows that can only support withdrawals of 0.24 mgd (0.37 cfs), then with careful planning it may still be possible to accumulate five million gallons for gas well development. These two examples illustrate the ability to manage the location, timing and magnitude of surface water withdrawals to maintain sufficient water in the stream for aquatic life, to ensure good water quality, and to protect the rights of downstream landowners to make beneficial use of the waters.

Without the authority to regulate water withdrawals, critical decisions on location, timing and pumping rates would depend on the independent decisions made by the well development operators. The choice to withdraw five million gallons of water over 21 days at an environmentally protective rate of 0.24 mgd (0.37 cfs), or to make the withdrawals over three days at a technically possible rate of 1.67 mgd or 2.6 cfs, would be solely up to the contractor.

For instance, the Simpson #1 gas well, which is currently shut-in, is in the Pocket Creek subwatershed in Lee County. Pocket Creek is the closest free flowing perennial stream. There are 24,090 acres or about 37.6 square miles in this subwatershed located in the USGS designated Hydrologic Area HA6. The USGS guidance[50] suggests a maximum estimate of the 7Q10 flow in a subwatershed of this size in an area designated as HA6 would be about 0.15 cfs based on 0.004 cfs per square mile. However, the USGS includes an additional caveat for this category that a drainage area of 45 square miles would likely be needed to produce a 7Q10 flow greater than zero.[51]

Streamflows in Pocket Creek, as in all surface waters, vary considerably throughout the year and from year to year. However, with estimates of 7Q10 flows at zero cubic feet per second it is fairly clear that flows in Pocket Creek are very low for extended periods of time. It is likely there would be times when flows would be sufficient for 3.9 cfs withdrawals for two days to provide 5 million gallons of water. But without the authority to regulate withdrawals the contractors could take the water when it was most convenient for them and the resource management agencies and other water users would have to deal with the consequences. In a stream of this size there will be significant periods of time when withdrawals of 3.9 cfs would not leave enough water to support aquatic life, ensure good water quality, and protect the rights of other landowners to also make beneficial use of the water. Under current state law, DENR would not have the ability to prevent this from happening. Multiple well sites in this watershed could withdraw this volume of water at the same time or on successive days based on operational needs and without regard to the impact on other users.

North Carolina's Water Use Act of 1967 provides a tool to manage water withdrawals in situations where the Environmental Management Commission decides regulation is needed to protect the interests and rights of residents and property owners or the public interest.[52] This act has historically provided an after-the-fact remedy to address a depleted water source. After an investigation to document the need for regulation the EMC develops and adopts rules to regulate water withdrawals within a designated Capacity Use Area. Rules are designed to remedy the problems identified in the study with the goal of preventing further detrimental impacts and supporting resource recovery. This act provides a mechanism to manage a depleted water source and create conditions that allow it to recover. It probably does not provide the right regulatory structure for actions to prevent damage to the resource. The potential for an entirely new water use, such as hydraulic fracturing, highlights the need for water management tools capable of maintaining aquatic life, ensuring good water quality and protecting the rights of landowners to make beneficial use of the water.

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[50] Giese, G.L., and R.R. Mason, Jr. "Low-flow characteristics of streams in North Carolina: U.S. Geological Survey Water-Supply Paper 2403." USGS, 1993.

[51] Giese and Mason, 1993, in Table 1 provide a 7Q10 estimated for the Beaverdam Creek watershed in Granville County, a 44.2 square mile drainage area classified as HA6, of zero cubic feet per second.

[52] N.C. General Statute § 143-215.11 et. seq.

Actual water use for gas well development may be different than the amounts analyzed here. If laws are adopted to minimize impacts at this projected level of water usage, then actual water use may be less than the estimates presented here.

Conclusions related to water supply

With wise management, adequate water supplies would likely be available to support shale gas extraction in the vicinity of the Triassic Basins in North Carolina. However, there is no clear, existing regulatory path or framework that gives any state agency the ability to ensure that groundwater or surface water withdrawals for natural gas development are appropriately managed to avoid stream impacts and conflicts with other water users.

Available information indicates that drilling and hydraulic fracturing of natural gas wells typically uses from three to five million gallons of water per well. According to a fact sheet by Chesapeake Energy entitled "Water Use in Deep Shale Gas Exploration," dated May 2011, "the company uses a variety of water sources depending on availability."[53] To quote the fact sheet, "This water is typically transported via temporary pipelines or trucked to drilling locations for storage prior to use in tanks or impoundments."

If the necessary volumes of water can be accumulated over an extended period of time rather than only on the days when hydraulic fracturing actually occurs, then needs could be met by smaller withdrawals. That flexibility would make it possible to draw from a larger set of potential water sources. Overall withdrawal times could be reduced for sources capable of supporting larger withdrawals, because of stream size or seasonally higher flows. It is not possible to develop a more specific characterization of water needs and available sources prior to the initiation of shale gas development operations and the resulting determination of the site-specific needs in the Triassic Basins of North Carolina. However, most of the areas where natural gas exploration is expected to occur do appear to possess the capability to support additional surface water withdrawals and continue to support the needs of the local population.

Some public water systems in the vicinity of the Triassic Basins may have unused capacity that could supply water for shale gas exploration and production. These water sources have already been evaluated for their potential environmental impacts at their maximum withdrawal levels. Therefore, the time and expense of evaluating potential impacts of new withdrawals could be avoided. Increased water sales would be a boost to utility revenues and their ability to cover the costs of existing debt. The relatively short-term nature of gas well drilling and development would allow the option for time-limited commitments on the part of the utilities to take advantage of currently unused capacity, while at the same time keeping that capacity available in the future to provide water to a growing customer base. Details on the volume of water made available and duration of the commitment would be subject to negotiation between the parties.

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[53] Chesapeake Energy. "Water Use in Deep Shale Gas Exploration." 2011. Retrieved January 9, 2012 from http://www.naturalgaswaterusage.com/Pages/information.aspx.

Many local government and large community water systems across the state have seen their per capita demand for water decline because of their customers' experiences during recent droughts. For many systems, daily water use has not returned to the levels seen prior to drought response activities over the last decade. This phenomenon, combined with the downturn in economic expansion and the exodus of manufacturing facilities, has put some water utilities in the position of making payments on debts for unused system capacity. In addition, reduced per capita demand has resulted in reduced revenues to cover debt payments.

According to data in the 2010 local water supply plans, Sanford, Eden, Mayodan, Madison, Anson County and Montgomery County water systems do not currently use all the water available to them. Local plan data indicate that, based on water treatment plant capacities, the surface water systems in the Dan River hydrologic sub-basin could have about 17 million gallons per day available on an average day basis. In the Wadesboro geologic sub-basin, Montgomery County could have about three million gallons per day available on average, and in the Sanford geologic sub-basin the city of Sanford could have about six million gallons per day available on average for the next few years. Several of these systems do not indicate in their local water supply plans needing the total volume of their available supplies before 2060. Of course, the ability to make use of this water depends on the ability of the parties to come to a mutually acceptable agreement.

DENR suggests that the gas industry and public water utilities work together to meet water needs for gas exploration and encourages the investigation of options that take advantage of unused capacity at existing withdrawal facilities.

Based on the experience in other oil and gas producing states, DENR recommends that gas drillers be required to have an approved water management plan that identifies the location of water sources to be used, the volume of water to be withdrawn and the pace of withdrawal. New surface water withdrawals for gas wells be limited such that the cumulative instantaneous withdrawals in the vicinity of the intake do not exceed 20 percent of the 7Q10 flow calculated at the time of the withdrawal request. Instantaneous withdrawals greater than 20 percent of the 7Q10 should require site-specific evaluations of potential impacts. This threshold has been used for many years to differentiate activities having a minimum potential for environmental effects and has been shown to be protective of other existing water users and the environment. This approach has several inherent advantages: it would protect small watersheds with low 7Q10 flows and the existing water users; it would prevent excessive withdrawals during periods of peak usage, it would be consistent with existing state protocols; and it would prevent any surface water in North Carolina from drying up due to natural gas withdrawals. As a further precaution to protect water resources, gas well withdrawals should be prohibited during droughts and low-flow conditions.

Much of this analysis focused on surface water resources because of the historically low yields available from wells drilled in the Triassic Basins. Higher yields have been produced from some wells drilled in these areas, but the ability to estimate yields prior to investing in drilling a water supply well is limited by the highly variable nature of the fracture networks that may or may not be intersected by a wellbore. Table 3-18 provides yield information for the public water supply wells located in the Triassic Basins. Groundwater is available from a well because it can move into the well bore through the network of pathways in the rock formations. The uncertainty of the nature of these pathways also makes it difficult to predetermine the possible impacts on neighboring wells from the addition of new wells within or near shared fracture networks. Because of the variability of groundwater resources, DWR cautions that they may be inadequate to meet water needs for hydraulic fracturing operations. However, if operators choose to use groundwater to meet water needs DWR recommends implementation of several precautionary measures to protect neighboring groundwater users. Prior to initiation of water well drilling all existing water supply wells within the vicinity of the planned well should be identified and their water levels measured and reported. Prior to use of the new well, a 24-hour pump test should be conducted to evaluate aquifer conditions and potential impacts to neighboring wells. Wells within the area, for which owner permission is granted, should have water levels monitored throughout well development and production.

Table 3-18. Triassic Public Water Supply Wells (gpm = gallons per minute)

Subwatershed	Geologic Unit	Geologic Formation	Public Water Supply #	Source Name	Depth (feet)	Yield (gpm)	Yield (mgd)	Yield (cfs)
Chatham County								
030300020604	TRc	Chatham Group-Undivided	4019004	WELL #7	1000	39	0.056	0.087
030300020604	TRc	Chatham Group-Undivided	4019004	WELL #4	400	49	0.071	0.109
030300020604	TRc	Chatham Group-Undivided	4019004	WELL #2	400	41	0.059	0.091
030300020604	TRc	Chatham Group-Undivided	4019004	WELL#1A	400	14	0.020	0.031
030300020604	TRc	Chatham Group-Undivided	0319439	WELL #1	225	5	0.007	0.011
030300020605	TRc	Chatham Group-Undivided	4019015	WELL #2	500	98	0.141	0.219
030300020605	TRc	Chatham Group-Undivided	0319440	WELL #1	28	60	0.086	0.134
030300020608	TRc	Chatham Group-Undivided	0319456	WELL #1	Unk.	60	0.086	0.134
030300020608	TRc	Chatham Group-Undivided	0319424	WELL #1	Unk.	60	0.086	0.134
030300020608	TRc	Chatham Group-Undivided	0319471	WELL #2	305	7	0.010	0.016
030300020608	TRc	Chatham Group-Undivided	4019016	WELL#1	Unk.	10	0.014	0.022
030300020608	TRc	Chatham Group-Undivided	0319457	WELL #1	110	10	0.014	0.022
030300020608	TRc	Chatham Group-Undivided	0319124	WELL #2	120	15	0.022	0.033
030300020608	TRc	Chatham Group-Undivided	0319124	WELL #1	125	25	0.036	0.056
030300020610	TRc	Chatham Group-Undivided	4019020	WELL #1	365	10	0.014	0.022
030300020610	TRc	Chatham Group-Undivided	0319469	WELL #1	125	60	0.086	0.134
030300020610	TRc	Chatham Group-Undivided	0319425	WELL #6	411	20	0.029	0.045
030300020610	TRc	Chatham Group-Undivided	0319425	WELL #8	320	120	0.173	0.268
030300020610	TRc	Chatham Group-Undivided	0319426	WELL #1	162	30	0.043	0.067
030300020610	TRc	Chatham Group-Undivided	0319428	WELL #1	250	70	0.101	0.156
030300020610	TRc	Chatham Group-Undivided	0319136	WELL #1	145	120	0.173	0.268
030300020705	TRcp	Pekin Formation	0319125	WELL A	130	24	0.035	0.054
030300020705	TRcp	Pekin Formation	0319125	WELL B	220	14	0.020	0.031
030300040104	TRcs	Sanford Formation	0319463	WELL #1	180	60	0.086	0.134
Durham County								
030202010403	TRc	Chatham Group-Undivided	0332584	WELL #1	100	10	0.014	0.022
030202010404	TRc	Chatham Group-Undivided	0332135	WELL #1	325	55	0.079	0.123
030202010404	TRc	Chatham Group-Undivided	0332580	WELL #1	Unk.	60	0.086	0.134
030202010404	TRc	Chatham Group-Undivided	0332575	WELL #1	Unk.	60	0.086	0.134
030202010502	TRc	Chatham Group-Undivided	0332526	WELL #1	Unk.	60	0.086	0.134
030202010502	TRc	Chatham Group-Undivided	0332554	WELL #1	Unk.	60	0.086	0.134
030202010502	TRc	Chatham Group-Undivided	0332109	WELL #3	205	37	0.053	0.083
030202010504	TRc	Chatham Group-Undivided	0332106	WELL #1	146	60	0.086	0.134
030202010504	TRc	Chatham Group-Undivided	0332106	WELL #2	255	30	0.043	0.067
030202010504	TRc	Chatham Group-Undivided	0332106	WELL #4	303	100	0.144	0.223
030202010504	TRc	Chatham Group-Undivided	0332141	WELL #32	300	30	0.043	0.067
030202010504	TRc	Chatham Group-Undivided	0332141	WELL #9	250	65	0.094	0.145
030202010504	TRc	Chatham Group-Undivided	0332528	WELL #1	Unk.	60	0.086	0.134
030202010504	TRc	Chatham Group-Undivided	0332582	WELL #1	Unk.	60	0.086	0.134
030202010504	TRc	Chatham Group-Undivided	4032016	WELL #1	Unk.	12	0.017	0.027
030202010801	TRc	Chatham Group-Undivided	0332574	WELL #1	Unk.	60	0.086	0.134
030202010801	TRc	Chatham Group-Undivided	0332590	WELL #1	265	10	0.014	0.022
030202010802	TRc	Chatham Group-Undivided	0332571	WELL #1	Unk.	60	0.086	0.134
030300020601	TRc	Chatham Group-Undivided	0332453	WELL #1	Unk.	60	0.086	0.134
030300020604	TRc	Chatham Group-Undivided	0332441	WELL #2	Unk.	80	0.115	0.178
Lee County								
030300030603	TRcs	Sanford Formation	0353127	WELL #3	405	5	0.007	0.011
030300030603	TRcs	Sanford Formation	0353127	WELL #1	300	76	0.109	0.169
030300030603	TRcs	Sanford Formation	0353127	WELL #4	300	25	0.036	0.056
030300030607	TRcs	Sanford Formation	0353420	WELL #1	100	60	0.086	0.134
Granville County								
030202010404	TRc	Chatham Group-Undivided	0239495	WELL #2	345	1	0.001	0.002
030202010404	TRc	Chatham Group-Undivided	0239495	WHITE RABBIT WELL #3	405	10	0.014	0.022
030202010501	TRc	Chatham Group-Undivided	0239446	WELL#1	200	15	0.022	0.033
030202010503	TRc	Chatham Group-Undivided	0239435	WELL #1	150	60	0.086	0.134
Montgomery County								
030401040401	TRc	Chatham Group-Undivided	0362562	WELL #1	Unk.	80	0.115	0.178
030401040402	TRc	Chatham Group-Undivided	0362436	WELL #1	180	180	0.259	0.401

Table 3-18 (continued) Triassic Public Water Supply Wells (gpm = gallons per minute)

Subwatershed	Geologic Unit	Geologic Formation	Public Water Supply #	Source Name	Depth (feet)	Yield (gpm)	Yield (mgd)	Yield (cfs)
Moore County								
030300030301	TRcp	Pekin Formation	0363500	WELL #1	Unk.	60	0.086	0.134
030300030302	TRcp	Pekin Formation	0363447	WELL #1	100	10	0.014	0.022
030300030302	TRcp	Pekin Formation	0363448	WELL #1	303	60	0.086	0.134
030300030303	TRcs	Sanford Formation	0363429	WELL #1	50	60	0.086	0.134
030300030408	TRcp	Pekin Formation	0363436	WELL #1	Unk.	60	0.086	0.134
030300030601	TRcs	Sanford Formation	0363541	WELL #1	200	40	0.058	0.089
030300030601	TRcs	Sanford Formation	0363538	WELL #1	Unk.	60	0.086	0.134
030300030601	TRcs	Sanford Formation	0363527	WELL #1	186	7	0.010	0.016
030300030604	TRcc	Cumnock Formation	0363470	WELL #1	Unk.	60	0.086	0.134
030300040305	TRcs	Sanford Formation	0363537	WELL #1	110	41	0.059	0.091
Orange County								
030300020601	TRc	Chatham Group-Undivided	0368444	WELL #1	Unk.	60	0.086	0.134
Rockingham County								
030101030305	TRds	Stoneville Formation	0279741	WELL #1	176	4	0.006	0.009
030101030306	TRds	Stoneville Formation	0279455	WELL #1	175	20	0.029	0.045
030101030306	TRdp	Pine Hall Formation	0279150	WELL #1	545	22	0.032	0.049
030101030409	TRds	Stoneville Formation	0279625	WELL #1	Unk.	60	0.086	0.134
030101030503	TRds	Stoneville Formation	0279505	WELL #1	Unk.	60	0.086	0.134
030101030503	TRds	Stoneville Formation	3079003	WELL #1	Unk.	60	0.086	0.134
030101030503	TRds	Stoneville Formation	3079025	WELL #2	400	14	0.020	0.031
030101030503	TRds	Stoneville Formation	3079025	WELL #1	385	5	0.007	0.011
030101030503	TRdc	Cow Branch Formation	3079004	WELL#2	210	7	0.010	0.016
Stokes County								
030101030203	TRds	Stoneville Formation	0285101	WELL #1	315	25	0.036	0.056
030101030203	TRds	Stoneville Formation	0285447	WELL #9	305	25	0.036	0.056
030101030203	TRds	Stoneville Formation	0285455	WELL #1	Unk.	60	0.086	0.134
030101030203	TRds	Stoneville Formation	0285015	WELL #1-FIRE STATION	1230	140	0.202	0.312
030101030203	TRds	Stoneville Formation	0285015	WELL #2-FOWLER PARK	1150	95	0.137	0.212
030101030203	TRds	Stoneville Formation	0285015	WELL #6-BICYCLES WELL	903	40	0.058	0.089
030101030204	TRds	Stoneville Formation	0285015	WELL #3	600	35	0.050	0.078
030101030204	TRds	Stoneville Formation	0285015	WELL #4-CLUB STREET	805	55	0.079	0.123
030101030204	TRdc	Cow Branch Formation	0285015	WALNUT TREE WELL	130	126	0.181	0.281
030101030302	TRds	Stoneville Formation	3085005	WELL #1	265	10	0.014	0.022
030101030302	TRds	Stoneville Formation	0285015	WELL #5-HWY 311	605	36	0.052	0.080
030101030306	TRds	Stoneville Formation	0285401	WELL #1	200	5	0.007	0.011
030101030306	TRds	Stoneville Formation	0285473	WELL #6	268	100	0.144	0.223
030101030306	TRds	Stoneville Formation	0285473	WELL #1	465	100	0.144	0.223
030101030306	TRds	Stoneville Formation	0285473	WELL #7	300	50	0.072	0.112
030101030306	TRds	Stoneville Formation	0285473	WELL #8	400	50	0.072	0.112
030101030306	TRds	Stoneville Formation	0285473	WELL #5	100	100	0.144	0.223
030101030306	TRds	Stoneville Formation	0285419	WELL #1	Unk.	60	0.086	0.134
030101030306	TRdp	Pine Hall Formation	0285435	WELL #1	Unk.	60	0.086	0.134
030101030306	TRdc	Cow Branch Formation	0285428	WELL #1	175	50	0.072	0.112
Wake County								
030202010502	TRc	Chatham Group-Undivided	0392373	CHESTNUT OAKS_WELL #2	605	106	0.153	0.236
030202010503	TRc	Chatham Group-Undivided	4392121	WELL #2	255	9	0.013	0.020
030202010503	TRc	Chatham Group-Undivided	4392121	WELL #1	455	20	0.029	0.045
030202010503	TRc	Chatham Group-Undivided	4392479	WELL #2	300	7	0.010	0.016
030202010504	TRc	Chatham Group-Undivided	0392788	WELL #3 SB2	352	43	0.062	0.096
030202010504	TRc	Chatham Group-Undivided	0392788	WELL #2 SB3	304	12	0.017	0.027
030202010504	TRc	Chatham Group-Undivided	0392788	WELL #1 SB9	394	37	0.053	0.083
030300020608	TRc	Chatham Group-Undivided	4392514	WELL #1	Unk.	60	0.086	0.134
030300020608	TRc	Chatham Group-Undivided	0392416	WELL #1	Unk.	60	0.086	0.134
030300020609	TRc	Chatham Group-Undivided	0392448	WELL #1	Unk.	60	0.086	0.134
030300020609	TRc	Chatham Group-Undivided	0392672	WELL #1	Unk.	60	0.086	0.134
030300020609	TRc	Chatham Group-Undivided	4392505	WELL #1	Unk.	60	0.086	0.134
030300040102	TRc	Chatham Group-Undivided	4392520	WELL #1	300	2	0.003	0.004
030300040102	TRc	Chatham Group-Undivided	4392521	WELL #2	380	20	0.029	0.045
030300040102	TRc	Chatham Group-Undivided	0392271	WELL #2	300	15	0.022	0.033
030300040102	TRc	Chatham Group-Undivided	0392660	WELL #1	Unk.	60	0.086	0.134

B. Road and bridge infrastructure

Existing condition and effects of increased use

As with any industrial activity, natural gas extraction requires the use of vehicles and machinery. The types of vehicles and machinery most commonly used in the process of natural gas extraction are employee and delivery vehicles, specialized cement equipment and vehicles, flatbed tractor trailers and trucks to transport water, sand and chemicals.

Water can be delivered to the well pad either by trucks or by pipelines. Since pipelines do not yet exist in the Triassic Basin, it is likely that, water would be transported by truck for the first several years. One source states that one gas well service company uses tanker trucks that carry 5,460 gallons of water to transport water to the well pad.[54] A staff person at Chesapeake Energy Corporation, which conducts shale gas exploration and production using hydraulic fracturing in Pennsylvania and other states, said its trucks for transporting water hold between 4,000 and 5,000 gallons of water.[55]

Fracturing additives are transported in trucks or containers, typically flatbed trucks that carry plastic totes that hold the liquid additives. Liquid products used in smaller quantities are transported in one-gallon sealed jugs carried in the side boxes of the flatbed. Some additives, such as hydrochloric acid, are transferred in tanker trucks. Dry additives are transported on flatbeds in 50- or 55-pound bags set on pallets containing 40 bags each and shrink-wrapped, or in five-gallon sealed plastic buckets. Smaller quantities may be transported in the side boxes of trucks.[56] The flatbed trucks that deliver liquid totes to the site may be equipped with pumping systems for transferring the liquid. Sand or other proppants used in hydraulic fracturing are transported from their mined sources by rail or truck to the well pad.

In New York and Pennsylvania, additives are transported in trucks that are approved by U.S. Department of Transportation (USDOT) regulations. The New York State Department of Transportation (NYSDOT) has adopted federal regulations for transporting hazardous materials interstate and has adopted state standards for intrastate transportation.

For shale gas exploration and production using hydraulic fracturing, the number of trucks used would be particularly heavy during the first 50 days of the well pad development, when water and additives are transported to the site for hydraulic fracturing and wastewater may be trucked away from the site. The New York State Department of Environmental Conservation estimated the number of trucks required for a new well location during the early development of the shale play, and also for the peak development year for the shale play, when some water maybe transported by pipeline rather than by truck. Although the timeframe for this estimate is not provided, the report provides “the estimated duration of the various phases of activity

[54] Shaleshock. “Drilling 101.” Retrieved January 26, 2012 from http://shaleshock.org/drilling-101/.
[55] Personal communication, February 1, 2012.
[56] NYSDEC, pp. 5-79 – 5-80.

involved in the completion of a typical installation."[57] This timeframe ranges from 40 to 61 days, as shown in Table 3-19 below.

Table 3-19. NYSDEC Assumed Construction and Development Times[58]

Operation	Estimated Duration (days)
Access roads	3 - 7
Site preparation/well pad	7 - 14
Well drilling	28 - 35
Hydraulic fracturing single well	2 - 5

During early shale play development, NYSDEC estimates 1,148 one-way heavy-duty truck trips per well during construction and 831 one-way light-duty truck trips per well during construction for all truck traffic needs. For early well pad development, this is a total of 2,296 round-trip heavy-duty truck trips[59] and 1,662 round-trip light-duty truck trips per well when all water is transported by truck. During the peak development period of the shale play, when pipelines are assumed to be used for some water transport, NYSDEC estimates 625 one-way heavy-duty truck trips per well and 831 one-way light-duty truck trips per well.[60] For peak well pad development, this is a total of 1,250 round-trip heavy-duty truck trips and 1,662 round-trip light-duty truck trips. These figures are shown by stage of the well development process in Table 3-20.

[57] NYSDEC, p. 6-298.
[58] This table is copied from NYSDEC, p. 6-298.
[59] The number as reported in NYSDEC's Draft Supplemental Generic Environmental Impact Statement is actually 3,950, however, we believed this to be a typographical error, since (831 + 1,148) * 2 = 3,958.
[60] The number of one-way light-duty truck trips per well is reported as 795, however, the numbers in Table 3-20 add up to 831 (this table appears in the NYSDEC Draft Supplemental Generic Environmental Impact Statement). For a breakdown of truck trips used for this estimate by the type of materials being hauled, see NYSDEC, p. 6-302.

Table 3-20. Estimated Number of One-Way (Loaded) Trips per Well: Horizontal Well[1]

Well Pad Activity	Early Well Pad Development (all water transported by truck)		Peak Well Pad Development (pipelines may be used for some water transport)	
	Heavy Truck	Light Truck	Heavy Truck	Light Truck
Drill pad construction	45	90	45	90
Rig mobilization[2]	95	140	95	140
Drilling fluids	45		45	
Non-rig drilling equoipment	45		45	
Drilling (rig crew, etc.)	50	140	50	140
Completion chemicals	20	326	20	326
Completion equipment	5		5	
Hydraulic fracturing equipment (trucks and tanks)	175		175	
Hydraulic fracturing water hauling[3]	500		60	
Hydraulic fracturing sand	23		23	
Produced water disposal	100		17	
Final pad prep	45	50	45	50
Miscellaneous	-	85	-	85
Total One-Way, Loaded Trips per Well	**1,148**	**831**	**625**	**831***

* This number is reported in New York's Draft Supplemental Generic Environmental Impact Statement as 795, however, the numbers in the column total to 831.

Source: This table is copied from the New York State Department of Environmental Conservation's Draft Supplemental Generic Impact Statement, p. 6-302. Their source for the table is ALL Consulting. Their footnotes to the table are below.

"1. Estimates are based on the assumption that a new well pad would be developed for each single horizontal well. However, industry expects to initially drill two new wells on each well pad, which would reduce the number of truck trips. The well pad would, over time, be developed into a multi-well pad.

2. Each well would require two rigs, a vertical rig and a directional rig.

3. It was conservatively assumed that each well would use approximately 5 million gallons of water total and that all water would be trucked to the site. This is substantially greater than the likely volume of water that would be trucked to the site."

If 164 wells are drilled in North Carolina in a single year (the maximum number of wells that could be drilled in a year, as posited in Table 3-17), and 2,296 heavy-duty round-trip truck trips and 1,662 light-duty round-trip truck trips are required for those wells, activity in the Dan and Deep River Basin would result in an additional 649,112 truck trips per year. Using the NYSDEC's estimate for peak development of the shale play, when some water is transported by pipeline rather than truck, those same 164 wells would result in an additional 477,568 round-trip truck trips per year. As noted earlier in the report it is unlikely that 164 wells would be drilled in a single year.

The increase in heavy-duty truck traffic can have implications for the condition and long-term maintenance of roads. Some of these trucks can weigh as much as 80,000 to 100,000 pounds when fully loaded,[61] and due to the vehicle's weight, heavy trucks in general cause more damage to roads and bridges than cars or light trucks. Road damage could range from minor cracking to potholes, rutting or complete failure.

Existing road conditions

Staff of the N.C. Department of Transportation (NCDOT) analyzed a sample of roads in each of seven counties within the Triassic Basins (Anson, Chatham, Lee, Moore, Richmond, Rockingham and Stokes counties), examining the average pavement condition rating for each county and the average percentage of alligator cracking on the road sections (interconnecting cracks in pavement that form a pattern resembling an alligator's skin) in each of the counties.[62] NCDOT defines pavement condition as the percent of highway lane miles in good condition, and "good condition for pavement is defined as a Pavement Condition Rating (PCR) of 80 or higher."[63] Based on the analysis of a small sample of roads in these counties, the road sections analyzed had more than 15 percent alligator cracking for each county except Stokes County. Pavement conditions were poorest in Chatham and Moore counties. Summary statistics for these counties are shown in Table 3-21.

Table 3-21. Pavement Conditions in Sample of Roads in the Triassic Basin

County	Pavement Condition Rating	% Alligator Cracking	Number of Routes in Sample
Anson	88.13	15.42	24
Chatham	76.06	41.94	62
Lee	83.43	25.91	22
Moore	78.13	33.64	33
Richmond	88.02	17.92	24
Rockingham	88.98	15.6	25
Stokes	93.52	6.67	28

Many of the secondary roads in the area of the Deep and Dan river basins are constructed to deal with very few heavy trucks. According to NCDOT, the secondary roads in these areas are "thin pavements built on unimproved subgrade and can be expected to tear up under the heavy repeated loadings" associated with shale gas exploration and production activities.[64] Larger roads, such as interstate highways, receive more frequent maintenance than smaller, local roads, which are more likely to be used for gas drilling operations.

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[61] Marcellus-Shale.us. "Our Look at Road Damage from Heavy Truck Traffic." Retrieved February 29, 2012 from http://www.marcellus-shale.us/road_damage.htm.

[62] Personal communication, February 10, 2012.

[63] North Carolina Department of Transportation. *Performance Dashboard Documentation*. September 15, 2010, p. 3. Retrieved February 16, 2012 from http://www.ncdot.gov/download/performance/dashboarddetails.pdf.

[64] Personal communication, February 10, 2012.

NCDOT staff analyzed the impact of additional truck traffic to a typical roadway currently receiving a low volume of traffic. The road analyzed is a new road, beginning in good condition, consisting of three inches of asphalt on six inches of aggregate base. With existing minimal trucks, this type of design is expected to last 20 years. With only an additional 100 heavy-duty trucks per day from natural gas drilling and production, the road would fail in less than two years. Based on NCDOT's sample, roads in the Triassic Basin are not all in good condition currently, and may fail in even less time.[65]

Bridges in all areas of the Triassic Basin may not provide clearance for the height of heavy-duty trucks. Table 10-1 in Appendix A: Bridges in the Triassic Basins with minimum clearance shows 220 bridges in the areas underlain by the Triassic Basins with minimum clearance.

Costs for road repair or replacement

The NYSDEC states that it cannot estimate costs associated with roads and bridges because:

> "these costs are a factor of (1) the number, location, and density of wells; (2) the actual truck routes and truck volumes; (3) the existing condition of the roadway; (4) the specific characteristics of the road or bridge (e.g., the number of lanes, width, pavement type, drainage type, appurtenances, etc.); and (5) the type of treatment warranted."[66]

However, within NYSDEC's draft environmental impact statement, the New York State Department of Transportation (NYDOT) estimated that the replacement costs for a bridge could range from $100,000 to $24 million per bridge, with an average of $1.5 million per bridge. NYDOT estimated the cost to repair local roads to range from $70,000 to $150,000 per lane mile for low-level maintenance to $400,000 to $530,000 per lane mile for higher-level maintenance. Total reconstruction could range from $490,000 to $1.9 million per lane mile.[67]

Estimates to repair or replace state bridges and roads were even higher. State bridge replacement could range from $100,000 to $31 million per bridge, averaging $3.3 million per bridge. Low-level maintenance for state roads would range from $90,000 to $180,000 per lane mile; higher-level maintenance would range from $540,000 to $790,000 per lane mile. "Full depth reconstruction" can range from $910,000 to $2.1 million per lane mile.[68]

Road construction costs are variable based on topography and area of the country. It is recommended that further research be conducted to assess the potential costs to North Carolina.

Depending on the amount of natural gas extraction and production that occurs, there is a possibility that bridges and state roads would require more frequent maintenance and possibly replacement. However, as NYSDEC points out, it is difficult to calculate how much damage to state roads would be attributable to hydraulic fracturing. The impacts from this activity may be

[65] Personal communication, February 13, 2012.
[66] NYSDEC, p. 6-312.
[67] Ibid, p. 6-312.
[68] Ibid, p. 6-313.

clearer on local roads, which do not generally experience a high volume of industrial truck traffic and are therefore built to lower standards. As NYSDEC states, on local roads, "actual contribution of heavy trucks to road and bridge deterioration would be greater than suggested by their proportion to total traffic."[69]

Safety considerations

Any increase in traffic can lead to an increase in accidents on the road. Moreover, an increase of heavy-duty trucks on narrow roads not built to accommodate the larger widths and weights of these trucks would have an even greater likelihood of increasing the number of accidents. To mitigate such impacts, local governments and NCDOT can install safety features, such as turn lanes and traffic signals. For local roads, NYSDEC estimates that installing a turn lane could cost from $17,000 to $34,000, the installation of a flashing red or yellow signal could cost $35,000, and the installation of a three-color signal could range from $100,000 to $150,000.

Road impacts

Some communities where shale gas drilling has rapidly increased experience road and bridge damage that places a financial burden on the local government and distresses residents who use the roads. In a conversation with DENR staff and four members of the N.C. House of Representatives, one Bradford County, Pennsylvania official said of the traffic in Towanda (a town of approximately 3,000 people), "There have been days when it takes 40 minutes to drive three miles."[70] Bradford County officials also said that trucks for drilling operations have gotten stuck in ditches, requiring local government emergency management services to extract them, and that trucks have "taken out traffic lights and bridges."[71]

Penn State Cooperative Extension conducted a study of how gas development is affecting the demand for municipal government services in Susquehanna and Washington counties. Cooperative Extension staff performed statistical analysis of local government audit data and held focus group interviews with 17 municipal officials from both counties. Penn State Cooperative Extension reports:

> "Road impacts were by far the main issue municipal officials raised with us in the interviews. Gas development creates significant increases in truck and other traffic, and wear and tear on roads is often very visible. For many of Pennsylvania's smallest townships, road maintenance and repair historically accounts for the largest share of their spending."[72]

In many cases, drilling operators have worked to resolve issues related to roads. Bradford County officials said that once drilling operators saw the damage being caused to roads, they were proactive about repairing them. Drilling operators have established "road use and maintenance agreements" (RUMA) with some towns in Pennsylvania. Penn State Cooperative

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[69] Ibid, p. 6-314.
[70] Personal communication, February 2, 2012.
[71] Ibid.
[72] Penn State Cooperative Extension. Impacts of Marcellus Shale Development on Municipal Governments in Susquehanna and Washington Counties, 2010. The Pennsylvania State University, 2011.

Extension reports that the township officials who were interviewed "generally were very satisfied with the quality of the repairs and upgrades, and noted that company policies are to leave the roads in equal or better condition than before the gas development began."[73] In one township, more than a third of their roads had been repaired.[74]

In Pennsylvania, RUMAs are common. According to a Chesapeake Energy PowerPoint, they have "been used extensively for Chesapeake's operations area in Pa." Under a typical RUMA, the operator agrees to reimburse the municipality or county "for any additional costs incurred, associated with the maintenance of said roadway as a result of the Operator's activities during construction, drilling and completion" of wells. The operator also agrees "to maintain roads to a condition consistent with that prior to operations [and] assumes all liability for subcontractors working on Operators behalf." Chesapeake will perform the road maintenance to the local government's specifications, or the local government can perform the work itself.[75]

There are some downsides to RUMAs. Roads are sometimes repaired using higher quality materials or have larger dimensions than the original road. This can require additional costs on the part of the local government for maintenance and repair, especially if the roads have been widened. In addition, township officials reported to Penn State Cooperative Extension, "major difference between companies on how they dealt with roads," and while some companies were proactive, others "were more reactive or even difficult to contact and less communicative."[76]

Rather than leaving each individual municipality or county to negotiate its own agreement with drilling operators, some states have considered developing a model road use and maintenance agreement. The County Commissioners Association of Ohio and the Ohio Township Trustee Association worked on the development of a model agreement and discussed the possibility that the Ohio Department of Natural Resources could require that an agreement be in place with the local government before issuing a drilling permit. However, at a recent meeting with the Ohio Department of Transportation, the Ohio Department of Natural Resources and the Office of Governor John Kasich, "a number of stakeholders were surprised when officials said that rather than require a RUMA as a condition to an ODNR permit to drill, ODNR will instead mimic the concentrated animal feeding operation (CAFO) process by only inquiring whether a RUMA is in place or if good faith efforts have been made to negotiate a RUMA," and if the answer to either question is yes, the permit will be granted.[77]

Weight limits

In addition to community concerns about traffic and road maintenance, there have also been concerns expressed about trucks exceeding weight limits on roads. Shale gas drilling often takes

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[73] Ibid.
[74] Ibid.
[75] Chesapeake Energy. "Chesapeake Energy Shale Operations Overview." Retrieved March 1, 2012 from http://jfs.ohio.gov/owd/Initiatives/Docs/Chesapeake-Ohio-Basic-Drilling.pdf.
[76] Penn State Cooperative Extension, 2011.
[77] County Commissioners Association of Ohio. "Update on Oil & Gas Road Use Maintenance Agreements." *Statehouse Report*, February 17, 2012. Retrieved March 1, 2012 from http://www.ccao.org/Portals/0/Statehouse/SHR20120217.pdf.

place in rural areas where weigh stations are infrequent. In Jefferson County, Pa., one farmer lost patience with hydraulic fracturing trucks repeatedly driving down a road that had a 10-ton weight limit and was off-limits to heavy-duty trucks. After the state police told the farmer they would have to catch truck drivers in the act, the farmer blocked the road with his pickup, trapping heavy-duty trucks on the road, and holding them there until state troopers arrived to issue fines and citations.[78]

In Pennsylvania, heavy-duty trucks can drive on roads with a vehicle in excess of the weight limit if the truck is bonded and the company has entered into a maintenance agreement with the road owner. The maintenance agreement establishes the responsibility of the truck owner to pay for excess maintenances costs for the roadway due to the heavy hauling activities.[79] According to Penn State Cooperative Extension, most of the townships interviewed from Washington County had performed "road engineering studies to allow posting weight limits on the road, while in Susquehanna County only one township had done so."[80] These studies are performed at the expense of the local government.

Management options

Several options exist for managing the impacts to road and bridge infrastructure from natural gas exploration and production. While considering these options, it is important to bear in mind that in North Carolina, the NCDOT uses data on pavement condition, traffic congestion and road safety, as well as input from local governments and NCDOT staff, to determine transportation priorities. This approach ranks projects for all transportation modes in priority order, based on the department's goals.[81] The management options are:

- Patch or otherwise improve roads prior to beginning shale gas exploration and production.
- Require a bond from the gas operator sufficient to perform full-depth reclamation on all roads used for hauling in the likely event that the roads are damaged. In Pennsylvania, "in order to have a case in court, municipalities must post weight limits on roads prior to hauling activity. After posting, the municipality may permit heavier loads to be hauled on the road and may require a bond from the hauler."[82]
- Build up the roadways in advance, which would require advanced knowledge of which roads will be used.

[78] Phillips, Susan. "Fed Up Farmer Uses Pickup to Block Frack Trucks." StateImpact. February 27, 2012. Retrieved February 28, 2012 from http://stateimpact.npr.org/pennsylvania/2012/02/27/fed-up-farmer-uses-pickup-to-block-frack-trucks/.

[79] Bradford County Government. "Natural Gas Information." Retrieved Febraury 28, 2012 from http://www.bradfordcountypa.org/Natural-Gas.asp?specifTab=5.

[80] Penn State Cooperative Extension, 2011.

[81] North Carolina Department of Transportation. "Transportation Reform – The Process." Retrieved April 13, 2012 from http://www.ncdot.gov/download/performance/performance_TheProcess.pdf.

[82] Lovegreen, Mike. "Impacts of Marcellus Well Drilling on Local Communities." PowerPoint presentation. February 2, 2012.

- Require gas operators to enter into road use and maintenance agreements prior to natural gas drilling.
- Ask drilling operators to provide NCDOT with well locations and haul routes in advance. This would allow NCDOT to try to minimize damage and prepare a photographic log of existing pavement conditions in the event of damage.

We recommend that the General Assembly direct the North Carolina Department of Transportation to study the issue of road management and options for mitigating the impacts of increased traffic on roads, such as requiring bonds or road use management agreements.

C. Transportation methods

Rail transportation

If shale gas exploration and production comes to North Carolina, a large amount of pipe, drilling equipment, chemicals and other materials would have to be transported from manufacturing facilities to well pads. Many of these materials will be transported from manufacturing facilities by rail to rail depots, and from rail depots by trucks to well pads. The use of rail depots for transporting the large amount of material associated with shale gas exploration and production would likely increase truck traffic near rail depots and on roads in the vicinity of rail depots.

Transportation of fresh water

Fresh water would not likely be transported by rail. Water could be delivered from the source to the well pad by truck or by overland pipeline. Recently, some shale gas operators have begun building centralized surface water impoundments that can serve several well pad sites. Water is transported from the source by overland pipeline to the surface water impoundment and then trucked from the surface water impoundment to the well pads that it serves. Surface water impoundments allow operators to withdraw water during periods of high flow and store the water for use during hydraulic fracturing. This reduces the need for operators to withdraw water during periods of low flow, which can have negative impacts on aquatic environments and water supply for other users. These impoundments can serve well pads within a radius of four miles, and "impoundment volume could be several million gallons with surface acreage of up to five acres."[83] Surface water impoundments may present an attractive nuisance to wildlife such as birds and deer – this may be mitigated by installing fencing and netting.

Transportation of gas

The gas transportation system

Once natural gas leaves the well, it enters gathering lines, which are low pressure, small diameter (6-20 inches) steel pipes that carry raw natural gas from the wellhead to a natural gas processing facility or an interconnection with a larger pipeline.[84] A gathering system may include field compressors to move the gas to the pipeline or the processing plant. Field

[83] NYSDEC, p. 5-85.

[84] Penn State Cooperative Extension. *Negotiating Pipeline Rights-of-Way in Pennsylvania*. The Pennsylvania State University, 2010.

compressors are machines "driven by an internal combustion engine or turbine that creates pressure to 'push' the gas through the lines."[85] In some cases, the natural gas may be processed in the gathering system at a processing facility.[86] Natural gas must be processed to eliminate other hydrocarbons, water, sand and impurities that occur naturally with the natural gas. In some cases hydrocarbons, such as butane and propane, can be sold separately from the natural gas. There are no natural gas processing plants in North Carolina. If shale gas development occurred on a large scale in North Carolina, it is likely that a gas processing plant could be developed here.

From the gathering system, the natural gas moves through the transmission system. Transmission pipelines are wide diameter (20-48 inches), long-distance pipelines that move natural gas from producing regions to areas where gas is used. These pipelines are either interstate or intrastate. Interstate pipelines carry natural gas across state boundaries, while intrastate pipelines transport gas within a state.

Natural gas is highly pressurized as it travels through pipelines. To ensure natural gas remains pressurized, it is compressed periodically along the pipe at compressor stations. Compressor stations are located about "every 50 to 60 miles along each pipeline to boost the pressure that is lost through the friction of the natural gas moving through the steel pipe."[87] Generally, internal combustion engines provide the power to run compressors. These engines are fired using raw or processed natural gas. Compressor stations may also separate natural gas from hydrocarbons or water that naturally occurs with the gas. Bradford County officials told DENR staff that eventually there would be one compressor station for every 50 wells or every 10 well pads.[88]

When the natural gas in a pipeline reaches a gas utility, it normally passes through a gate station that reduces the pressure in the line to distribution levels, adds an odorant to the gas so consumers can smell gas leaks, and measures the amount of gas being received by the utility.[89] From the gate station, natural gas moves into distribution lines. The gas utility can control the pressure in the distribution lines. From distribution lines, natural gas enters service lines, and service lines deliver gas to pipes in homes and businesses.[90]

North Carolina does not currently produce natural gas and "the majority of North Carolina's natural gas is supplied by the Transcontinental Gas Pipeline Co. as the pipeline traverses the State en route from the Gulf Coast to major population centers in the Northeast."[91] Because of this, there are currently no gathering lines in North Carolina. If shale gas development occurs in North Carolina, a new web of gathering lines and additional transmission lines would have to be

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[85] American Gas Association. "How Does the Natural Gas Delivery System Work?" Retrieved March 1, 2012 from http://www.aga.org/Kc/aboutnaturalgas/consumerinfo/Pages/NGDeliverySystem.aspx.
[86] Ibid.
[87] Ibid.
[88] Personal communication, February 2, 2012.
[89] American Gas Association.
[90] Ibid.
[91] U.S. Energy Information Administration. "North Carolina." Retrieved March 1, 2012 from http://www.eia.gov/state/state-energy-profiles-analysis.cfm?sid=NC.

developed to carry the gas to markets. Bradford County officials told DENR staff that so far, "600 to 700 miles of pipeline" had been installed in Bradford County,[92] an area of 1,147 square miles and home to 62,622 people as of the 2010 Census estimate.[93] A total of 1,734 well permits have been issued for Bradford County as of July 15, 2011.[94]

Regulation of natural gas transportation systems

While the development of new pipelines would create additional jobs and have other positive economic impacts, it would also create safety concerns and disturb large amounts of surface area. The Federal Energy Regulatory Commission (FERC) regulates the construction of interstate pipelines and the transportation of natural gas in interstate commerce and "is responsible for authorizing the siting, construction, and operation of interstate natural gas pipelines."[95] As part of this process,

> "Virtually all applications to the FERC for interstate natural gas projects require some level of coordination with one or more federal agencies to satisfy the FERC's requirements for environmental review under the National Environmental Policy Act (NEPA), the Endangered Species Act, the National Historic Preservation Act, and the Magnuson-Stevens Act."[96]

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) and state agencies regulate pipeline safety. PHMSA regulates natural gas gathering lines based on their proximity to populated and environmentally sensitive areas. Under the current regulatory system, PHMSA does not regulate most of the gathering lines in the United States because they are located in rural, less populated areas, called "Class I" areas.[97]

Intrastate pipelines are regulated by states rather than FERC. Transmission lines may be regulated by a state public utilities commission, as is the case in North Carolina. However, in some cases, gathering lines may not be regulated at all. Pennsylvania only recently adopted legislation that grants the Public Utility Commission (PUC) more control over the safety of gathering lines. On Dec. 22, 2011, Gov. Tom Corbett signed Pennsylvania's Gas and Hazardous Liquids Pipelines Act (called the Pipeline Act), which expands the PUC's "authority to enforce federal pipeline safety laws as they relate to gas and hazardous liquids pipeline equipment and facilities," including gathering lines. Under the Pipeline Act, the PUC "will develop a registry and conduct safety inspections of the lines for all 'pipeline operators' in the state. The Commission

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92 Personal communication, February 2, 2012.

93 U.S. Census Bureau. "Bradford County, Pennsylvania." *State and County QuickFacts*. Retrieved March 1, 2012 from http://quickfacts.census.gov/qfd/states/42/42015.html.

94 Lovegreen, 2012.

95 Federal Energy Regulatory Commission. "Processes for the Environmental and Historic Preservation Review of Proposed Interstate Natural Gas Facilities." May 29, 2003. Retrieved March 1, 2012 from http://www.ferc.gov/industries/gas/enviro/gasprocess.pdf.

96 Federal Energy Regulatory Commission, 2003.

97 United States Government Accountability Office (GAO). *Pipeline Safety: Collecting Data and Sharing Information on Federally Unregulated Gathering Pipelines Could Help Enhance Safety*. March 2012. Retrieved April 13, 2012 from http://www.gao.gov/assets/590/589514.pdf.

also will identify and track the development of pipelines in less populated areas that transport gas from unconventional gas wells." The Pipeline Act is effective as of February 20, 2012.[98]

Pennsylvania's new law does not apply to pipelines in the most rural areas of the state where shale gas drilling is common, however, because the federal laws do not apply in rural areas with low-density populations.[99]

Since gathering lines are not regulated as a utility in Pennsylvania and are considered private lines, Bradford County officials told DENR staff that the local planning department went to individual gas operators to ask where the company was constructing pipelines.

One of the potential impacts of gathering lines as private, relatively unregulated lines is that each gas operator develops its own gathering lines. In some states, such as Pennsylvania, gathering lines are not subject to eminent domain, and "the pipeline operator must negotiate easements with each individual landowner along the route."[100] This may occur even though gas is being transported along similar routes, creating multiple impacts on the environment and the community where a single, slightly larger line may have served the same purpose (and have saved gas operators money). Forests may be cleared to construct the pipelines, which can increase forest edges. The impacts of forest edges are discussed in Section 4.G of this report.

In North Carolina, the existing interstate and intrastate transmission pipelines in North Carolina are regulated by the North Carolina Utilities Commission (NCUC). NCUC conducts inspections and monitoring of all the natural gas pipeline systems operating in North Carolina. In addition, NCUC considers environmental and social impacts as part of its process of issuing Certificates of Convenience. The power of eminent domain is given to these types of pipelines. According to the NCUC, it is not known what, if any, regulatory authority would apply to gathering lines.[101] Regulations for gathering lines could address such issues as reporting the location of gathering lines to state and local agencies, siting and installation criteria, inspections, leak monitoring and maintenance.

Safety of Gathering Lines

Recently, the United States Government Accountability Office (GAO) surveyed state pipeline safety agencies in all 50 states and the District of Columbia about potential safety risks associated with gathering lines not regulated by PHMSA and the practices states use to ensure the safety of federally unregulated onshore gathering lines. The GAO study found that "While the safety risks of onshore gathering pipelines that are not regulated by PHMSA are generally considered to be lower than for other types of pipelines, PHMSA does not collect comprehensive data to identify the safety risks of unregulated gathering pipelines."[102] In

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[98] Pennsylvania Public Utility Commission. "Act 127 Information." Retrieved March 1, 2012 from http://www.puc.state.pa.us/naturalgas/Act_127_Info.aspx.

[99] Tice, Dale A. "Pipeline Regulation in Pennsylvania." *Marcellus Shale Law Monitor*. December 29, 2011. Retrieved March 1, 2012 from http://www.marcellusshalelawmonitor.com/marcellus-development/pipeline-regulation-in-pennsylvania/.

[100] Penn State Cooperative Extension, 2010.

[101] Personal communication, February 17, 2012.

[102] GAO, 2012.

response to GAO's survey, state pipeline safety agencies "cited construction quality, maintenance practices, unknown or uncertain locations and limited or no information on pipeline integrity as among the highest risks for federally unregulated pipelines." Land-use changes have resulted in development encroaching on existing pipelines, and the increase in shale gas development has led to an increase in the development of new gathering lines. The GAO interviewed state and federal officials, who "identified new gathering pipelines related to shale development as a potential public safety risk…primarily due to the characteristics and quantity of pipeline infrastructure required to support this new production." This is because the new gathering lines have larger diameters and operate at higher pressures than older gathering lines, and they are now "equivalent to traditional transmission pipelines, but without the regulatory requirements."[103]

Some of the safety measures states use for gathering pipelines are damage prevention programs, such as: marking the rights-of-way for pipelines above ground to reduce excavation damage; targeting areas of highest risk for inspections or other monitoring; performing recurring, scheduled or unscheduled safety inspections; public outreach and communication; and enforcement activities.[104]

GAO concludes, "PHMSA is currently not able to determine the performance and safety of these gathering pipelines because it does not collect the necessary pipeline operator data." Based on this study, GAO recommends that the Secretary of Transportation direct the PHMSA Administrator to "Collect data from operators of federally unregulated onshore hazardous liquid and gas gathering pipelines" and "Establish an online clearinghouse or other resource for state to share information" on safety practices.

Given the gathering line safety issues and the lack of a regulatory system for gathering lines in North Carolina, DENR recommends that the General Assembly should authorize DENR and the North Carolina Utilities Commission to work together to close the regulatory gaps for gathering lines in North Carolina.

[103] Ibid.
[104] Ibid.

Figure 3-12. Construction of Underground Pipeline

Photo Credit: Mike Lovegreen

D. Domestic wastewater treatment

Given the relatively small size of North Carolina's shale deposits compared to those in other states, and the economic impact analysis estimate of a maximum of 858 additional jobs in a single year, it is not anticipated that managing the additional domestic wastewater load associated with development of shale gas will present a significant challenge.

Industrial wastewater treatment options and environmental impacts are considered in Section 4.D.