The Water Supply Plan for Rappahannock County and the Town of Washington

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Executive Summary

Objective

This plan has been developed to fulfill the requirements of the State Water Control Board's regulation 9 VAC 25-780 "Local and Regional Water Supply Planning" as administered by the Virginia Department of Environmental Quality (DEQ).

The objective of this water supply plan (WSP) is twofold: first, to provide Rappahannock County planning authorities and residents with the information needed to understand the issues that must be addressed in order to maintain an adequate water supply in the County; and secondly, to help the County to prepare, in advance, for potential water supply problems in the future.

The County plans to regularly review and update this plan, as necessary, on a 5 to 10-year cycle. Information provided in this document pertains to Rappahannock County as a whole, including the incorporated town of Washington.

Summary of Findings

Rappahannock County has been and remains very rural and enjoys a low population density. The Rappahannock County Comprehensive Plan, zoning, and the Stormwater Management Ordinance, contains numerous provisions intended to maintain this rural nature and population level. Most residents (95% or more) rely on individual groundwater sources for their water supply. The town of Washington serves residents with groundwater from two wells in a public community water supply system, the only such system within the County.

The detailed information on water sources and uses will help the citizens and administrative bodies (Board of Supervisors, Planning Commission, and the Washington Town Council) to have a better understanding of the water supply conditions. In addition, recommendations for a Drought Response and Contingency Plan are provided in Section VII. A "water balance" approach to the water resources and supply is part of this document. This water balance indicates, using long-term data, that Rappahannock County uses a fraction of the water that is available to it. Even under "maximum" development scenarios, the water supply of Rappahannock seems adequate to meet its needs over the next 30 to 50 years.

Historically, existing groundwater has been adequate to meet the residential needs of the County population. Also, there has been sufficient stream flow, and enough springs and ponds, to support agricultural and ecological requirements. Recent years, however, have seen significant changes in stream flow and in spring flow. Both residents and

Shenandoah National Park personnel have observed that numerous springs are experiencing greatly reduced flow and that some have dried up entirely.

Rappahannock County has experienced numerous, severe drought events during the past twenty years as well as strong indicators of climate change (i.e., the lack of snow in the mountains). Many of these drought events have been accompanied by periods of unusually hot weather which, in combination with what seems to be increased thunderstorm events as opposed to gentler rains, have exacerbated their effect on the water supply and stream flow. The combination of all of these elements has led to serious concerns as to whether the water supply will in fact continue to meet the County's needs. Sections VIII and IX discuss this in greater detail and suggest measures that could be taken to ameliorate these conditions. Finally, we consider that the problem is most likely a regional issue and should probably be addressed for the entire Rappahannock River Basin.

List of Acronyms

BMP: Best Management Practice
cfs: cubic feet per second
CSWCD: Culpeper Soil and Water Conservation District
CU: Consumptive Use
CWS: Community Water System
DEQ: Virginia Department of Environmental Quality
DRASTIC: A study of the groundwater pollution potential in Rappahannock County that uses the following indicators: Depth to water table, net Recharge, Aquifer media, Soils, Topography, Impact of vadose zone, and hydraulic Conductivity
EPA: United States Environmental Protection Agency
ET: Evapotranspiration
GIS: Geographic Information System
gpd: gallons per day
gpm: gallons per minute
GWW: Groundwater Withdrawal
LID: Low Impact Development
MAP: Mean Annual Precipitation
NASS: National Agricultural Statistical Summary
NC: Non-Community
MGY: Million Gallons per Year
NHDPLUS: National Hydrography Dataset Plus
NOAA: National Oceanic and Atmospheric Administration
NTNC: Non-Transient Non-Community
PEC: Piedmont Environmental Council
PRISM: Parameter-elevation Regressions on Independent Slopes Model
PWS: Public Water Supplies
RAPPFLOW: Rappahannock Friends and Lovers of Our Watersheds
RCCA: Rappahannock County Conservation Alliance
RCCP: Rappahannock County Comprehensive Plan, 2004
RLEP: Rappahannock League for Environmental Protection
SNP: Shenandoah National Park
SWAP: Source Water Assessment Program
SWI: Surface Water Inflow
SWO: Surface Outflow
USDA: United States Department of Agriculture
USGS: United States Geological Survey
VA SOS: Virginia Save Our Streams
VDH: Virginia Department of Health
VEDP: Virginia Economic Development Partnership
WSP: Water Supply Plan
WWTP: Wastewater Treatment Plant

SECTION I: Overview of Rappahannock County

Portions of this section are drawn from the Rappahannock County Comprehensive Plan, July 2004 (RCCP 2004) and/or from the County description on its website http://www.rappahannockcountyva.gov/compplan.html (April 2011). When information has been derived from additional sources, these are cited within the text.

Physical Description

Rappahannock County is in the northern portion of the Commonwealth of Virginia. The town of Washington, the County seat, is about sixty-five miles southwest of Washington, DC, and 120 miles northwest of Richmond, the State Capital. The County extends north and south 24 miles and east and west about 21 miles, with an area of approximately 267 square miles. The northwestern boundary is in the Blue Ridge Mountains abutting Page and Warren Counties. The Rappahannock River forms the northeastern boundary, which is shared with Fauquier County. The County is bounded on the southeast by Culpeper County and on the southwest by Madison County.

Rappahannock County's residents have strong economic and social ties with jurisdictions on all sides, although the western boundary of the Blue Ridge historically has acted to lessen contacts with Page County as opposed to the more direct accessibility of the town of Warrenton in Fauquier County, the town of Culpeper in the County of the same name, and the town of Front Royal in Warren County, which, while over the Blue Ridge, is nevertheless served by a primary road that provides convenient access. These geographic realities have led to a regionalization of many trading activities for County residents. People living in the northern portion of the County (Flint Hill, Chester Gap) are more apt to shop, bank and attend events in Front Royal, while residents of the south and west (Sperryville, Woodville) often patronize Culpeper establishments and persons in the east (Amissville, Washington) tend to favor Warrenton businesses. The map in Figure I. illustrates Rappahannock County in its relationship to neighboring counties and shows the locations of the town of Washington and the major villages within the County.

Further connecting Rappahannock County to its eastern neighbors are stream courses. Rappahannock County lies entirely within the Rappahannock River Basin. Thus all streams in the County ultimately drain to this channel, which is a source of both agricultural and recreational waters for neighboring Counties and a major source of drinking water supply to jurisdictions farther downstream, including Spotsylvania and Stafford Counties and the City of Fredericksburg. Historically, these water courses likely also served as means of transportation and immigration.

Within the County, business hubs include the town of Washington and the villages of Flint Hill, Amissville, and Sperryville. Among the largest employers and individual water users in Rappahannock County are the public schools which are located in the Designated Development Area (RCCP 2004) along U.S. Route 211, located 2.5 miles east of

Sperryville and 1.5 miles west of Washington. About 7,035 people reside in Rappahannock County (U.S. Census 2009 estimate); additional people commute here regularly to work, (Virginia Economic Development Partnership – Community Profile) and a substantial number of people visit seasonal homes and for weekend recreation opportunities and amenities, that include in-stream and off-stream uses of Rappahannock County's surface- and ground- water resources.

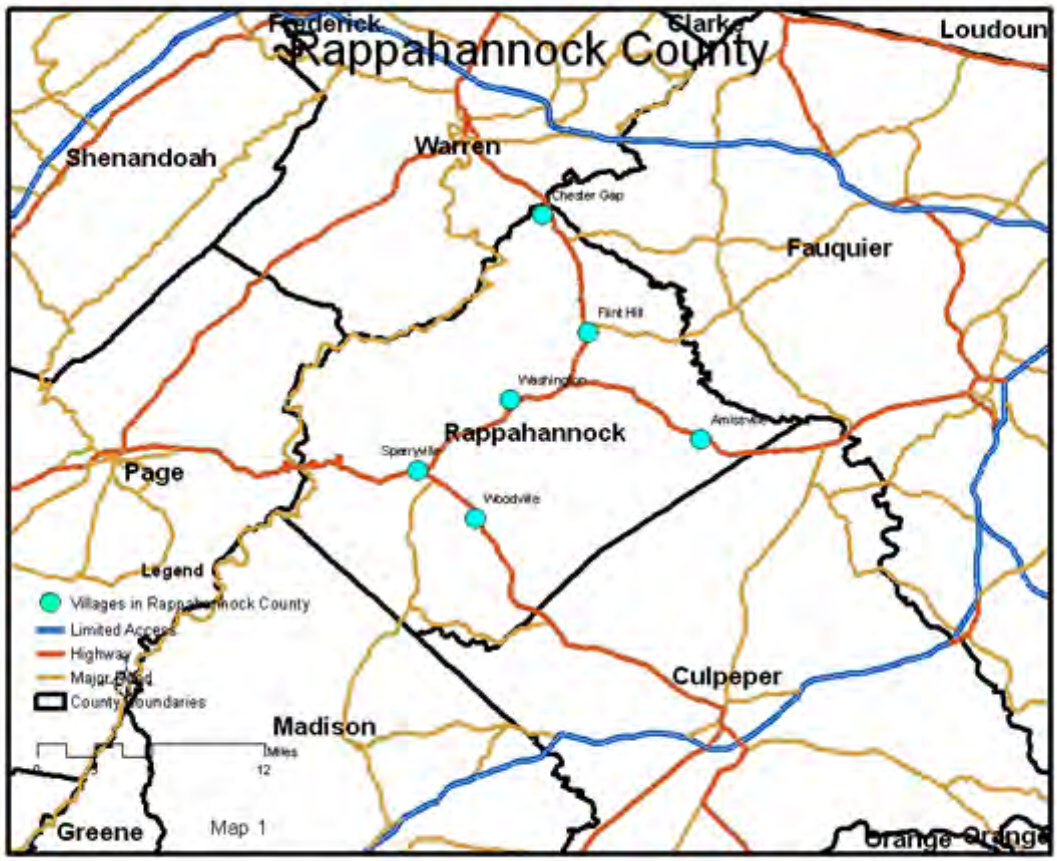


Figure I - Rappahannock County and Environs

Rappahannock County is rural in character, with about 38.2% of the land (65,084 acres or approximately 102 sq. miles), being in farms (National Agricultural Statistical Summary, NASS). Cattle farming, and grass farming to support cattle and other livestock, has become an increasingly important farming activity during recent decades. Portions of the listed farmlands are also designated by others as forested lands. Altogether, about 62% of Rappahannock County's land area (105,446 acres, or 164.76 sq. miles) was considered by the Virginia Division of Forestry to be "forested land" as recently as 1992. This percentage includes the Shenandoah National Park (SNP), established in 1926, which extends from the crest of the Blue Ridge Mountains down to the headwaters areas of several major stream drainages in the County.

Population

As discussed in greater detail in Sections II, III and V, the estimated total resident population of Rappahannock County for 2009 is 7,035 people. Below is a table and graph showing the historical variability in population from 1930 to 2009 (U.S. Census Bureau). It is interesting to note that the current population is lower than the population in 1930 and 1940.

Resident Population of Rappahannock County (Source: U.S. Census Bureau)

1930	1940	1950	1960	1970	1980	1990	2000	2009(Est.)
7,717	7,208	6,112	5,368	5,199	6,069	6,622	6,693	7,035

Table I: Population of Rappahannock County from 1930 to 2009

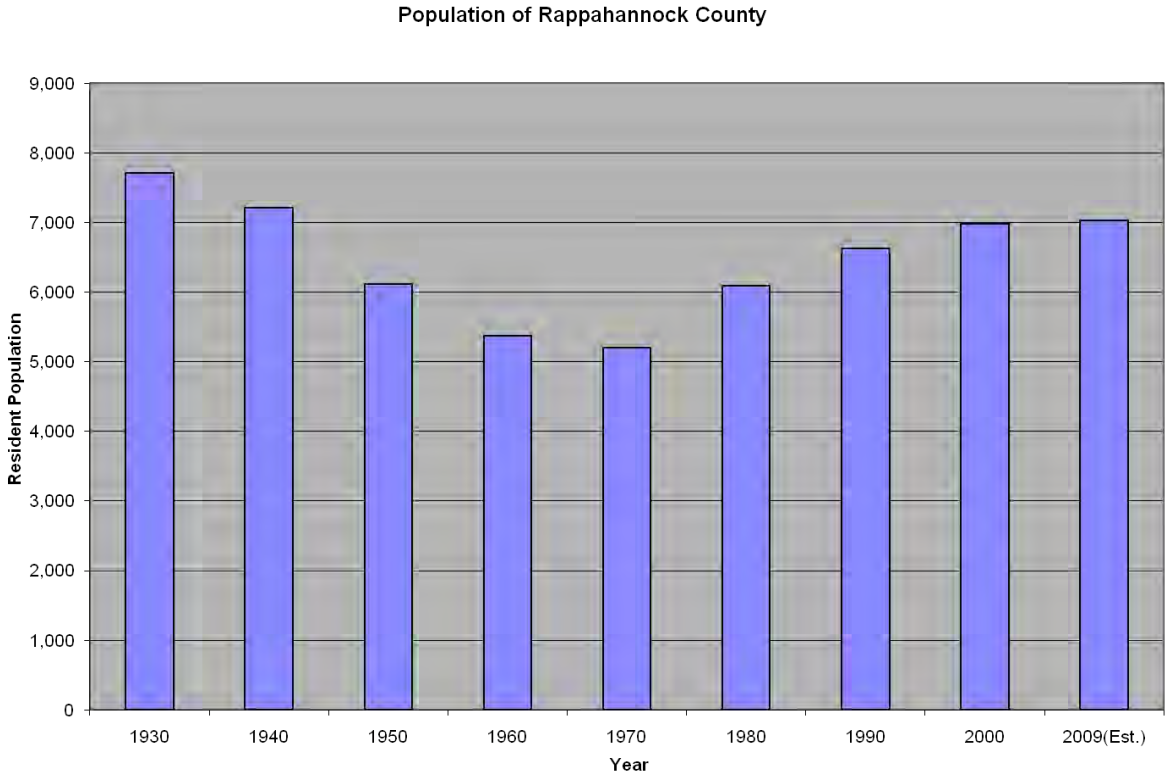


Figure II- Trends in the Population of Rappahannock County from 1930 to 2009

Residential Water Usage

Using an estimate of 85 gallons per day per person (source: DEQ WSP guidelines and USGS Water Use Data), the average daily residential water use in 2009 can be calculated to be 597,975 gallons per day (0.598 million gallons per day) if totaled County-wide for all 7,035 residents. Hence residential water use is estimated at 218.26 million gallons per year.

It is not immediately obvious whether larger populations in the past also meant greater total water use. The patterns of water use for agriculture (irrigation and livestock watering), wildlife-game management, commerce and materials processing, firefighting and sanitation have all likely undergone some changes during the 1930 to 2009 period.

Additional detailed population and water use information is found in Sections II and III.

Climate

Rappahannock County has historically enjoyed a temperate, comfortable climate (annual average temperatures near 56 degrees Fahrenheit) with generally mild to rigorous, but not severe, winters which usually include some snowfall between November and March. Moderate to warm summers usually include frequent thunderstorm activity. Average rainfall is interpolated as 43 inches per year (PRISM) and is well distributed throughout the year. Basically, the County's climate is influenced by the Blue Ridge Mountain range to the west and by the Atlantic Ocean and Chesapeake Bay to the east.

The typical growing season (from the last freeze in spring to the first freeze in autumn) is 181 days. Freezes usually do not occur between April 20 and October 18. However, freezing temperatures have occurred as late as May 17 and as early as September 25. (Climate data extrapolated from Culpeper County meteorological station 1951-1990).

Topography, Geology, and Physiography

Rappahannock County occupies a topographic position ranging from 360 to 3,720 feet above mean sea level. The lowest point in the County is the point at which the Rappahannock River crosses into Culpeper County. The highest point is The Pinnacle, which is located in the southwestern part of the County on the Page County boundary. There is little or no contiguous land mass at any higher elevation In Virginia to the west of the County.

As further discussed in Section IV, Rappahannock County landforms are associated with both the Blue Ridge Physiographic Province and the Piedmont Physiographic Province. In the west, the majority of the County's land area shares its characteristics with the Blue Ridge Physiographic Province. This includes the Blue Ridge Mountains and the neighboring foothills. This province is typified by steep and rugged terrain. Land surface altitudes or elevations in the Blue Ridge Physiographic Province primarily range from 1,000 to 3,500 feet.

To the east, a swath of the County with lower elevation land surfaces, ranging from 360 to 1500 feet above mean sea level, are primarily associated with the Piedmont Physiographic Province based on its appearance and landforms, though not on its geology. The Piedmont Physiographic Province is typified by gently sloping to moderately steep terrain. The smoother part of the Piedmont Physiographic Province is mostly sloping to gently sloping with some moderately steep areas. Elevations range from 360 to 900 feet. This province, especially in the Woodville area, is occasionally

broken by long, low mountains or hills. Most of the mountains in the Piedmont Province are moderately-steep to steep, with crests ranging from 900 to 1,500 feet above mean sea level.

Geologic conditions throughout the County include various types of fractured bedrock. All of the bedrock is of the Blue Ridge Geologic Province, as discussed in Section IV. The fractured bedrocks that underpin the land influence water resources that may flow within and across such structures in the continuum of ground water and surface water. Throughout Rappahannock County, bedrock fractures influence the percolation, storage and flow of groundwater. Fractures and erodible bedrock types and fracture orientations allow stream courses to form between the more resistant or massive bedrock, which forms the ridges. Geological conditions also influence the relative 'suitability for development' of landforms by virtue of the slope, soil types and soil thicknesses that blanket the geologic formations.

Below is a map showing the topography of Rappahannock County and the major streams. (An additional map of the major geologic bedrock types is provided in Section IV.)

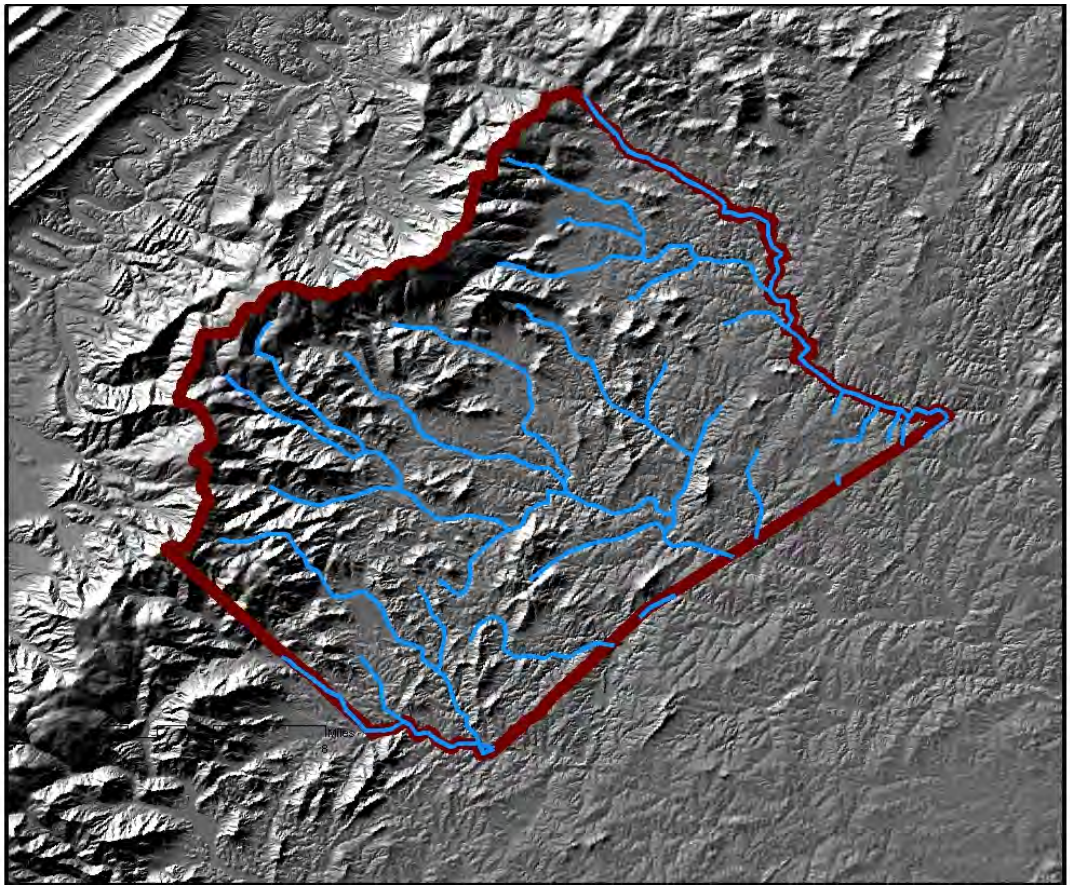


Figure III- Rappahannock County Topography and Major Streams

Source: NHDPLUS (To avoid obscuring topological details, see Fig. IV for Stream names.)

Watershed Characteristics

The headwaters of the County's major streams originate in the steeper slopes of the Blue Ridge Physiographic Province and streams flow down across the more gently sloped Piedmont Physiographic Province where they are joined by additional tributaries. Most of the small streams flow southeastward, perpendicular to the mountain ridges that divide the County into numerous sub-watersheds as shown in Figure V. The Piedmont Physiographic Province is an old plain that is strongly dissected by many small streams that flow in narrow, winding valleys. Drainage in the County is well developed with numerous flood plains. Flood plain soils account for 7,518 acres of land or 4.4% of the County. Total river and stream surface area is estimated at 195 acres.

Each of the Rappahannock, Thornton, Rush, Covington, and Hazel Rivers has its source in springs in the Blue Ridge Mountains. Battle Run, a tributary of the Thornton River, has its source in a mountain to the southeast of the Blue Ridge. The Rappahannock and Jordan Rivers drain the northern part of the County; the Thornton, Rush, Covington, and Piney Rivers drain the central part; and the Hazel and Hughes Rivers drain the southern part. Eventually, the Thornton River, having collected the flow from the other central drainages has a confluence with the Hazel River in Culpeper County, and it is the Hazel River that carries the flows into the Rappahannock River. Below is a map showing the streams in Rappahannock County.

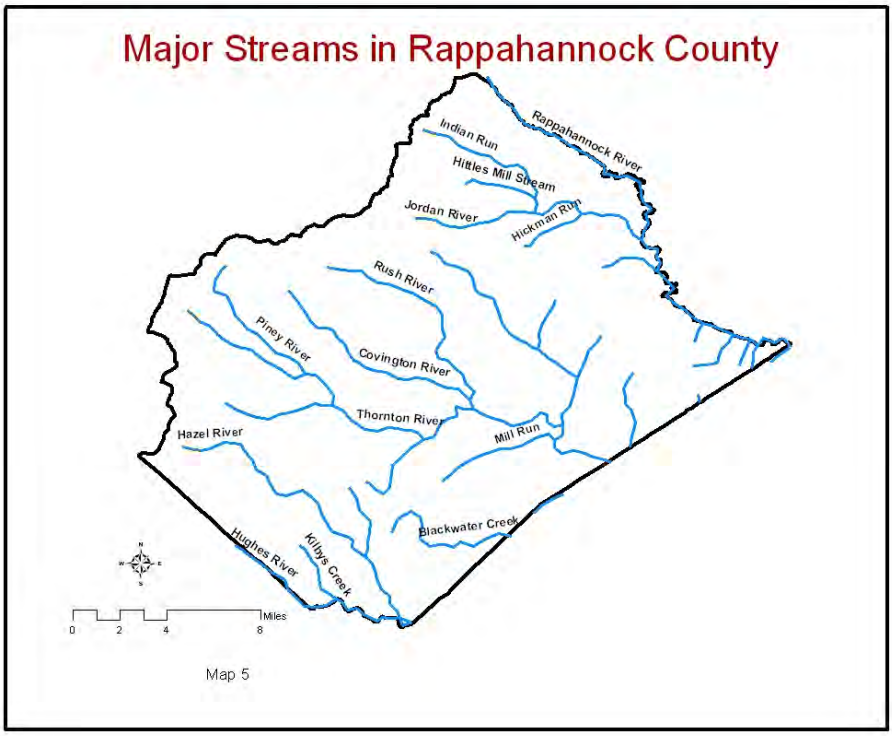


Figure IV - Major Streams in Rappahannock County (NHDPlus)

(Note: The stream to the east of the Rush River, Battle Run, is not labeled on the map.)

The total of river and stream course surface area in Rappahannock County is estimated at 195 acres. The number and surface area of ponds is not known at this time.

Water Resources and Water Sources

Precipitation, springs, wells, streams and ponds have historically provided adequate water for people and livestock, other agriculture, forests and game lands in the County during a "normal" range of weather conditions. Approximately 95% of the residences in the County depend upon private wells, springs or streams for their drinking water. Ground water quality in the County is generally good, although excessive hardness and acidic conditions are occasionally encountered.

Since the 1980's there have been increasing efforts to protect the quality of the County's water resources and to evaluate in some detail the quantity of water available to support a growing population and/or a shifting economy. To that end, several focused efforts have been undertaken to monitor and evaluate impacts on the County's water resources that result from variations in weather patterns, shifts in land use patterns and changes in water use and reclamation practices. To date these investigations have included:

- A well water testing program
- The DRASTIC ground water pollution potential study
- A set of Source Water Assessments for specific public water systems
- A study of groundwater resources, in the Sperryville area, to gauge specifically whether the shift from septic systems to sewered waste water collection would lower the ground water table and impact the individual wells that supply each water user in that village
- Citizen macroinvertebrate (VASOS) stream monitoring to serve as an indirect measure of not only water quality from surface water runoff, but also to gauge whether stream flow quantity from summertime base flows of ground water into stream beds is adequate to sustain in-stream biotic communities

Sections IV and VIII present a comprehensive analysis of the water resources in the County, using a "water balance" approach that takes into account the entire water budget, including water use, precipitation, water recycled to the atmosphere (evapotranspiration), stream flow, and groundwater recharge. This initial evaluation employs long-term averages. As discussed in the meteorological evaluation, recent experience of prolonged drought conditions within the County suggests that the water balance needs to be reassessed under more current conditions of less rainfall. Monitored data on water levels and spring flows will help to determine the impacts on ground water recharge, storage, flow and availability.

Land Use and Land Cover

Forests

Rappahannock County contains considerable forestland, much of which is deciduous, i.e. hard wood of an oak and hickory type. In 1981 approximately 105,795 acres or 62% of the total County land area was forestland. The figures for 1992 showed a statistically insignificant decline to 105,446 acres. Approximately 70% or 73,707 acres of this forestland was classified as commercial forestland and 31,739 additional acres were considered "productive reserve" or forestland sufficiently productive to qualify as commercial forestland, but withdrawn from timber utilization through statute or administrative designation. This additional acreage probably refers to forestland in the Shenandoah National Park. Forested lands are a significant contributor to the total water resources of the County because forests promote water retention in soils and because of evapotranspiration (ET) during the leaf-out season. Evapotranspiration is the natural process whereby living plants take up water and then subsequently release it back into the atmosphere.

Cattle Farming

Beef cattle operations in the County grew steadily in importance over the past several decades, both as a principal farming operation and as one aspect of integrated farm management plans. Since 1986, for example, the number of beef cattle and calves increased from 11,900 to 15,500 in 1992, 16,041 in 1997, and 17,548 in 2002. More recently, the trend has been downward, attributable primarily to market conditions. There were approximately 13,000 head of beef cattle in the county during 2010. (Kenner Love, Rappahannock County Agricultural Extension Agent)

Water use by beef cattle in 2010 is estimated at 47.450 to 85.410 million gallons per year. Water for cattle comes from open stream drinking and from BMPs like watering troughs or ponds supplied by springs, wells, or streams.

Shenandoah National Park

The map below illustrates the area of the Shenandoah National Park in the County, shaded in light blue. The Park's protected lands help to protect the headwaters of most streams in the county, ensuring clean and reliable water sources.

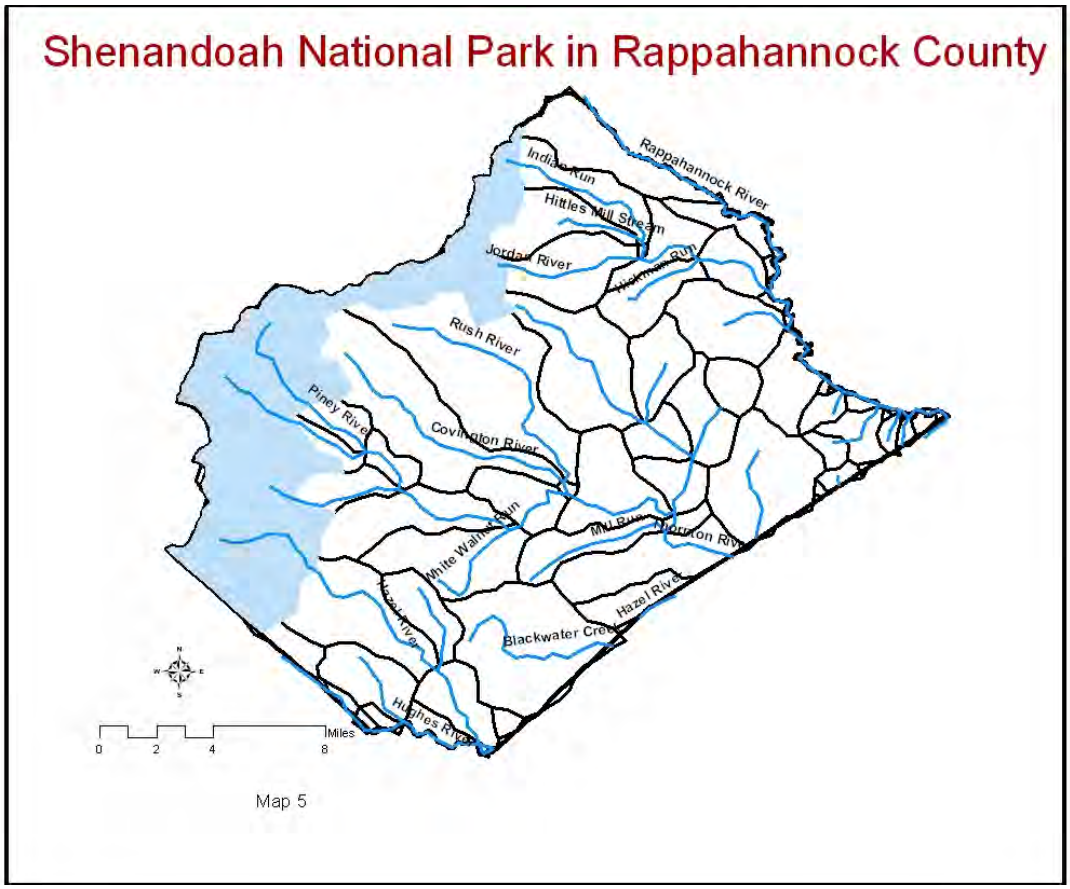


Figure V – Shenandoah National Park in Rappahannock County

Positive Factors That Affect Land Use, Development and Potential Water Savings

There are several factors that have a positive impact on retaining the rural character of Rappahannock County as well as the ability to maintain water retention within the County.

The Rappahannock County Comprehensive Plan emphasizes the use of Low Impact Development (LID) practices during the design and the construction of new residences. LID practices include the use of riparian buffers, water saving measures such as rain barrels, and minimizing the effects of impervious surfaces through proper drainage practices. In addition, the RCCP business area for development in the County is limited to an area 2.5 miles east of Sperryville to 1.5 miles west of Washington along the U.S. Route 211 Corridor.

The Shenandoah National Park, which is critical to maintaining upland water resources, is protected from development, so that streams, springs and natural drainage will be maintained.

There is an active program within the county to place land in conservation easement. Conservation easements provide protection from future development. In 2010, there were 27,000 acres in conservation easement in Rappahannock County (Rappahannock County Conservation Alliance - RCCA).

The Culpeper Soil and Water Conservation District (CSWCD) is actively assisting farmers to develop riparian buffers along stream corridors. This work is funded by the Conservation Reserve Program of USDA and through other grants. Riparian buffers serve three important functions. First, they protect the streams from pollutants carried in runoff (nutrients, bacteria, pesticides and herbicides). Second, they help to restore and maintain the stream banks, which prevent erosion. Third, the buffers can help prevent excessive runoff by giving precipitation a greater opportunity to be absorbed, replenishing groundwater rather than draining into the streams and flowing out of the County. Currently, 702 riparian acres of County land have been placed in these protective buffers. (Greg Wichelns, Director, CSWCD).

SECTION II: Existing Water Sources – (9VAC25-780-70)

Community Water Systems Using Ground Water Sources

The town of Washington is served by the only community water system within Rappahannock County. There are two wells available as sources in the system. The newer Well #3 is the well that is customarily used, while the refurbished Well #1, currently inactive, is always available as a backup well. This provides sufficient redundancy/reliability to meet VDH requirements for community water systems that have more than 50 connections. In 2010 there were 133 people in the Town, with 134 connections. The water system serves the residents and several commercial and government offices. The largest user is the Inn at Little Washington, followed by County offices and two Bed and Breakfasts. The design capacity for the system is 108,000 gpd (Source: VDH Office of Drinking Water System Sanitary Report, dated September 1, 2009). There is a 200,000 gallon reservoir tank used in the water supply system.

Well #3 has an 8-inch diameter to a total depth of 205 ft., the casing extends to 56 ft. below land surface, and the remainder of the borehole, to 205 ft. depth, is an open borehole through fractured bedrock. The driller's log for the well indicates that within the open borehole section two water-bearing zones were encountered: one at depths between 65 to 70 ft. and another at 160 to 165 ft. below land surface. Stabilized yield from Well #3 is 150 gpm.

The driller's log for Well #1 has not been located although the June 30, 1992 VDH Engineering Description Sheet provides the following information. The Well #1 yield is 35 gpm when operated with Well #3. The capacity is 100 gpm when used alone. Well #1 is rarely used other than at times when there is maintenance needed related to Well #3.

Water System Name (PWSID)	Number of Wells	Permitted Number of Connections	VDH Permitted System Capacity (gpd)	Withdrawal Design Capacity: AVERAGE DAILY (gpd)	Withdrawal Design Capacity: MAXIMUM DAILY (gpd)	Well Yield (gpm)
Town of Washington (# 6157400)	2	N/I	108,000	-	-	-
Well 3	-	-	-	121,500	216,000	150
(Backup) Well 1	-	-	-	81,000	144,000	100

Table II Town of Washington Well Information

AVERAGE DAILY water yield is calculated for Well #3 as follows:
* multiply Well Yield by 60 minutes in an hour and by 13.5 hours, which is the assumed average daily operating time during the maximum month of water use for a well. With no more than 13.5 hours of operating time and at least10.5 hours of resting time the groundwater drawdown in a well is allowed to recharge, rise and recover to near static water levels each day. [150 * 60 * 13.5 = 121,500 gallons per day (gpd)]

For MAXIMUM DAILY:
* multiply Well Yield by 60 minutes in an hour and by 24 hours. This calculation acknowledges that when unusual demands are experienced by a system, it may have to operate for up to 24 hours per day, but this operation cannot be sustained for multiple days under VDH guidelines.

Usually if, as in this case, the VDH Permitted System Capacity (108,000 gpd) is less than the estimated Design Capacity for Average Daily Withdrawal (121,500 gpd), it indicates that available storage or treatment filtration rates, or another system component is the limiting factor.

There are no applicable DEQ permitted withdrawal limitations for the Town of Washington community water system, nor on any other ground water user, since Rappahannock County is not located within a Ground Water Management Area.

Community water systems using surface water reservoirs or interconnected reservoirs

There are no community water systems using surface water reservoirs or operating interconnected reservoirs in Rappahannock County.

Community water systems using surface stream intakes or springs

There are no existing community water systems using surface water intakes in Rappahannock County.

Self-supplied users of more than 300,000 gallons per month of surface water for non-agricultural uses

There are no existing self -supplied users of more than 300,000 gallons per month of surface water for non-agricultural uses. A few facilities with the capacity to use water at these rates from surface water sources for playing field watering and game management facilities (pond level maintenance) are located in the lower reaches of Battle Run and the Thornton River in the Laurel Mills vicinity, but are not currently (2009, 2010) established reporting users.

Self-supplied users of more than 300,000 gallons per month of ground water for non-agricultural uses

There are no existing self -supplied users of more than 300,000 gallons per month of ground water for non-agricultural uses.

Ground or surface water to be purchased from water supply systems outside the geographic boundaries of the planning area

There is no water being purchased from outside the Town of Washington or Rappahannock County from other water supply systems.

Water available to be purchased from water supply systems outside the planning area from any source with the capacity to withdraw more than 300,000 gallons per month of ground or surface water

There is no water availability of this category for the Town of Washington or Rappahannock County.

Existing Water Sources for Agricultural Users of More Than 300,000 gallons per month of Ground Water and/or Surface Water

With 194 cattle operations, and an estimated upper limit water use of 108 MGY, the average monthly water use is approximately 46,000 gallons per month. There are no cattle operations identified existing agricultural water users of more than 300,000 gallons per month in Rappahannock County. There are numerous smaller agricultural water users. These water users are discussed and the agri-business water source capacity is estimated in the following section on water users of less than 300,000 gallons per month.

Existing Water Sources for Self-supplied users of less than 300,000 gallons per month

The **existing** currently developed source capacity of individual private groundwater wells, and other private users' water sources of less than 300,000 gallons per day is estimated to serve more than 2,673 residences with a population of 6,683 residents, plus some weekenders and seasonal habitants, and to serve approximately 340 businesses (including sole proprietorships) supporting employees and serving customers and visitors, as well as supporting livestock and crops. These water sources and capacity to serve were estimated as follows:

Residential Water Users

It has been estimated that 95% of the residents of Rappahannock County use private groundwater wells. Traditionally some mountain and farm homes have utilized spring systems or pond-stream intakes or cisterns for household water, and these practices continue. That means that approximately 352 people out of the population of 7,035 are not on individual groundwater wells. 133 of these people reside in Washington, and the

remaining 219 people can be assumed to be using springs, surface water, or cisterns. That leaves approximately 6,683 citizens using individual groundwater wells, with each well withdrawing less than 300,000 gallons per month.

DEQ guidance, based on the 2000 U.S. Census, gives an average density of 2.50 persons per household for Rappahannock County. Based on that, approximately 2,673 households use private groundwater wells. This includes the residences in each of the villages of Amissville, Flint Hill, Sperryville, Chester Gap and Woodville. About 323 of these residences are also workplaces for residents and staff. Some residential properties are likely to also provide shelter, feed and water for hobby livestock such as horses and ponies.

If each resident household has one well, there are at least 2,673 individual wells making withdrawals within the County. Some additional "residential" wells are likely associated with properties that are occupied principally on weekends or seasonally, by people who are not counted as residents in the Census, but who do use water periodically.

Business and Institutional Water Users (Non-Agricultural)

Among the approximately 340 places of employment, including sole proprietorships, throughout Rappahannock County, as of 2011 there are five Non-Transient Non-Community water systems and three (transient) Non-Community water systems that serve the public using individual well systems as groundwater sources. These systems are regulated by the VDH. They are listed in the table below, with the number of persons each water system serves or has permitted capacity to serve.

Non-Transient Non-Community PWS		**(Transient) Non-Community PWS**	
	People Served		People Served
Child Care & Learning Center	75	Blue Rock Inn	59
Hearthstone School	75	Griffin Tavern	162
Wakefield Country Day School	291	Sperryville Corner Store	97
Rappahannock Elementary School	620		
Rappahannock High School	446		

Table III Business and Industrial Water Users

County-wide, there are sixteen inns and lodgings serving meals. Five are in Washington and are served by the community water system. Of the remaining 11 which are self-supplied for water, three are just outside Washington, five are in Sperryville and three are on rural farms or vineyards.

Other facilities or businesses using individual water supplies include five volunteer fire companies: Sperryville, Flint Hill, Amissville, Chester Gap, and Castleton. The Washington Volunteer Fire Company uses the town of Washington's system for its water supply.

Agri-Business Water Users

The NASS reports that in 2007 there were a total of 416 farms covering 65,084 acres in Rappahannock County. Further, 102 of those farms report having hired farm labor totaling 260 employees. Seventy-four of these employees work on farm jobs more than 150 days a year, while 186 employees work less than 150 days per year. Capacity for drinking water and daytime sanitary water uses for these employees may be part of the developed source capacity for these farms.

Irrigation

From among Rappahannock County's 416 reporting farms, 27 farms reported having a total of 131 acres of irrigated lands during 2007. Those numbers constitute fewer farms and less acreage than were reported in 2002. The Year 2002 NASS survey results suggest that 334 acres of farmland in Rappahannock County had irrigation sources developed for them, but not all of this was being utilized in 2007. With a few uncertainties, it appears that most irrigated plots are less than 10 acres in size. Both harvested croplands and pasturelands were among the irrigated acreage. The source of water (e.g. springs, ponds, streams or groundwater wells) was not noted in the survey.

Livestock watering and care

Beef cattle are readily identifiable as the largest livestock population in Rappahannock County. The NASS livestock inventory data is summarized in the following table.

	Farms	Number of Animals
Cattle & Calves	194	11,869
Hogs & Pigs	13	80
Sheep & Lambs	14	347
Horses & Ponies	121	767
Layers	46	1,275
Broilers	16	1,136

Table IV – NASS Livestock Inventory

Source Water Assessment Program (SWAP) Findings

The SWAP program is administered by VDH. In 2006, it identified the following public water supplies (PWS) as having a high susceptibility to contamination:

Child Care & Learning Center NTNC
Flint Hill Public House NC
Hearthstone School NTNC

The Blue Rock Inn NC
Wakefield Country Day School NTNC
Rappahannock Elem School NTNC
Rappahannock High School NTNC

Town of Washington Community

The SWAP Susceptibility for each of these PWS facilities was rated "high" in assessments during 2002 and 2003. The primary reason for these PWS facilities to have a high rating is because there are no confined aquifer layers in Rappahannock County, so that any nearby contaminant sources can get into the well. It should be considered bad practice to place contaminant sources near these wells. The same susceptibility will exist for private residential or other wells. Therefore, it should be considered good practice for all well owners to ensure that there are no contaminant sources close to their wells.

DRASTIC Analysis

The DRASTIC analysis (circa 1988) was developed by the National Water Well Association under contract to EPA. The methodology is named for the seven parameters used to evaluate groundwater: Depth to groundwater, net Recharge, Aquifer media, Soils, Topography, Impact of vadose zone, and hydraulic Conductivity. The results should be considered to be generalized, with a resolution of 100 acres or more. The DRASTIC results identified six areas of concern:

1. Rappahannock Lakes, located in the northeastern portion of the County. It has generally shallow and poorly drained soils.
2. Sperryville, having floodplain soils combined with a generally high water table
3. Poe's Cabin, a river alluvium with very shallow depth to groundwater
4. Covington River, characterized by shallow depth to groundwater
5. Laurel Mills, having a very sandy, porous filtration media
6. Amissville, characterized by sandy loam soils and moderate depth to groundwater

Groundwater Quantity Evaluation (July 8, 1996) and Monitoring of Well Depths in Sperryville by ENSAT Corporation between June 1999 and January 2003

The reason for this work was concern that the transition from septic systems to a sewer system could have a negative impact on the groundwater. The groundwater quantity evaluation included a detailed fracture analysis and evaluations of recharge potential for the Thornton River in the Sperryville area. This study found that the groundwater withdrawals would have a negative impact on the base flow of the Thornton River in low flow periods and a large-volume groundwater withdrawal could seriously impact the water levels in existing wells.

The regular monitoring the three wells in Sperryville did not find any conclusive lasting changes in depth-to-water at the three wells. The monitoring data showed no particular trends over time in the depth-to water at these wells.

SECTION III: Existing Water Uses – (9VAC25-780-80)

Within Rappahannock County there is only one community water system, which is owned and operated by the Town of Washington. 100% of the Washington residents are served by the system. It withdraws groundwater through two wells and serves potable drinking water inside the boundaries of the town of Washington and to some existing adjoining properties along roadways, including the Washington Volunteer Fire Department and the Washington WWTP.

Water System Name (PWSID)	Number of Wells	Population Served	Number of Connections	Average Daily Withdrawal (MGD)	Maximum Daily Withdrawal (MGD)
Town of Washington (6113300)	2	133	134	*0.031*	0.061
Well 3	-	-	-	**0.031**	-
Backup Well 1	-	-	-	N/A	-

Table V - Water Use Data for Year 2010 – Town of Washington

According to Laura Dodd, Town Manager, the highest commercial use tends to be in October and the lowest use is in August. The water withdrawal and use in Washington for the years 2009 and 2010, by month is shown in the table below.

Month/Year	Gallons Pumped	Backwash	Billlable Gallons	Gallons Billed	Unknown/loss
Jan-09	881,000	42,800	838,200	770,261	67,939
Feb-09	758,000	34,000	724,000	647,583	76,417
Mar-09	771,600	45,100	726,500	638,593	87,907
Apr-09	819,400	44,900	774,500	606,159	168,341
May-09	902,300	45,200	857,100	761,010	96,090
Jun-09	847,100	40,900	806,200	767,860	38,340
Jul-09	1,005,400	44,800	960,600	868,535	92,065
Aug-09	1,047,500	41,800	1,005,700	867,855	137,845
Sep-09	849,200	32,700	861,500	834,954	26,546
Oct-09	910,600	42,400	868,200	914,230	-46,030
Nov-09	833,300	44,300	789,000	721,284	67,716
Dec-09	925,460	45,400	880,060	680,547	199,513
Jan-10	1,001,240	40,100	961,140	649,100	312,040
Feb-10	778,200	44,500	733,700	719,450	14,250
Mar-10	833,600	41,600	792,000	550,619	241,381
Apr-10	865,300	42,400	822,900	953,290	-130,390
May-10	1,014,600	47,500	967,100	765,644	201,456
Jun-10	1,048,400	36,800	1,011,600	868,870	142,730
Jul-10	1,391,200	36,200	1,355,000	1,110,910	244,090
Aug-10	1,167,000	37,000	1,130,000	1,227,121	-97,121
Sep-10	1,064,300	43,400	1,020,900	1,016,520	4,380
Oct-10	993,800	37,300	956,500	842,110	114,390
Nov-10	845,500	43,100	802,400	712,730	89,670
Dec-10	817,500	37,400	780,100	699,555	80,545
Total	22,371,500	991,600	21,424,900	19,194,790	2,230,110
Monthly Average	932,146	41,317	892,704	799,783	92,921
Daily Average	30,646	1,358	29,349	26,294	3,055
Percent of Gallons Pumped		4.43%	95.77%	85.80%	9.97%
Average Annual Water Use (MGD)	11.186	0.496	10.712	9.597	1.115

Table VI - Monthly Water Use in Washington For 2009 and 2010

Note that the "Unknown/Loss" amount is less than 10%. The chart below shows the pattern of gallons pumped and gallons billed by month for 2009 to 2010:

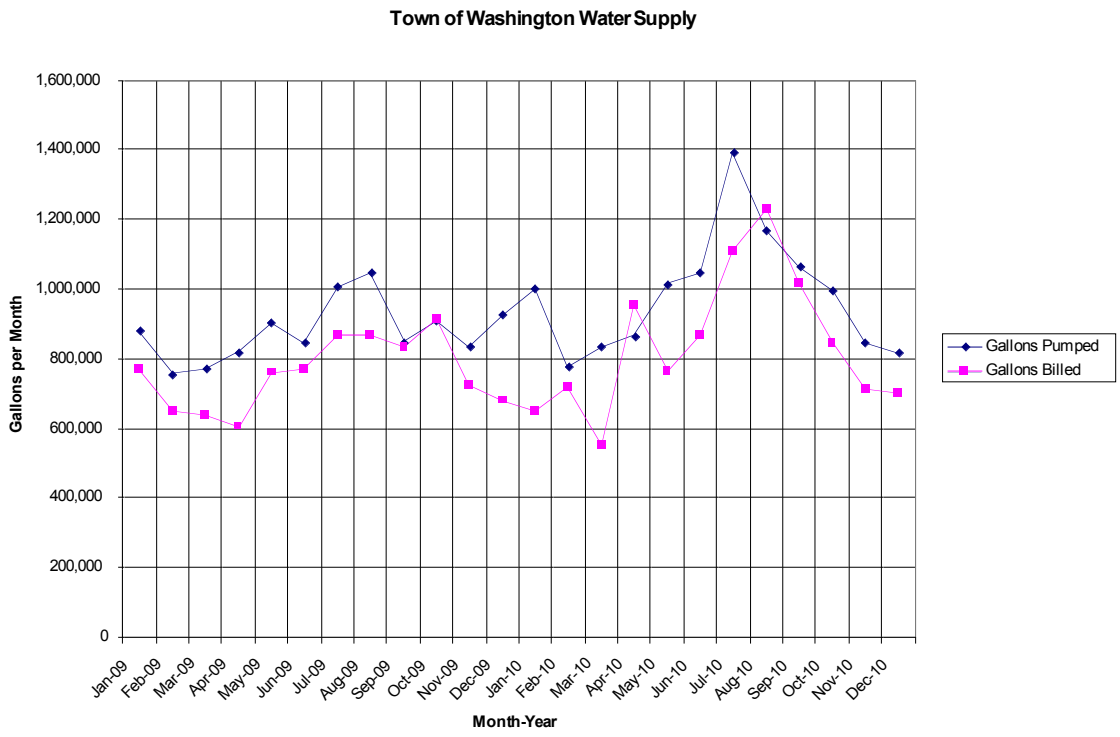


Figure VI - Gallons Pumped and Gallons Billed in Washington for 2009 to 2010

Note that there are what appear to be a couple of anomalies when the gallons billed are greater than the gallons pumped. However, these months are preceded by months when the gallons pumped is significantly higher than the gallons billed. This is most likely due to a lag effect when there was significant pumping to fill the 200,000 gallon storage tank in that preceding month.

Peak daily water withdrawal by month in Washington for 2010 is shown in the table below. These values are based on the meter readings at the pump. Because of the 200,000 gallon storage tank, some judgment was needed to arrive at the values. For instance, a day with a high amount of pumping that is preceded by a day of low pumping is not precisely reflective of the peak demand because a large portion of that day's pumping would be used for filling the storage tank.

Month	Day	Gallons
January	16	43,200
February	14	41,300
March	7	36,700
April	2	38,200

May	16	35,700
June	26	46,400
July	12	60,900
August	23	53,600
September	26	39,800
October	9	35,500
November	27	37,800
December	28	34,800

Table VII - 2010 Peak Daily Pumping By Month for Washington

Note the high monthly and peak daily values for July, August, and September, which most likely reflect increased watering of lawns and gardens during the peak drought period in 2010. Also, it should be noted that the system design capacity of 108,000 gpd is nearly double the peak usage rates.

There are 134 individual accounts for the water supply system in Washington: 49 commercial (2 inactive), 55 residential, and 20 users outside of town. A breakout of water usage in Washington by residential vs. commercial usage is not normally tracked by the town, but a breakout for three months that reflects the range of this differential was performed by Laura Dodd, Town Manager. Note that this analysis only includes Residential vs. Commercial usage, not total usage shown in the previous table. This breakout is shown in the table below.

Month	Total Billed (gallons)	Total Residential (gallons)	Total Commercial (gallons)
February	703,101	252,795	450,366
July	1,034,539	447,609	589,930
October	842,110	257,060	585,050

Table VIII Water usage divided by residential and commercial for three months in 2010

There are no self-supplied nonagricultural users of more than 300,000 gallons per month in the CWS

There are no self-supplied agricultural users of more than 300,000 gallons per month in the CWS

There are no self-supplied users of less than 300,000 gallons per month in the CWS

It must be acknowledged that individual water usage estimates are just that: estimates. However, the chart above gives us an opportunity to "test the waters", so to speak. In the town of Washington, with 133 residents, the above chart gives us the actual total residential water usage for three months in 2010. We can therefore calculate that in February of 2010, over a period of 28 days, each of the 133 residents used an average of 68 gallons of water per day. In July, the same 133 residents used an average of 109

gallons per person per day. This variability could be the result of hotter weather, more showers taken, the increased consumption due to weekend guests or the effects of watering parched gardens. Nonetheless, despite all the possible variables, the average water consumption in the two months is 88.5 gallons per day per person. This gives a measure of credence to the figures used in our estimations.

There are no self-supplied nonagricultural users of more than 300,000 gallons per month, on an annual average basis, outside of the Washington CWS

There are no self-supplied agricultural users of more than 300,000 gallons per month, on an annual average basis, outside of the Washington CWS

Estimated Existing Water Use by Self–Supplied Users of Less than 300,000 gallons per month

Residential

It has been estimated that 95% of the residents of Rappahannock County use private groundwater wells. That is approximately 6,683 people in residences using groundwater wells, with each well withdrawing less than 300,000 gallons per month -- out of an estimated total population of 7,035 residents (Yr. 2009 est.). This excludes all of the 133 residents of Town of Washington.

DEQ guidance, based on 2000 U.S. Census, gives an average density of 2.50 persons per household for Rappahannock County. Based on that, approximately 2,701 households use private groundwater wells. This includes the residences in each of the villages of Amissville, Flint Hill, Sperryville and Woodville. About 323 of these residences are also workplaces for their residents and in some cases, for additional staff. Some residential properties are also likely to provide shelter, feed and water for hobby livestock such as horses and ponies.

If each resident household has one well, there are more than 2,673 individual wells making withdrawals within the County. The additional "residential" wells are those likely associated with properties that are occupied principally on weekends or seasonally, by people who are not counted as residents in the Census, but who do use water periodically. Traditionally some mountain and farm homes have utilized spring systems or pond-stream intakes or cisterns for household water, and this practice continues.

Consumption estimates can vary, but each person uses on the order of 80-100 gallons of water per day [85 gallons per person per day (source: '2000 Census' and USGS http://ga.water.usgs.gov/edu/qahome.html USGS Water Science for Schools website)]. Using the 85 gallons per person per day figure to calculate, the average daily residential water use in Rappahannock County in 2009 would be 597,975 gallons per day (0.598 million gallons per day) for all 7,035 residents. Residential water use is thus estimated at 218.26 million gallons per year.

As of 2009, an estimated 6,683 persons (95% of the County population) in approximately 2,673 households (2.5 persons per household) use an annual average 568,055 gallons per day of ground water from wells that withdraw less than 300,000 gallons per month. This is an annual total water withdrawal of 207,340,075 gallons of water per year (365 days).

For planning purposes we have used the high end of the USGS estimated range, i.e. 100 gallons per person per day, to estimate water use from residential wells, springs, etc., because in Rappahannock County's rural setting we must account for other water uses from individual wells, i.e. weekend and seasonal dwellers, tourists, hobby livestock and garden produce processing, as well as in-home workplaces, and a significant number of retired and semi-retired residents who are at home using water for more of the day. There is evidence that this per person water use figure may not be accurate for the village of Sperryville, where wastewater discharge per connected household per day is significantly lower. There are at least two reasons for this: (1) there are a significant number residences used for small businesses and shops in the village; and, (2) there are a number of residences identified as having only one individual in residence.

For the year 2009 estimated County population of 7,035 residents total, there are an estimated 6,902 persons living outside the Town of Washington community water system service area. In addition to the groundwater well users the remaining 219 residents are assumed to use water from springs or cisterns. Because these users currently comprise only about 3.11% of the county population, and because their use would likely be converted to groundwater withdrawals eventually, this planning document groups the individually self-supplied spring- and cistern-users with the groundwater users for assessment and planning purposes.

Schools

Water use for the elementary and high schools can be estimated using figures for the average discharge at the small WWTP's at each school. The average WWTP discharge at the elementary school is 4,000 to 6,000 gpd, at the High School it is 2,000 to 2,500 gpd.

Non-agricultural Businesses

Business water use can only be estimated – the use of water at businesses is highly variable and the total number of businesses varies over time and is not known precisely. Minimally, business water use will usually include drinking water and coffee, toilets and hand washing for employees and janitorial water use. Outside the town of Washington, there are an estimated 11 Accommodation and Food Service Facilities (16 total minus the five in the town of Washington) as well as a variety of other small businesses. For water supply planning purposes, a "ballpark" estimate of 20 total commercial establishments outside of Washington will be used. If we estimate the average use by these commercial establishments to be similar to a typical residence, then the total water use would be 4,250 gpd.

Agri-business and Silviculture

In our inquiries for information about water use for crop irrigation the most common response was – we are simply grass farmers, hay and straw dominating, and don't use supplemental irrigation. Those crops are consistent with the raising of cattle in many cases, but they do not constitute the whole picture for agricultural water use in Rappahannock County. There are, of course, other crops raised, notably vineyards supporting wineries, a variety of vegetables, melons, eggs, peaches and apples from orchards, berries and grain for livestock as well as wildlife-game management lands.

The data reported for farm income tax purposes is summarized below from the NASS. The NASS indicates that in 2007 there were a total of 416 farms covering 65,084 acres in Rappahannock County.

Further, 102 of those farms report having hired farm labor, totaling 260 employees – 74 of these employees work on farm jobs more than 150 days a year, while 186 employees work less than 150 days per year.

Irrigation

The 416 farms reported having a total of 131 acres of irrigated lands during 2007, which was less than reported in 2002. Despite a few uncertainties, it appears that most irrigated plots are less than 10 acres in size. Both harvested croplands and pasturelands were among the irrigated acreage. The source of water for irrigated land, e.g. springs, ponds, streams or groundwater wells - is not noted in the survey. The 2002 survey results suggest that over 300 acres have had irrigation sources developed for them in Rappahannock County, but not all of this capacity was utilized in 2007.

For estimating purposes, in a year during which most of the existing potential irrigated acreage is, in fact, irrigated, one inch of water applied to 300 acres equals 300 acre-inches, which represents 8,146,200 gallons of water. It is not known how much of this water would be taken from developed sources capacity such as wells or pumped stream withdrawals and how much would be taken from direct rainfall, etc. The salient fact is that only 131 to 334 acres of irrigated farm lands were reported county-wide in the 2007 census of agriculture.

Non-Irrigation, i.e. Livestock

Table VII estimates the water use for NASS Year 2007 surveyed livestock inventory, supplemented by USGS SIR 2009-5041. The gallons per day and MG per year values use the upper limit of the water requirements per day.

Rappahannock County – (NASS 2007)	Farms	Number of Animals	Water Requirements gallons per animal per day	Gallons per day used for all animals of this type	MG per year for all animals of this type
Cattle & Calves	194	11,869	8-25	296,725	108
Horses & Ponies	121	767	8-25	19,175	7
Sheep & Lambs	14	347	2-4	1,388	0.51
Hogs & Pigs	13	80	2-8.1	648	0.24
Layers (Hens)	46	1,275	0.02-0.12	153	0.06
Broilers	16	1,136	0.02-0.12	136	0.05
TOTAL water use: all livestock	-	-	-	318,225	115.86

Table IX - Estimated Water Use by Livestock Type

SECTION IV: Existing Resource Conditions – (9VAC25-780-90)

Aquifer flow in Rappahannock County is primarily fractured bedrock with widespread small withdrawals across the County. Rappahannock County is located at the top of its groundwater and surface water watersheds. The crest of the Blue Ridge Mountains forms the County's western boundary meaning that there is no significant volume of water resource stored above it since there is no land mass there to hold it. This means that precipitation (rainfall, snowfall and snow melt or other climatic water) is the principal source for replenishing both the County's groundwater storage and streamflow.

An important role of Rappahannock County in regional resources is that it yields both groundwater and surface water of significant quantity and good quality to the localities that are downstream of it in the Rappahannock River watershed and downgradient of it in the fractured rock aquifers of the Blue Ridge Geologic Province and beyond in Piedmont Province. Rappahannock County lies entirely within the Rappahannock River Basin. All streams in the County ultimately drain to this channel, which is a major source of drinking water supply to downstream jurisdictions including Culpeper, Spotsylvania and Stafford Counties and the City of Fredericksburg. Clearly, if Rappahannock County uses more water from its groundwater and surface water sources than can be replenished by climatic events, this can and will have a negative impact on all of the jurisdictions downstream.

Geologic Conditions

Based principally on landforms, topography and the appearance of the landscape, the lower elevation eastern portion of Rappahannock County has traditionally been described as lying in the Piedmont Physiographic Province while the steeper western portion of the County has been described as lying in the Blue Ridge Physiographic Province. Despite appearance, however, the underlying geology associates all of Rappahannock County lands with the Blue Ridge Geologic Province or complex, as discussed further in this section.

Rappahannock County is underlain by various bedrock of the Blue Ridge Geologic Province, with generalized rock types shown in the Map below. The bedrock also has a variety of fracture patterns and fracture intensity and generates overlying soils of varying thicknesses and chemical characteristics.

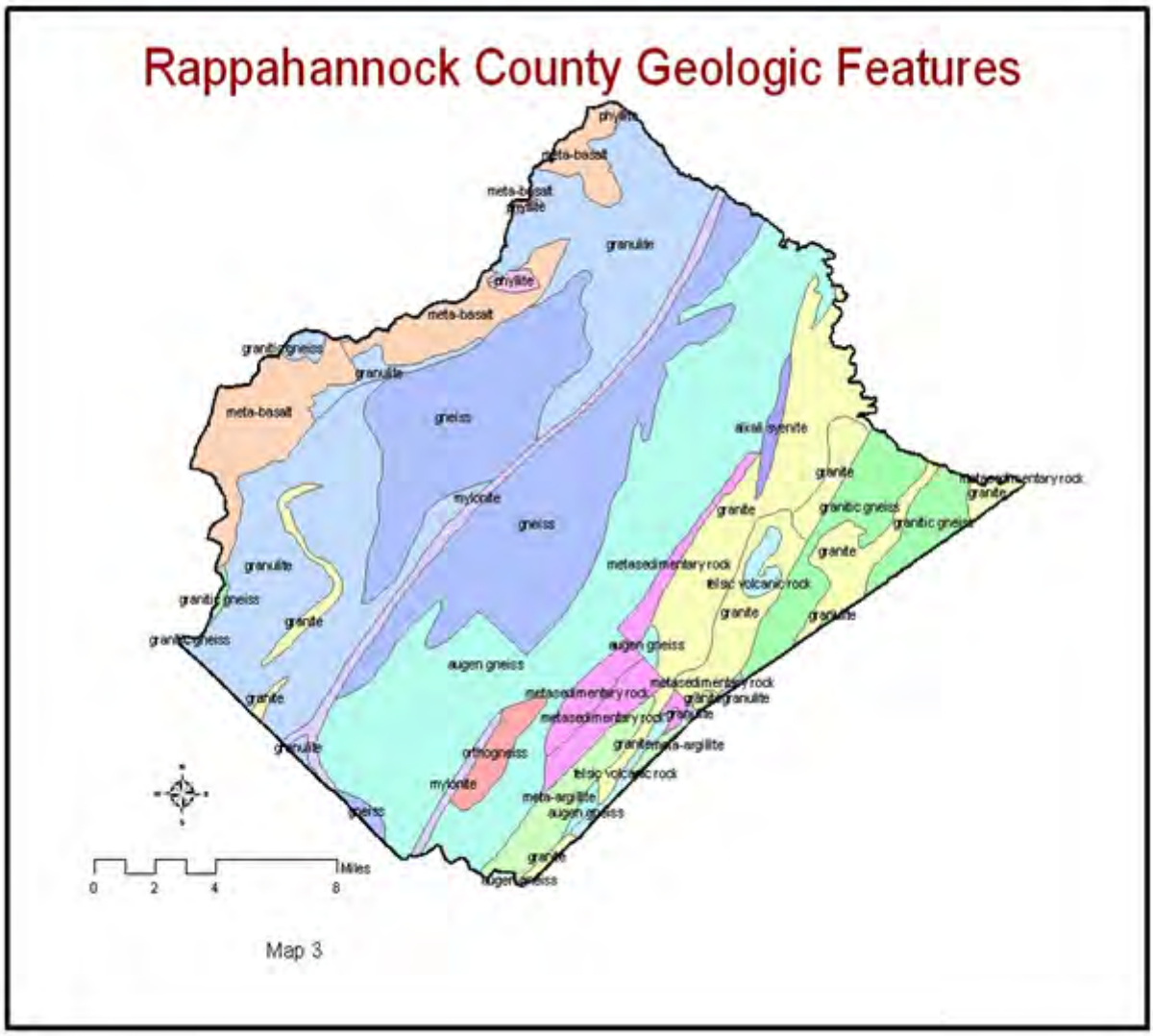
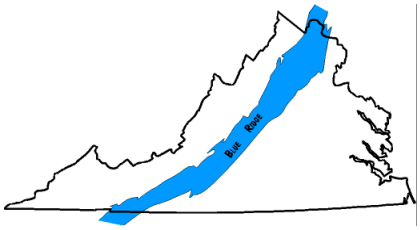


Figure VII - Rappahannock County Geologic Features

The Blue Ridge Geologic Province in Rappahannock County's western portion is typified by steep and rugged terrain and is underlain with igneous and metamorphic bedrocks - granitic rock, granulite, gneiss, augen gneiss, phyllite, greenstone (meta basalt), mylonite and some sandstone. The lower eastern portion, wider at the north, is typified by gently sloping to moderately steep terrain, which, especially in the Woodville area, is occasionally broken by long, low mountains or hills. It is primarily underlain with granitic rock, quartzite, phyllite, and arkosic sandstone. (alkali syenite, granite, granitic gneiss, metasedimentary rock, metaargillite, felsic volcanic rock, augen gneiss)

The James Madison University website on the Geologic Evolution of Virginia and the Mid-Atlantic Region, “A Description of the Geology of Virginia” describes the Blue Ridge geologic province as follows:

Blue Ridge



The Blue Ridge province includes both the Blue Ridge mountains (Skyline Drive and the Blue Ridge Parkway), and the strip of land to the east running through Galax, Charlottesville, Culpeper, and Warrenton (*map*). This is an instance where the physiography and the geology do not exactly correspond. The geologic province is defined primarily by the rocks underlying it, (coarse grained igneous and metamorphic *Grenville* basement rocks) rather than by its topography. [The eastern part of the geologic province blends in topographically with the *piedmont* physiographic province in many places, and appears different than the Blue Ridge Mountains to which they are related geologically]. In northern Virginia the Blue Ridge province geology, as crossed by I66, extends from about 5 miles east of Front Royal to Bull Run Mountain just west of Manassas. Here it is about 20 miles wide.

Structurally the Blue Ridge province is a large, eroded anticline overturned to the west (*cross section*). The core of the anticline is composed of igneous and metamorphic rocks collectively known as the *Grenville*, although there are also late Proterozoic intrusives and sediments present too. They are the oldest rocks in the state at 1.1 billion (and a protolith [earlier rock now modified to something else] back to 1.8 billion).

The east and west flanks of the anticline are much younger volcanics (Crossnore event) and clastic sediments. The clastic sediments fill rift grabens on the *northwest* and *southeast* flanks of the anticline (Lynchburg, Ocoee, Grandfather Mtn., Mt. Rogers Groups). Stratigraphic thicknesses range from about 3000 meters to 7000 meters. The final filling of the graben and creation of a divergent continental margin is preserved in the metamorphosed lava flows (*Catoctin formation*) and sedimentary rocks (*Chilhowee Group* and *Evington* formation) about 570-600 million years old (*Blue Ridge cross section*).

If you are reading a hard copy version of this water supply plan, you can find the electronic source for this information and access to the links at:
http://csmres.jmu.edu/geollab/vageol/vahist/PhysProv.html#provinces

Geological conditions underpinning land, especially fracture trends and intensity, their intersections with land surface have impact on water resources that may lie within such structures or flow across them, the thickness of the overlying granular materials and on the relative suitability for development of soil types that blanket the formations. Most of the Blue Ridge province is well drained, but some small areas of colluvial material at the foot of the mountains are poorly drained.

Hydrogeology

It is the fractures in the bedrock and the pore spaces within the overlying regolith and soils that form the aquifers that store and move groundwater for Rappahannock County. Performing hydrogeolgic analyses are difficult, and have not been performed in Rappahannock County. One major part of the difficulty lies in the fact that the state of the art in modeling fractured bedrock formations is not well developed and can be considered unreliable at best.

Water Resources

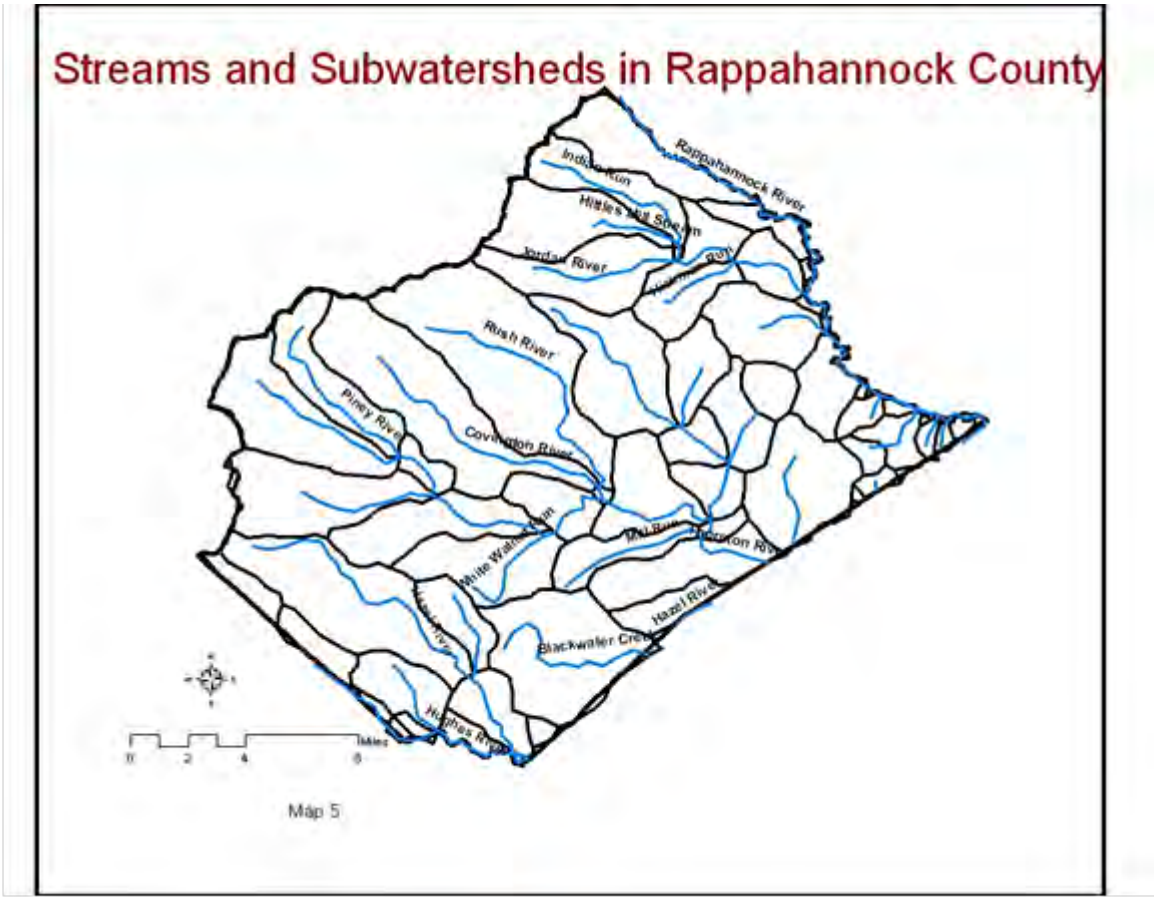


Figure VIII - Streams and Subwatersheds in Rappahannock County

Rappahannock County lies entirely within the Rappahannock River Basin. Thus all streams in the County ultimately drain to this channel, which is a major source of drinking water supply to downstream jurisdictions including Spotsylvania and Stafford Counties and the City of Fredericksburg. Drainage in the County is well developed with

most of the smaller streams draining southeasterly perpendicular to the mountains. Total river and stream surface area is estimated at 195 acres.

Springs, wells, streams and ponds currently provide adequate water for the people and livestock in the County. Indeed, approximately 95% of the residences in the County depend upon private wells, springs or streams for their drinking water. Water quality in the County is generally good, although excessive hardness and acidic conditions are occasionally encountered.

A great deal of concern exists both to protect the quality of the County's water resources and to analyze in some detail the quantity of water available to support future needs. To that end, many efforts have been undertaken, including a well water testing program, a DRASTIC water pollution potential study and, a study of groundwater resources in the Sperryville area.

This Section will present a more detailed analysis of the water resources in the County, using a "water balance" approach that takes into account the entire water budget, including water use, precipitation, water lost to the atmosphere (evapotranspiration), stream flow, and groundwater recharge.

Given the inability to analyze or model the hydrogeology, there are hydrologic methods available that can determine the critical numbers needed for evaluating the water resources in the County, including the groundwater recharge rate. The groundwater withdrawal rate can be estimated by the water use numbers developed in this report. Because virtually all County residents rely on groundwater as their principle water source, the water withdrawal rate can be estimated. By comparing the water withdrawal rate to the recharge rate it can be determined to some degree of accuracy whether or not Rappahannock County is in danger of over-withdrawing its groundwater. Further, this evaluation can be used to determine if potential future growth and other scenarios will allow for adequate water supplies in the future.

The analytical method presented here is a "water balance" approach, which takes all of the primary water resource components into account. The water balance approach for evaluating water resources is a classic approach that has been in use for decades. This analysis employs long-term historical data and does not necessarily reflect the more recent changes that have been noted in the Meteorology discussion.

Hydrology

<u>Using a Water Balance Approach to Address the Primary Objectives for a water supply plan</u>

A water balance approach will provide the county with the information needed to manage water resources in order to ensure adequate supplies and to monitor the implementation of the water supply plan as well as serve as a "warning system" if problems occur. One example would be the identification of unexpectedly low streamflows, which could be an indication of larger than normal agricultural withdrawals for irrigation.

Ideally, the water balance should be a replicable process that can be performed on multi-year, annual, and/or seasonal bases. To be able to do this, the primary terms in the water balance must be subject to estimation within these time frames. Unfortunately the currently existing data is not adequate for these relatively short term analyses.

The major terms in the water balance that apply to Rappahannock County are:

1. Precipitation
2. Evapotranspiration
3. Streamflow
4. Groundwater recharge
5. Irrigation withdrawals from streams, especially in drought situations
6. Human consumption of water, primarily via wells
7. Agricultural consumption; cattle are probably the major water user in this category

Because the county has such a small population density with no major industrial facilities, the water consumption factors (items 6 and 7) are quite small in relation to the other factors. This point will be shown in the following analysis which performs a basic long-term annual average water balance.

Development of the Long Term Mean Annual Water Balance

The factors considered in a classic water balance calculation are:

1. Mean Annual Precipitation (MAP): Rainfall is generally the most significant water input. For an average mean annual water balance, the Mean Annual Precipitation (MAP) is used.
2. Evapotranspiration (ET): This is a combination of surface evaporation and the transpiration of plants, which can release a significant amount of water vapor to the atmosphere.
3. Surface Water Inflow (SWI): The amount of water entering the county from streams. Because Rappahannock County is at the Headwaters, this term is zero.
4. Surface Water Outflow (SWO): The amount of water leaving the county via surface waters.
5. Groundwater Recharge (GWR): This is the water that enters into the groundwater table.
6. Surface Water Withdrawal (SWW): The amount of water taken from surface water for municipal, industrial and agricultural purposes.
7. Groundwater Withdrawal (GWW): This is the amount of water that is withdrawn from the groundwater, primarily for residential, commercial, industrial and agricultural use.
8. Consumption Use (CU): Water consumed within the county. For Rappahannock County, the primary sources of CU are the people and facilities in the County, and livestock. There are additional sources of consumption, such as other agricultural

uses, e.g., vineyards. At this time, there is no estimate for these additional sources. It is important to note that much of the CU is returned to the groundwater because the primary waste disposal method is via septic systems.

The Water Balance Equation

The following figure illustrates the concepts of water balance and shows the primary components in this water balance. The four scenarios presented in Fig. VIII also illustrate how development can alter this water balance. The water source for the county comes in the form of precipitation. Because Rappahannock County is very rural with mostly natural groundcover in the form of forests and fields, the water balance in the upper left, "Natural Ground Cover" is most reflective of the county's water resource usage.

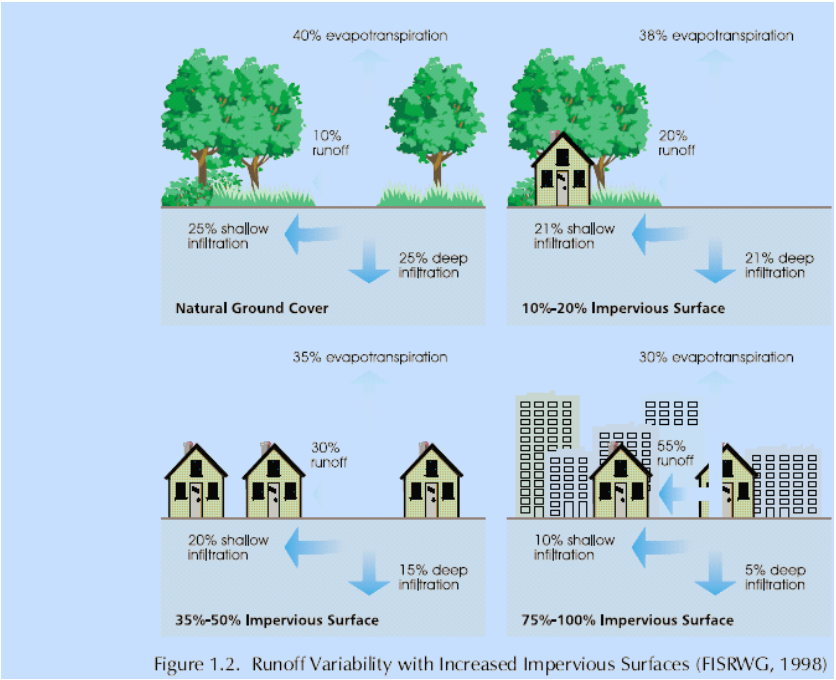


Figure from "Low-Impact Development Hydrologic Analysis", Prepared by Prince George's County, Maryland

Figure IX – Water Balance Components under Different Development Scenarios

The complete water balance equation is:

MAP – ET + SWI – SWO – GWR – SWW + GWW - CU = 0

If the sum of the terms is not zero, this means that the water balance analysis has not estimated one or more terms correctly. The magnitude of the non-zero term is what should be considered; a small non-zero term most likely reflects small errors in estimating one or more terms. A large non-zero value in relation to the MAP would call the validity of the water balance into question.

In the following analysis, the water balance equation will use inches/year for all terms.

There are several challenges involved in estimating a water balance for Rappahannock County:

First, arriving at a mean annual value for SWO (Surface Water Outflow) requires long-term monitoring of streamflows, which should consist of at least 10 to 20 years of data. The surface water outflow is computed using streamflow data from the USGS National Water Information System (USGS NWIS). This system is a nationwide network of physical measuring devices installed in watercourses. The gage that is used in the water balance analysis for Rappahannock County is gage number 01663500, on the Hazel River at Rixeyville. Fig. X illustrates the drainage area for this gage. The gage location is highlighted in red. This gage has 59 years of record, making it an excellent reference gage for the water balance analyses.

Note that this gage *does not* measure the runoff that goes directly into the Rappahannock River, representing a small land area within the County. The gage *does* include small portions of Madison and Culpeper Counties. These portions outside of Rappahannock have very similar landform characteristics to Rappahannock County as a whole. Rappahannock County has an area of 266.9 square miles. The drainage area of the gage is 287 square miles, thus the gage drainage area is 7% greater than the size of the county. In short, while this gage does not precisely line up with the county boundaries, it is a reasonable surrogate for the surface water discharge from Rappahannock County.

This gage has further advantages in that it is an "Active" USGS gage, recording daily streamflow values that can be very useful for monitoring of the county-wide streamflow. The mean annual flow, SWO, is reported as 337 cubic feet per second (cfs), which translates to 15.9 inches/year. As a point of reference, one inch of water in the gage watershed equals 5 billion gallons.

Another gage, 01662800, Battle Run, is also available as a cross-check of the patterns and trends in streamflow. The Battle Run gage is completely contained within Rappahannock County. The drainage area of this gage is 27.6 square miles and the mean flow is 26.566 cfs, based on 46 years of record.

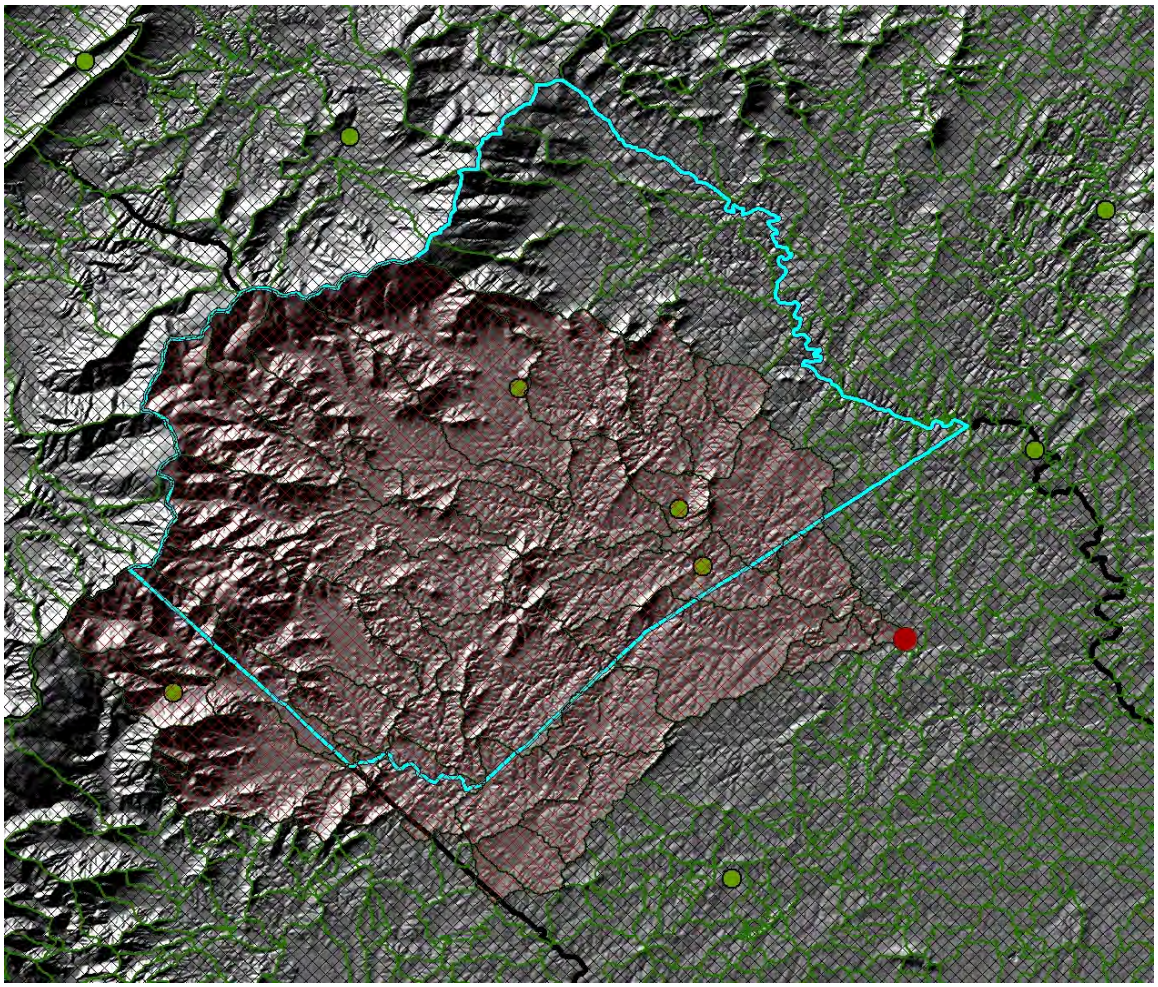


Figure X – The Watershed for USGS gage 01663500 On the Hazel River

The second analytical challenge is that determining the value for MAP (Mean Annual Precipitation) is complicated due to the fact that rainfall amounts can vary widely across the County. Much of this variability can be attributed to the "shadow" effects of the Blue Ridge Mountains and to the mountains and valleys within the County. While there is a rainfall gage in Sperryville, it is unlikely to be representative of the county as a whole. It is quite common, for example, that Sperryville can experience a significant rainfall event while other parts of the County receive no rain at all. Likewise, the southern part of the County can experience rainfall while the upland areas, including Sperryville, receive little or no rain. To arrive at a value for MAP, the PRISM database as incorporated into the NHDPlus system is used. Prism provides a long-term 1 sq. km. grid of mean annual precipitation. Based on NHDPlus, the MAP in the gage watershed is 43 inches/yr.

The third challenge, estimating the ET, can be an involved process, especially on a seasonal basis, which in turn can be highly dependent on seasonal cropping patterns, meteorological considerations, etc. These variables are beyond the current scope of this analysis. In lieu of a comprehensively detailed ET analysis, a general "rule of thumb" for

our area is that ET = 40% (see Fig. IX) of the mean annual precipitation. Given a MAP = 43 inches/yr., the value for ET is estimated to be 17 inches/yr.

GWR is estimated using USGS Water-Supply Paper 2457. For the Hazel River gage, mean recharge is ~10.9 inches/yr.

At this time, there are no known regular surface water withdrawals within the County; consequently SWW is set = 0. Agricultural users do withdraw surface water, e.g., water used for watering cattle, etc., but these withdrawals are primarily reflected in the gage flow.

For the purposes of this analysis, GWW and CU will be lumped together as one loss term. For this part of the analysis we will consider all of the water uses quantified thus far. This part of the analysis is very conservative, using high-end values for water use. Total estimated water use is 115.86 MGY for livestock, 8.14 MGY for irrigation, and 218.26 MGY for residential use. This adds up to 342.26 MGY, which translates to 0.068 inches per year. Given other uses such as schools, businesses, etc., and being very conservative, we will round this figure up to 0.1 inches per year. Note that, even when using high-end consumption values and rounding them up, this is by far the smallest term in the water balance. Also, it is not taking into account the fact that much of the consumptive use is returned to the watershed via septic systems and cattle urination. **In other words, using long-term historical data, the total water used by Rappahannock County is a small fraction of the water resources in the County.**

The summary of the estimated water balance terms (inches/year):

MAP = 43
ET = 17 (40% of MAP)
SWI = 0
SWO = 15.9 (37% of MAP)
GWR = 10.9 (23% of MAP)
(GWW – CU) = 0.1 (0.2% of MAP)

The mean annual water balance = 43 – 17 + 0 -15.9 – 10.9 – 0.1 = -0.8

<u>Interpretation of the water balance</u>

The water balance does not equal zero, but the rough approximation for ET and potential estimation problems in the PRISM MAP values and the groundwater recharge can all affect the results. This should be considered to be a very reasonable water balance calculation. Considering that the MAP = 43 inches per year, the water balance is "off" by 0.2 %. The (GWW-CU) value of 0.1 is by far the smallest term in the water balance, and strongly indicates that Rappahannock County is using a small fraction of the water that it theoretically could use. Note that the term is rounded significantly upward, and also uses the highest-end estimated values for water use. Also, the water balance does not take into account that most people are on septic systems, which will mean that a significant portion

(>50%?) of the GWW is returned as GWR. When comparing the 0.1 inches of water use to the 10.9 inches of recharge, there is no apparent problem in Rappahannock County's water supply situation using a long-term historical basis for analysis.

Two possible additional sources of increased water consumption are presented below:

1. Agricultural withdrawal from streams: There are no known permits for agricultural withdrawals in the county. However, by law, an agricultural entity is allowed to withdraw up to 1 million gallons per month without a permit. This translates into 0.002 inches per year if the 1 million gallons is withdrawn every month. It is unlikely that this water would be withdrawn every month. Suppose 20 agricultural entities each withdrew one million gallons per month during the driest three months: this would equate to **0.01 inches/yr.**
2. Population increases could account for increased GWW. Using the "build out" analysis described in Section V, the maximum population of the County could theoretically increase from the current 7,035 to 18,000 people, representing an increase of 10,965 people. Assuming 100 gallons per capita per day (using the larger estimate to account for some increase in businesses as well), this translates to 1.1 MGD, which is 400 MGY in increased water use or approximately 0.08 inches of GWW per year.

These potential increases are considered "maximum" amounts. If we add the two values for increased water use, we arrive at an increase of 0.09 inches per year. Because the County Stormwater Management Ordinance requires Low Impact Development (LID) and Best Management Practices (BMPs), maximized development would result in a decreased cattle population. Given a current long-term recharge rate of 10.9 inches per year and a SWO of 15.9 inches, there should be no significant issues for Rappahannock County to sustain this population based on the long-term water balance.

In summary, the long-term water balance approach indicates that Rappahannock County is currently and on a long-term basis, able to provide sufficient water for its residents and agriculture.

<u>Issues in the water balance analyses</u>

There is a "flaw" in this water balance approach for evaluating Rappahannock County's ability to sustain adequate water supplies, whether under current conditions or under "maximum" increased use situations. The fundamental flaw is that the water balance assumes that the long-term analysis is reflective of current and future conditions. Significant changes have been noted in the state of the County's water resources over the past 20 years. The description of meteorological conditions, immediately below, describes these changes and trends. Sections VIII and IX will focus on the emerging issues and problems and describe actions that could be taken. The water balance analysis should be updated to depend less on historical information and to focus more on recent information: for instance, perform the analysis in terms of data from only the past ten years. Streamflow (SWO) can certainly be re-computed, groundwater recharge (GWR)

may be able to be re-estimated, but ET estimates are dependent on detailed data that is not available at this time, but may become available if more sophisticated data collection and modeling methods are introduced. This would entail much more refined methods such as incorporating NEXRAD radar and satellite remote sensing information into an ET modeling system. These refinements are beyond the scope of County resources and would need to be done as part of a larger regional approach.

Meteorological Conditions

The County's precipitation has tended to be well-distributed over the twelve months of the year, with less precipitation in the winter and more in the Spring and Fall. Further, there have been numerous springs in the highlands, which have provided a steady base flow for many of the streams, as well as providing a reliable water source for farmers in low rainfall conditions.

The history of Rappahannock County can be considered to be one of plentiful water resources. Consistently low population density, with its resultant low use of water, has helped to maintain this situation. Because of this history of abundant water resources, Rappahannock County has not seen the need to develop long-term, consistent monitoring systems for groundwater levels and climate (precipitation, temperature, wind, etc.). There have been some efforts toward this, particularly a groundwater monitoring well in Sperryville (Ensat Corporation, 1996) and volunteer meteorological stations, including one in Sperryville and another at the High School. Two long-term USGS stream flow gages are maintained, one on Battle Run and one on the Hazel River, just outside the County boundaries. These gages are critical resources in evaluating the hydrologic conditions within the County.

Most County residents are quite conscious of the recent variability of local precipitation, temperature, and stream flow conditions. These factors are critical to the water supply and to the availability of surface waters for farmers and ecological needs. Up until approximately 1990, Rappahannock County's precipitation and stream flows were considered quite adequate. The numerous springs originating in the mountainous regions have enabled a reasonably steady stream flow, even in summer conditions of high temperatures and sporadic thunderstorms.

Since approximately the year 2000, however, residents have noticed some disturbing changes. These changes include a lack of snowfall in the winter months, historically perennial springs drying up, higher temperatures and a changing precipitation pattern in the summer. The precipitation pattern has been marked by long dry periods with high temperatures interspersed with sporadic, heavy thunderstorms, and very few occurrences of the kinds of sustained, "gentle" rains that soak into the ground. This change in the precipitation and temperature patterns has resulted in a situation in which the soils become hard in the hot, dry periods, and are essentially impervious. Short, violent thunderstorms do not soak into the soil; they run off into the channels and streams. This renders the thunderstorms of very little use in replenishing the soil moisture.

The drying up of springs has exacerbated the situation described above. These springs have historically provided a reasonably steady base flow for many streams and replenishment of water for farm ponds, both of which are essential to farmers, particularly during dry periods in the summer. With springs becoming dry, the stream flows and pond recharge have become highly problematic. The implications of this situation will be discussed in more detail in Sections VIII and IX in the considerations of future needs.

It is hypothesized that the drying up of springs is related to the lack of snowfall and the more frequent thunderstorms (as opposed to gentle, soaking rains). While the data to provide a full analysis of the changes and their effects is not available, observations of National Park staff and County residents provide compelling evidence of these changes. Below is a summary of some of their observations:

- From Steve Bair, NPS Backcountry, Wilderness and Trails Manager:
    - "Many springs have dried up in the Park."
    - "The changes seem to have started about 20 years ago."
    - "We used to always have snow in December through March, now it is rare."
- From Bill Fletcher, long-time resident and farmer:
    - On the small mountain that drains to his land, he noticed that the springs higher up dried up about 20 years ago, the lower-level springs dried up about 10 years ago. This is causing severe water shortages for his farming operations.
- Similar feedback from others:
    - Wells going dry in Sperryville
    - Farmers not being able to get water from streams for mixing fertilizers
    - "Where are the nice, long-lasting, drenching rains?"
    - "It seems we get storms instead."

As part of the meteorological analysis, several rain gages were considered for summarizing the long-term precipitation patterns: The station at Big Meadows in the Shenandoah National Park was rejected because it reflects conditions at the mountain peak rather than conditions in the County. The Culpeper station was rejected because it primarily reflects the Atlantic effects instead of the situations in Rappahannock County. The data at Sperryville was rejected for two reasons: the period of record covers 1995 to 2008, which does not include the period before the observed changes took place. As a balance, the station at Lincoln, VA is used. This station is located near Hamilton, VA, which is reasonably representative of Rappahannock County and its trends, and it has a very long period of record, going from 1901 to 2010. Below is a graph of total annual precipitation from 1901 to 2010:

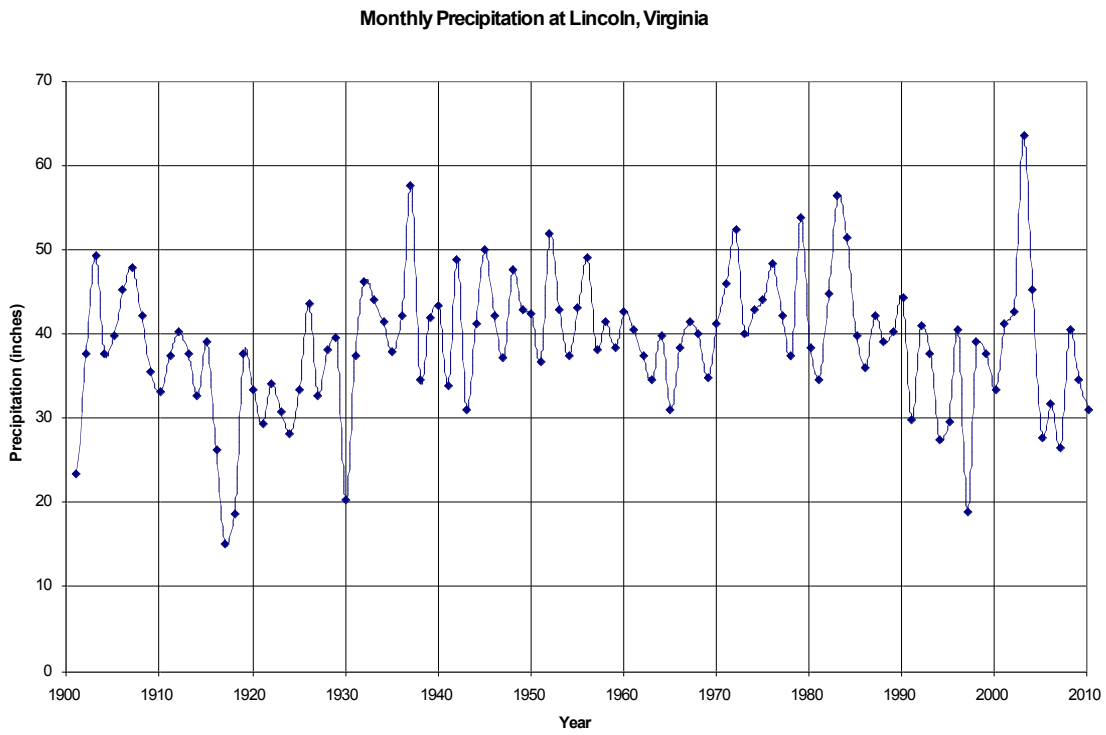


Figure XI– Monthly Precipitation at Lincoln, VA from 1901 to 2010

The mean annual precipitation at Lincoln is 41 inches per year. Note that there are two 20-year periods of mostly lower than normal precipitation: 1909 to 1930 and 1991 to 2010. The high precipitation value in 2003 is somewhat misleading, because 37.2 of the 63.5 inches of precipitation (59%) occurred in the months of May through September. The normal rainfall pattern is much more consistent over the 12 months of the year. The normal, average rainfall in this five-month period is 19.7 inches. Otherwise, the data shows a continuing precipitation deficit from 1991 to 2010. This period corresponds to the observations of Rappahannock citizens and others cited above.

The fact that there are two long periods of lower than normal rainfall could indicate a long-term cycle. However, in addition to the low recorded rainfall, the Southeast Regional Climate Center has observed a 2 degree increase in temperatures since 1970, an increase in heavy thunderstorms, and a continuation of these trends. Therefore, it is prudent from a water supply perspective to prepare for the distinct possibility that the changes observed over the past 20 years have become more of a new “normal” situation and for Rappahannock County to consider adopting measures to work within current conditions.

Note that the rest of this Section of the WSP is required pursuant to 9 VAC 25-780-90.

State or Federal listed Threatened and endangered species or habitats of concern

The following chart of threatened and endangered species was developed by the Virginia Department of Game and Inland Fisheries.

Species Code	Status *	WAP **	Common Name	Scientific Name
020045	FESE	I	Salamander, Shenandoah	*Plethodon shenandoah*
040096	ST	I	Falcon, peregrine	*Falco peregrinus*
040129	ST	I	Sandpiper, upland	*Bartramia longicauda*
040293	ST	I	Shrike, loggerhead	*Lanius ludovicianus*
100155	FSST	I	Skipper, Appalachian grizzled	*Pyrgus wyandot*
040292	ST		Shrike, migrant loggerhead	*Lanius ludovicianus migrans*
100248	FS	I	Fritillary, regal	*Speyeria idalia idalia*
030063	CC	III	Turtle, spotted	*Clemmys guttata*
030012	CC	IV	Rattlesnake, timber	*Crotalus horridus*
040225		I	Sapsucker, yellow-bellied	*Sphyrapicus varius*
040319		I	Warbler, black-throated green	*Dendroica virens*
040306		I	Warbler, golden-winged	*Vermivora chrysoptera*
040052		II	Duck, American black	*Anas rubripes*
040105		II	Rail, king	*Rallus elegans*
040320		II	Warbler, cerulean	*Dendroica cerulea*
040266		II	Wren, winter	*Troglodytes troglodytes*
030068		III	Turtle, eastern box	*Terrapene carolina carolina*
040094		III	Harrier, northern	*Circus cyaneus*
040204		III	Owl, barn	*Tyto alba pratincola*
050024		III	Myotis, eastern small-footed	*Myotis leibii*

100150		III	Butterfly, mottled duskywing	*Erynnis martialis*
010363		IV	Darter, Appalachia	*Percina gymnocephala*
010131		IV	Eel, American	*Anguilla rostrata*
020031		IV	Salamander, Jefferson	*Ambystoma jeffersonianum*
030045		IV	Ribbonsnake, common	*Thamnophis sauritus sauritus*
030024		IV	Snake, eastern hog-nosed	*Heterodon platirhinos*
030033		IV	Snake, queen	*Regina septemvittata*
040100		IV	Bobwhite, northern	*Colinus virginianus*
040272		IV	Catbird, gray	*Dumetella carolinensis*
040337		IV	Chat, yellow-breasted	*Icteria virens virens*
040214		IV	Chuck-will's-widow	*Caprimulgus carolinensis*
040264		IV	Creeper, brown	*Certhia americana*
040202		IV	Cuckoo, yellow-billed	*Coccyzus americanus*
040142		IV	Dowitcher, short-billed	*Limnodromus griseus*
040240		IV	Flycatcher, willow	*Empidonax traillii*
040358		IV	Grosbeak, rose-breasted	*Pheucticus ludovicianus*
040028		IV	Heron, green	*Butorides virescens*
040229		IV	Kingbird, eastern	*Tyrannus tyrannus*
040344		IV	Meadowlark, eastern	*Sturnella magna*
040330		IV	Ovenbird	*Seiurus aurocapilla*
040312		IV	Parula, northern	*Parula americana*
040243		IV	Pewee, eastern wood	*Contopus virens*
040391		IV	Sparrow, field	*Spizella pusilla*
040378		IV	Sparrow, grasshopper	*Ammodramus savannarum pratensis*
040248		IV	Swallow, northern rough-winged	*Stelgidopteryx serripennis*
040217		IV	Swift, chimney	*Chaetura pelagica*
040355		IV	Tanager, scarlet	*Piranga olivacea*

040273		IV	Thrasher, brown	*Toxostoma rufum*
040277		IV	Thrush, wood	*Hylocichla mustelina*
040375		IV	Towhee, eastern	*Pipilo erythrophthalmus*
040297		IV	Vireo, yellow-throated	*Vireo flavifrons*
040302		IV	Warbler, black-and-white	*Mniotilta varia*
040307		IV	Warbler, blue-winged	*Vermivora pinus*
040340		IV	Warbler, Canada	*Wilsonia canadensis*
040333		IV	Warbler, Kentucky	*Oporornis formosus*
040328		IV	Warbler, prairie	*Dendroica discolor*
040303		IV	Warbler, prothonotary	*Protonotaria citrea*
040305		IV	Warbler, worm-eating	*Helmitheros vermivorus*
040313		IV	Warbler, yellow	*Dendroica petechia*
040332		IV	Waterthrush, Louisiana	*Seiurus motacilla*
040215		IV	Whip-poor-will	*Caprimulgus vociferus*
040140		IV	Woodcock, American	*Scolopax minor*
050106		IV	Cottontail, Appalachian	*Sylvilagus obscurus*
050046		IV	Skunk, eastern spotted	*Spilogale putorius putorius*
050040		IV	Weasel, least	*Mustela nivalis allegheniensis*
050081		IV	Woodrat, Allegheny	*Neotoma magister*
070104		IV	Crayfish	*Orconectes obscurus*
100223		IV	Butterfly, frosted elfin	*Callophrys irus*
010175			Bass, rock	*Ambloplites rupestris*
010186			Bass, smallmouth	*Micropterus dolomieu*
010183			Bluegill	*Lepomis macrochirus*
010066			Chub, bluehead	*Nocomis leptocephalus*
010103			Chub, creek	*Semotilus atromaculatus*
010067			Chub, river	*Nocomis micropogon*
010106			Chubsucker, creek	*Erimyzon oblongus*
010101			Dace, blacknose	*Rhinichthys atratulus*

010102			Dace, longnose	*Rhinichthys cataractae*
010060			Dace, mountain redbelly	*Chrosomus oreas*
010204			Darter, glassy	*Etheostoma vitreum*
010213			Darter, shield	*Percina peltata*
010104			Fallfish	*Semotilus corporalis*
010143			Killifish, banded	*Fundulus diaphanus*
010129			Madtom, margined	*Noturus insignis*
010099			Minnow, bluntnose	*Pimephales notatus*
010063			Minnow, cutlips	*Exoglossum maxillingua*
010182			Pumpkinseed	*Lepomis gibbosus*
010283			Sculpin, mottled	*Cottus bairdi*
010072			Shiner, comely	*Notropis amoenus*
010080			Shiner, common	*Luxilus cornutus*
010068			Shiner, golden	*Notemigonus crysoleucas*
010087			Shiner, highland	*Notropis micropteryx*
010073			Shiner, satinfin	*Cyprinella analostana*
010086			Shiner, swallowtail	*Notropis procne*
010108			Sucker, northern hog	*Hypentelium nigricans*
010105			Sucker, white	*Catostomus commersoni*
010180			Sunfish, redbreast	*Lepomis auritus*
010052			Trout, brook	*Salvelinus fontinalis*
010051			Trout, brown	*Salmo trutta*
020004			Bullfrog, American	*Lithobates catesbeianus*
020012			Frog, eastern cricket	*Acris crepitans crepitans*
020008			Frog, northern green	*Lithobates clamitans melanota*
020013			Frog, pickerel	*Lithobates palustris*
020018			Frog, upland chorus	*Pseudacris feriarum feriarum*
020019			Frog, wood	*Lithobates sylvaticus*
020065			Newt, red-spotted	*Notophthalmus viridescens*

				viridescens
020071			Peeper, northern spring	*Pseudacris crucifer crucifer*
020043			Salamander, eastern red-backed	*Plethodon cinereus*
020029			Salamander, four-toed	*Hemidactylium scutatum*
020035			Salamander, marbled	*Ambystoma opacum*
020038			Salamander, northern dusky	*Desmognathus fuscus*
020070			Salamander, northern red	*Pseudotriton ruber ruber*
020077			Salamander, northern spring	*Gyrinophilus porphyriticus porphyriticus*
020053			Salamander, northern two-lined	*Eurycea bislineata*
020075			Salamander, seal	*Desmognathus monticola*
020049			Salamander, spotted	*Ambystoma maculatum*
020051			Salamander, three-lined	*Eurycea guttolineata*
020080			Salamander, white-spotted slimy	*Plethodon cylindraceus*
020059			Toad, eastern American	*Anaxyrus americanus americanus*
020062			Toad, Fowler's	*Anaxyrus fowleri*
020007			Treefrog, gray	*Hyla versicolor*
030041			Brownsnake, northern	*Storeria dekayi dekayi*
030016			Copperhead, northern	*Agkistrodon contortrix mokasen*
030022			Cornsnake, red	*Pantherophis guttatus*
030049			Earthsnake, eastern smooth	*Virginia valeriae valeriae*
030044			Gartersnake, eastern	*Thamnophis sirtalis sirtalis*
030038			Greensnake, northern rough	*Opheodrys aestivus aestivus*
030026			Kingsnake, eastern	*Lampropeltis getula getula*

030027			Kingsnake, mole	*Lampropeltis calligaster rhombomaculata*
030002			Lizard, eastern fence	*Sceloporus undulatus*
030029			Milksnake, eastern	*Lampropeltis triangulum triangulum*
030018			Racer, northern black	*Coluber constrictor constrictor*
030008			Racerunner, eastern six-lined	*Aspidoscelis sexlineata sexlineata*
030023			Ratsnake, eastern	*Pantherophis alleghaniensis*
030006			Skink, broad-headed	*Plestiodon laticeps*
030004			Skink, common five-lined	*Plestiodon fasciatus*
030007			Skink, little brown	*Scincella lateralis*
030005			Skink, southeastern five-lined	*Plestiodon inexpectatus*
030042			Snake, northern red-bellied	*Storeria occipitomaculata occipitomaculata*
030020			Snake, northern ring-necked	*Diadophis punctatus edwardsii*
030052			Stinkpot	*Sternotherus odoratus*
030051			Turtle, eastern mud	*Kinosternon subrubrum subrubrum*
030060			Turtle, eastern painted	*Chrysemys picta picta*
030050			Turtle, eastern snapping	*Chelydra serpentina serpentina*
030034			Watersnake, northern	*Nerodia sipedon sipedon*
030019			Wormsnake, eastern	*Carphophis amoenus amoenus*
040346			Blackbird, red-winged	*Agelaius phoeniceus*
040282			Bluebird, eastern	*Sialia sialis*
040361			Bunting, indigo	*Passerina cyanea*
040401			Bunting, snow	*Plectrophenax nivalis nivalis*
040357			Cardinal, northern	*Cardinalis cardinalis*

040258			Chickadee, Carolina	*Poecile carolinensis*
040113			Coot, American	*Fulica americana*
040024			Cormorant, double-crested	*Phalacrocorax auritus*
040353			Cowbird, brown-headed	*Molothrus ater*
040373			Crossbill, white-winged	*Loxia leucoptera*
040255			Crow, American	*Corvus brachyrhynchos*
040256			Crow, fish	*Corvus ossifragus*
040203			Cuckoo, black-billed	*Coccyzus erythropthalmus*
040364			Dickcissel	*Spiza americana*
040198			Dove, mourning	*Zenaida macroura carolinensis*
040061			Duck, wood	*Aix sponsa*
040032			Egret, great	*Ardea alba egretta*
040367			Finch, house	*Carpodacus mexicanus*
040366			Finch, purple	*Carpodacus purpureus*
040221			Flicker, northern	*Colaptes auratus*
040239			Flycatcher, Acadian	*Empidonax virescens*
040234			Flycatcher, great crested	*Myiarchus crinitus*
040242			Flycatcher, least	*Empidonax minimus*
040284			Gnatcatcher, blue-gray	*Polioptila caerulea*
040371			Goldfinch, American	*Carduelis tristis*
040045			Goose, Canada	*Branta canadensis*
040352			Grackle, common	*Quiscalus quiscula*
040008			Grebe, pied-billed	*Podilymbus podiceps*
040360			Grosbeak, blue	*Guiraca caerulea caerulea*
040365			Grosbeak, evening	*Coccothraustes vespertinus*
040368			Grosbeak, pine	*Pinicola enucleator*
040099			Grouse, ruffed	*Bonasa umbellus*
040089			Hawk, broad-winged	*Buteo platypterus*
040086			Hawk, Cooper's	*Accipiter cooperii*

040088			Hawk, red-shouldered	*Buteo lineatus lineatus*
040087			Hawk, red-tailed	*Buteo jamaicensis*
040090			Hawk, rough-legged	*Buteo lagopus johannis*
040085			Hawk, sharp-shinned	*Accipiter striatus velox*
040027			Heron, great blue	*Ardea herodias herodias*
040218			Hummingbird, ruby-throated	*Archilochus colubris*
040252			Jay, blue	*Cyanocitta cristata*
040387			Junco, dark-eyed	*Junco hyemalis*
040098			Kestrel, American	*Falco sparverius sparverius*
040119			Killdeer	*Charadrius vociferus*
040220			Kingfisher, belted	*Ceryle alcyon*
040285			Kinglet, golden-crowned	*Regulus satrapa*
040286			Kinglet, ruby-crowned	*Regulus calendula*
040245			Lark, horned	*Eremophila alpestris*
040399			Longspur, Lapland	*Calcarius lapponicus*
040051			Mallard	*Anas platyrhynchos*
040251			Martin, purple	*Progne subis*
040271			Mockingbird, northern	*Mimus polyglottos*
040112			Moorhen, common	*Gallinula chloropus cachinnans*
040216			Nighthawk, common	*Chordeiles minor*
040262			Nuthatch, red-breasted	*Sitta canadensis*
040261			Nuthatch, white-breasted	*Sitta carolinensis*
040348			Oriole, Baltimore	*Icterus galbula*
040347			Oriole, orchard	*Icterus spurius*
040095			Osprey	*Pandion haliaetus carolinensis*
040209			Owl, barred	*Strix varia*
040206			Owl, great horned	*Bubo virginianus*
040211			Owl, short-eared	*Asio flammeus*

040101			Pheasant, ring-necked	*Phasianus colchicus*
040236			Phoebe, eastern	*Sayornis phoebe*
040197			Pigeon, rock	*Columba livia*
040254			Raven, common	*Corvus corax*
040341			Redstart, American	*Setophaga ruticilla*
040275			Robin, American	*Turdus migratorius*
040132			Sandpiper, solitary	*Tringa solitaria*
040134			Sandpiper, spotted	*Actitis macularia*
040205			Screech-owl, eastern	*Megascops asio*
040370			Siskin, pine	*Carduelis pinus*
040141			Snipe, Wilson's	*Gallinago delicata*
040389			Sparrow, chipping	*Spizella passerina*
040395			Sparrow, fox	*Passerella iliaca*
040342			Sparrow, house	*Passer domesticus*
040377			Sparrow, savannah	*Passerculus sandwichensis*
040398			Sparrow, song	*Melospiza melodia*
040397			Sparrow, swamp	*Melospiza georgiana*
040383			Sparrow, vesper	*Pooecetes gramineus*
040393			Sparrow, white-crowned	*Zonotrichia leucophrys*
040394			Sparrow, white-throated	*Zonotrichia albicollis*
040294			Starling, European	*Sturnus vulgaris*
040247			Swallow, bank	*Riparia riparia*
040249			Swallow, barn	*Hirundo rustica*
040250			Swallow, cliff	*Petrochelidon pyrrhonota pyrrhonota*
040246			Swallow, tree	*Tachycineta bicolor*
040044			Swan, tundra	*Cygnus columbianus columbianus*
040356			Tanager, summer	*Piranga rubra*
040189			Tern, Caspian	*Sterna caspia*
040278			Thrush, hermit	*Catharus guttatus*

040260			Titmouse, tufted	*Baeolophus bicolor*
040102			Turkey, wild	*Meleagris gallopavo silvestris*
040281			Veery	*Catharus fuscescens*
040298			Vireo, blue-headed	*Vireo solitarius*
040299			Vireo, red-eyed	*Vireo olivaceus*
040301			Vireo, warbling	*Vireo gilvus gilvus*
040295			Vireo, white-eyed	*Vireo griseus*
040081			Vulture, black	*Coragyps atratus*
040080			Vulture, turkey	*Cathartes aura*
040316			Warbler, black-throated blue	*Dendroica caerulescens*
040325			Warbler, blackpoll	*Dendroica striata*
040315			Warbler, Cape May	*Dendroica tigrina*
040323			Warbler, chestnut-sided	*Dendroica pensylvanica*
040338			Warbler, hooded	*Wilsonia citrina*
040314			Warbler, magnolia	*Dendroica magnolia*
040311			Warbler, Nashville	*Vermivora ruficapilla*
040329			Warbler, palm	*Dendroica palmarum*
040326			Warbler, pine	*Dendroica pinus*
040317			Warbler, yellow-rumped	*Dendroica coronata cornata*
040331			Waterthrush, northern	*Seiurus noveboracensis*
040290			Waxwing, cedar	*Bombycilla cedrorum*
040227			Woodpecker, downy	*Picoides pubescens medianus*
040226			Woodpecker, hairy	*Picoides villosus*
040222			Woodpecker, pileated	*Dryocopus pileatus*
040223			Woodpecker, red-bellied	*Melanerpes carolinus*
040224			Woodpecker, red-headed	*Melanerpes erythrocephalus*
040268			Wren, Carolina	*Thryothorus ludovicianus*
040265			Wren, house	*Troglodytes aedon*

040336			Yellowthroat, common	*Geothlypis trichas*
050028			Bat, big brown	*Eptesicus fuscus fuscus*
050029			Bat, eastern red	*Lasiurus borealis borealis*
050033			Bat, evening	*Nycticeius humeralis humeralis*
050030			Bat, hoary	*Lasiurus cinereus cinereus*
050020			Bat, little brown	*Myotis lucifugus lucifugus*
050025			Bat, silver-haired	*Lasionycteris noctivagans*
050037			Bear, black	*Ursus americanus americanus*
050069			Beaver, American	*Castor canadensis*
050051			Bobcat	*Lynx rufus rufus*
050055			Chipmunk, Fisher's eastern	*Tamias striatus fisheri*
050103			Cottontail, eastern	*Sylvilagus floridanus mallurus*
050125			Coyote	*Canis latrans*
050108			Deer, white-tailed	*Odocoileus virginianus*
050050			Fox, common gray	*Urocyon cinereoargenteus cinereoargenteus*
050049			Fox, red	*Vulpes vulpes fulva*
050085			Lemming, Stone's southern bog	*Synaptomys cooperi stonei*
050042			Mink, common	*Mustela vison mink*
050017			Mole, eastern	*Scalopus aquaticus aquaticus*
050016			Mole, hairy-tailed	*Parascalops breweri*
050019			Mole, star-nosed	*Condylura cristata cristata*
050071			Mouse, eastern harvest	*Reithrodontomys humulis virginianus*
050098			Mouse, house	*Mus musculus musculus*
050099			Mouse, meadow jumping	*Zapus hudsonius americanus*

050073			Mouse, northern white-footed	*Peromyscus leucopus noveboracensis*
050124			Mouse, prairie deer	*Peromyscus maniculatus bairdii*
050093			Muskrat, large-toothed	*Ondatra zibethicus macrodon*
050022			Myotis, northern	*Myotis septentrionalis septentrionalis*
050001			Opossum, Virginia	*Didelphis virginiana virginiana*
050045			Otter, northern river	*Lontra canadensis lataxina*
050027			Pipistrelle, eastern	*Pipistrellus subflavus subflavus*
050038			Raccoon	*Procyon lotor lotor*
050094			Rat, black	*Rattus rattus rattus*
050095			Rat, Norway	*Rattus norvegicus norvegicus*
050002			Shrew, ashen masked	*Sorex cinereus cinereus*
050013			Shrew, Kirtland's short-tailed	*Blarina brevicauda kirtlandi*
050015			Shrew, least	*Cryptotis parva parva*
050010			Shrew, pygmy	*Sorex hoyi winnemana*
050004			Shrew, smoky	*Sorex fumeus fumeus*
050007			Shrew, southeastern	*Sorex longirostris longirostris*
050047			Skunk, striped	*Mephitis mephitis nigra*
050048			Skunk, striped	*Mephitis mephitis mephitis*
050063			Squirrel, eastern fox	*Sciurus niger vulpinus*
050058			Squirrel, northern gray	*Sciurus carolinensis pennsylvanicus*
050065			Squirrel, southern flying	*Glaucomys volans volans*
050059			Squirrel, talkative red	*Tamiasciurus hudsonicus loquax*
050087			vole, common Gapper's	*Clethrionomys gapperi*

			red-backed	*gapperi*
050082			Vole, meadow	*Microtus pennsylvanicus pennsylvanicus*
050091			Vole, pine	*Microtus pinetorum scalopsoides*
050041			Weasel, long-tailed	*Mustela frenata noveboracensis*
050054			Woodchuck	*Marmota monax monax*
060025			Mussel, eastern elliptio	*Elliptio complanata*
070102			Crayfish, Appalachian brook	*Cambarus bartonii bartonii*
070094			Crayfish, no common name	*Cambarus acuminatus*
070098			Crayfish, spiny cheek	*Orconectes limosus*
100043			Armyworm	*Pseudaletia unipuncta*
100041			Borer, European corn	*Ostrinia nubilatis*
100220			Butterfly, American copper	*Lycaena phlaeas*
100262			Butterfly, American lady	*Vanessa virginiensis*
100245			Butterfly, American snout	*Libytheana carinenta*
100250			Butterfly, Aprhodite fritillary	*Speyeria aphrodite*
100251			Butterfly, Atlantis fritillary	*Speyeria atlantis*
100254			Butterfly, Baltimore checkerspot	*Euphydryas phaeton*
100232			Butterfly, banded hairstreak	*Satyrium calanus*
100092			Butterfly, black swallowtail	*Papilio polyxenes asterius*
100137			Butterfly, brown elfin	*Callophrys augustinus*
100205			Butterfly, cabbage white	*Pieris rapae*
100167			Butterfly, carus skipper	*Polites carus*

100206			Butterfly, checkered white	*Pontia protodice*
100094			Butterfly, clouded sulphur	*Colias philodice*
100165			Butterfly, cobweb skipper	*Hesperia metea*
100156			Butterfly, common checkered-skipper	*Pyrgus communis*
100277			Butterfly, common wood-nymph	*Cercyonis pegala*
100230			Butterfly, coral hairstreak	*Satyrium titus*
100147			Butterfly, dreamy duskywing	*Erynnis icelus*
100188			Butterfly, dusted skipper	*Atrytonopsis hianna*
100238			Butterfly, eastern tailed-blue	*Everes comyntas*
100093			Butterfly, eastern tiger swallowtail	*Papilio glaucus*
100209			Butterfly, falcate orangetip	*Anthocharis midea*
100139			Butterfly, golden-banded skipper	*Autochton cellus*
100249			Butterfly, great spangled fritillary	*Speyeria cybele*
100270			Butterfly, hackberry emperor	*Asterocampa celtis*
100219			Butterfly, harvester	*Feniseca tarquinius*
100224			Butterfly, Henry's elfin	*Callophrys henrici*
100178			Butterfly, Hobomok skipper	*Poanes hobomok*
100148			Butterfly, Juvenal's duskywing	*Erynnis juvenalis*
100160			Butterfly, least skipper	*Ancyloxypha numitor*
100279			Butterfly, little wood-	*Megisto cymela*

			satyr	
100217			Butterfly, little yellow	*Eurema lisa*
100252			Butterfly, meadow fritillary	*Boloria bellona*
100079			Butterfly, monarch	*Danaus plexippus*
100090			Butterfly, mourning cloak	*Nymphalis antiopa*
100143			Butterfly, northern cloudywing	*Thorybes pylades*
100272			Butterfly, northern pearly-eye	*Enodia anthedon*
100236			Butterfly, olive juniper hairstreak	*Callophrys gryneus gryneus*
100211			Butterfly, orange sulphur	*Colias eurytheme*
100257			Butterfly, pearl crescent	*Phyciodes tharos*
100359			Butterfly, Peck's skipper	*Polites peckius*
100200			Butterfly, pipevine swallowtail	*Battus philenor*
100259			Butterfly, question mark	*Polygonia interrogationis*
100264			Butterfly, red admiral	*Vanessa atalanta*
100235			Butterfly, red-banded hairstreak	*Calycopis cecrops*
100268			Butterfly, red-spotted purple	*Limenitis arthemis astyanax*
100082			Butterfly, silver-spotted skipper	*Epargyreus clarus*
100255			Butterfly, silvery checkerspot	*Chlosyne nycteis*
100146			Butterfly, sleepy duskywing	*Erynnis brizo*
100142			Butterfly, southern cloudywing	*Thorybes bathyllus*
100202			Butterfly, spicebush swallowtail	*Papilio troilus*

100239			Butterfly, spring azure	*Celastrina ladon*
100169			Butterfly, tawny-edged skipper	*Polites themistocles*
100247			Butterfly, variegated fritillary	*Euptoieta claudia*
100266			Butterfly, viceroy	*Limenitis archippus*
100207			Butterfly, West Virginia white	*Pieris virginiensis*
100227			Butterfly, white M hairstreak	*Parrhasius m-album*
100204			Butterfly, zebra swallowtail	*Eurytides marcellus*
100042			Earworm, corn	*Heliathis zea*
100290			Moth, buck	*Hemileuca maia*
100040			Moth, codling	*Cydia pomonella*
100047			Moth, gypsy	*Lymantria dispar*
110230			Tick, American dog	*Dermacentor variabilis*
110232			Tick, brown dog	*Rhipicephalus sanguineus*
110228			Tick, lone star	*Amblyomma americanum*
110231			Tick, rabbit	*Haemaphysalis leporispalustris*
110229			Tick, winter	*Dermacentor albipictus*

* FE=Federal Endangered; FT=Federal Threatened; SE=State Endangered; ST=State Threatened; FP=Federal Proposed; FC=Federal Candidate; FS=Federal Species of Concern; SC=State Candidate; CC=Collection Concern; SS=State Special Concern

** I=VA Wildlife Action Plan - Tier I - Critical Conservation Need; II=VA Wildlife Action Plan - Tier II - Very High Conservation Need; III=VA Wildlife Action Plan - Tier III - High Conservation Need; IV=VA Wildlife Action Plan - Tier IV - Moderate Conservation Need

List completeness is dependent on a search for published scientific records of which there may be many naming counties but few for other area types.

The following was prepared by the U. S. Fish and Wildlife Service, Virginia Field Office:

September 17, 2008
Prepared by U.S. Fish and Wildlife Service, Virginia Field Office

RAPPAHANNOCK COUNTY, VIRGINIA

Federally Endangered, Threatened, Proposed, and Candidate Species

SCIENTIFIC NAME	COMMON NAME	STATUS
AMPHIBIANS		
Plethodon Shenandoah	Shenandoah salamander	LE
MAMMALS		
Myotis sodalis[1]	Indiana bat	LE

Species of Concern (No official Federal status)

INVERTEBRATES		
Elliptio lanceolata	Yellow lance	G2G3

[1]This species has been documented in an adjacent county and may occur in this county.

Anadromous fish (habitat), trout and other significant fisheries

The Virginia Economic Development Partnership (VEDP) County Profile mentions that brook trout and rainbow trout are stocked in Rappahannock's cool, clean waters, but it is not clear whether this refers only to the Shenandoah National Park.

River segments that have recreational significance, including state scenic river status

The Jordan River and Rappahannock Rivers are listed as State Scenic Rivers by the Virginia Department of Conservation and Recreation.

Sites of historic or archeological significance

Below is a list of National and State Locations and their ID numbers in Rappahannock County from the Virginia Department of Historic Resources.

Ben Venue 078-0003
Boxwood Hill 078-5078
Caledonia Farm 078-0064
Flint Hill Baptist Church 078-0066
Laurel Mills Historic District 078-0058
Meadow Grove 078-0059
Miller, John W. House 078-0161
Montpelier 078-0028
Mount Salem Baptist Meeting House 078-0033
Scrabble School 078-5107
Sperryville Historic District 078-0093
Sunnyside 078-0049

Washington Historic District 322-0011
Washington Mill 078-0089

Unusual Geologic Formations or Special Soil Types – Soils General

There are no readily available reports of unusual geologic formations (i.e. no karst and no "Triassic" basin), nor special soil types requiring consideration in regional water supply planning for Rappahannock County. Nonetheless, any specific potential development project would warrant site-specific investigation of these characteristics.

Soil characteristics are a determinant of the suitability of land for agriculture, forestry, and development. Different soils, depending upon their structure, fertility, and drainage are more, or less, suited for various land uses. The land use that generally causes the greatest stress and number of problems for soils is development. Construction strips the soil of its vegetative cover and exposes it to the forces of erosion. The soil is often required to support pavement or building foundations without shifting appreciably. The soil, particularly in rural areas, is also frequently used for the disposal of liquid or solid waste, i.e., septic fields. Thus, where soils easily accept liquid waste, fewer building limitations occur. Where soils do not accept such waste, development is limited unless central sewer facilities are available. The Virginia Department of Conservation and Recreation provides data for the location of prime agricultural soils.

As mapped and classified by the United States Department of Agriculture's Soil Conservation Service, there are thirteen soil associations in Rappahannock County. Seven broad soil types comprise 83% of the land area of the County and are described below. These soil associations are landscapes that have distinctive proportional patterns of one or more major and minor soil types. These associations are briefly described below:

Rappahannock County Soil Associations: General Descriptions

Louisburg-Albemarle-Culpeper Association:
Moderately deep and shallow, well drained and rapidly drained, sloping to steep soils on dissected Piedmont uplands comprises 13.9% of the County, or 23,752 acres. Mostly occurs in the eastern part of the County from the Hughes River to the Rappahannock River and in some areas around Five Forks.

Brandywine-Eubanks-Lloyd-Chester Association:
Shallow and moderately deep, well-drained and somewhat rapidly drained, sloping and gently sloping soils on dissected Piedmont uplands comprises about 31.8% of the County or 54,340 acres. This area extends from the Hughes River on the Madison County line through the central part of the County to the Rappahannock River.

Brandywine-Rockland, Acidic Association:
Shallow, rapidly drained, moderately steep and steep soils and rock land on low Piedmont Mountains comprises about 11.2% of the County, or 19,139 acres. Mostly near Woodville but occurs throughout the Piedmont Plateau.

Alluvial Land-Chewacla-Wehadkee Association:
Deep to moderately deep, moderately well drained to poorly drained, nearly level soils on flood bottoms comprises about 2.2% of the County, or 3,760 acres, largest areas along the Hughes, Hazel, Thornton, Covington, and Jordan Rivers.

Rock Land, Acidic-Halewood-Very Rocky Land Association:
Well-drained and rapidly drained rocky soils on mountain foothills underlain mainly by granodiorite, comprises about 5.4% of the County or 9,228 acres.

Very Rocky Land-Rockland, Acidic-Porters Association:
Rapidly drained, rocky and stony soils on mountains and underlain mainly by granodiorite comprises about 10.1% of the County, or 17,250 acres, mostly in the Shenandoah National Park.

Very Rocky Land-Rockland, Basic-Myersville Association:
Rapidly drained rocky soils on mountains underlain mainly by greenstone comprises about 8.7% of the County, or 14,867 acres, mostly in the Shenandoah National Park.

Flood Plains

Drainage in the County is well developed with numerous flood plains. Flood plain soils account for 7,518 acres of land or 4.4% of the County.

*Note: Specific flood plain boundaries can be found on Flood Insurance Rate Maps through the National Flood Insurance Program, Department of Housing and Urban Development.

Wetlands

Wetlands are important to natural animal and plant communities in watersheds, to storm runoff timing and to sustaining water quality in waters flowing overland to surface waters and percolating to groundwater. In some cases, wetlands may serve as indicators of groundwater levels and potential for baseflow discharges to sustain streamflow.

In Rappahannock County the variability of terrain and relief, with narrow stream valleys predominating, tends to limit the area in which wetlands have formed. A few broad flat flood plains near stream confluences or forks, narrow margins with associated springs, ponds and streams are the most prevalent wetlands areas in Rappahannock County. Applications for wetlands mitigation-related permits from Rappahannock

County to DEQ have been very limited since program inception. At this time, there are no reliable estimates for the area of wetlands in Rappahannock County.

Riparian buffers and conservation easements

The Culpeper Soil and Water Conservation District (CSWCD) has been actively assisting farmers to develop riparian buffers along stream corridors. This work is funded by the Conservation Reserve Program of USDA and by other grants. These riparian buffers serve three important functions. First, they protect the streams from pollutant runoff (nutrients, bacteria, pesticides and herbicides). Second, they help to restore and maintain the stream banks, which in turn prevents erosion. Third, buffers can help prevent excessive runoff, so that precipitation will have a greater opportunity to replenish groundwater rather than running off into the streams and leaving the County. Currently 702 riparian acres have been placed in these protective buffers (Greg Wichelns, Director of CSWCD).

There is an active program within the county to place land in conservation easement. Conservation Easements provide protection from future development. In 2010, there were 27,000 acres in conservation easement in Rappahannock County (Rappahannock County Conservation Alliance).

Land Use

According to the Rappahannock County Comprehensive Plan (2004), estimated land use distributions are shown in Table VIII below:

Land Use	Acres	Percent
Residential	1,450	0.80
Commercial	75	0.04
Industrial	45	0.03
Highways, Roads, R-O-W	2,050	1.20
SUB-TOTAL (DEVELOPED)	3,720	2.00
Agriculture Crops and Pasture	57,337	33.55
Forests		
Farms	31,349	18.34
Commercial	36,774	21.52
Federal	31,700	18.55
Vacant	10,000	5.85
SUB-TOTAL (UNDEVELOPED)	167,160	98.00
GRAND TOTAL	170,880	100.00

Table X - Estimated Land Use Distribution

Forests

Rappahannock County contains considerable forestland, most of which is hard wood of an oak and hickory type. According to the Virginia Division of Forestry, in 1981 approximately 105,795 acres or 62% of the total County land area was forestland. The figures for 1992 showed a statistically insignificant decline to 105,446 acres. Approximately 70% or 73,707 acres of this forestland was classified as commercial forestland and 31,739 acres were considered "productive reserve" or forestland sufficiently productive to qualify as commercial forestland, but withdrawn from timber utilization through statute or administrative designation. These figures are also little changed from 1981.

According to the National Land Cover Database, 68.9 percent of Rappahannock County land cover is deciduous (44.3%), mixed (21.2%), or evergreen (3.4%) forest. [Note: The National Land Cover Database was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The analysis and interpretation of the satellite imagery was conducted using very large, sometimes multi-state image mosaics (i.e. up to 18 Landsat scenes). Using a relatively small number of aerial photographs for 'ground truth', the thematic interpretations were necessarily conducted from a spatially-broad perspective.]

The invasion of the Gypsy Moth caterpillar into Rappahannock, which commenced in 1987, has had a dramatic effect on timber resources. Rapidly established as the major cause of hardwood mortality, the pest has caused an estimated 13,000 acres of hardwood losses, primarily in white, red, chestnut, black and scarlet oak. The County elected not to pursue a cooperative cost-share spraying program to suppress the insects, but to instead support private spraying efforts. As a result of the Shenandoah National Park's non-spray policy (except for public areas) the insect is impossible to eradicate from our area and will continue to cause hardwood losses until a new equilibrium is attained. A fire affecting over 25,000 acres in Rappahannock, Madison and Page Counties in September of 2000, while often spectacular, was contained largely within the Shenandoah National Park and has created no long-term forest management issues.

A closer look at the 73,707 acres in commercial forestland shows that 47,572 acres, or 62%, was held by farm operators while 27,184 acres or 36% was held by other private landowners. The ability of commercial forestlands in Rappahannock County to yield crops of industrial wood is limited. Based upon a classification system used by the Virginia Division of Forestry, called site class (the capacity to grow crops of industrial wood based on fully stocked natural stands), commercial forestlands in the County are poor producers. Approximately 3,400 acres are site class three, 54,366 acres are class four and 16,990 acres are class five. Class three lands produce 85 to 120 cubic feet per acre annually, class four lands 50 to 85 cubic feet, and class five lands below 50 cubic feet. The County has no class one or two lands which can produce more than 165 and 120 cubic feet respectively per acre annually.

The predominant forest types of the commercial forestland are: Loblolly-shortleaf (3,398 acres), Oak-pine (3,398 acres), Oak-hickory (64,562 acres), and White Pine-Hemlock (3,398 acres).

Agricultural Land

Cattle

In Rappahannock County beef cattle operations have grown in importance over the past several decades, both as a principal farming operation and as one aspect of an integrated farm management plan. Since 1986, for example, the number of beef cattle and calves increased from 11,900 to 15,500 in 1992, 16,041 in 1997, and 17,548 in 2002.

Recent trends from 2002 to 2010 have seen a significant reduction in beef cattle operation. There were approximately 13,000 head of cattle in 2010 (Kenner Love, Rappahannock County Agricultural Extension Agent). The decrease in cattle operations is primarily attributable to market conditions and numbers could increase again under more favorable market conditions.

Cattle use approximately 8 to 25 gallons per head per day. The water use by cattle in 2010 is therefore estimated at 37.96 to 118.625 million gallons per year.

Grasslands, such as well-managed pasture, have impacts on water quantity and quality. Though these impacts are greater than those occurring on forest lands, they are less than those of tilled land. In addition to water consumed, whether from withdrawal sources such as wells or stream intakes, or by direct drinking from streams and ponds, runoff from cattle manure has been identified as contributing to nutrient enrichment and bacterial contamination that result in impaired streams. Best management practices, particularly the creation of riparian buffers, have been established that help to ameliorate the detrimental impacts of cattle grazing on water resources. Well-managed cattle raising lands may not be actively in use at all times, but they are necessary. Changes in the acreage available for this land use would negatively impact the water resources of Rappahannock County.

The presence of impaired streams and the type of impairment

Eleven County stream segments are classified as impaired (DEQ, 2010). Ten of these segments are impaired due to e-coli contamination, which renders these segments unsuitable for recreational use. One segment of the Hazel River is impaired due to temperature, which makes this segment impaired for Aquatic Life Use. Table IX lists these 11 segments and Fig. XII shows the locations of these impaired segments.

ID Number	Length (Miles)	WATERBODY NAME	IMPAIRMENT CAUSE
VAN-E05R_THO01A02	3.4	Thornton River	Escherichia coli
VAN-E06R_BTL01A02	2.2	Battle Run	Escherichia coli
VAN-E03R_HUE02A02	3.1	Hughes River	Temperature, water
VAN-E04R_BLC01A10	8.2	Blackwater Creek	Escherichia coli
VAN-E04R_HAZ01A00	5.6	Hazel River	Escherichia coli
VAN-E03R_HUE01A00	3.7	Hughes River	Escherichia coli
VAN-E05R_BIG01A08	3.0	Big Branch	Escherichia coli
VAN-E05R_RUS02A02	5.9	Rush River	Escherichia coli
VAN-E01R_RPP02A00	2.2	Rappahannock River	Escherichia coli
VAN-E04R_HAZ02A02	0.8	Hazel River	Fecal Coliform
VAN-E06R_THO02A02	5.4	Thornton River	Escherichia coli

Table XI- Impaired Stream Segments in Rappahannock County (DEQ, 2010)

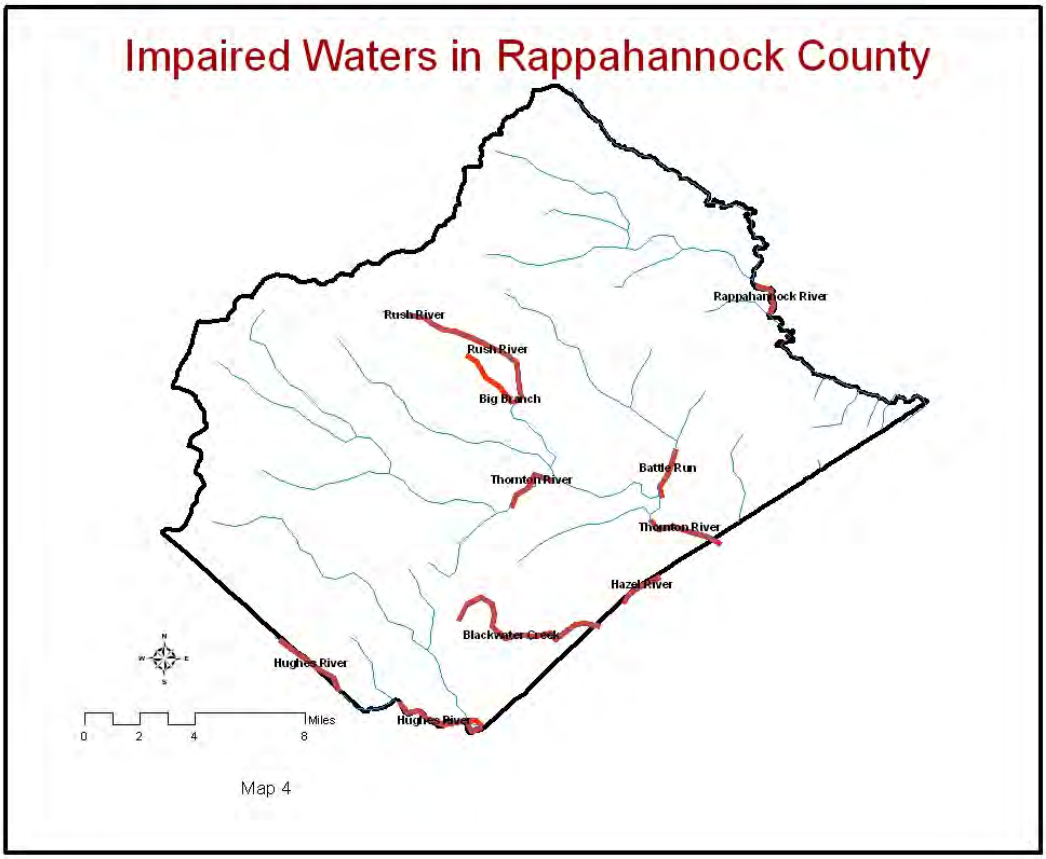


Figure XII - Impaired Stream Segments in Rappahannock County (DEQ, 2010)

Locations of point source discharges

There are five point source dischargers in Rappahannock County (USEPA NPDES, 2010). These point sources are the Sperryville WWTP, The High School, the Elementary School, the Washington Water Treatment Facility, and the Washington WWTP. Below is a table listing these five point source dischargers and their discharge flows. Fig. XIII shows the locations of these five dischargers.

NPDES ID	Name	DISCHARGE (MGD)
VA0062880	Sperryville WWTP	.01 - .015
VA0064181	Rappahannock County High School WWTP	.002 - .0025
VA0022471	Rappahannock County Elementary School WWTP	.004 - .006
VA0091651	Rush River WWTP for Washington	0.02
VA0087581	Washington Town Water Treatment Facility	.0014

Table XII- Point Sources Dischargers in Rappahannock County

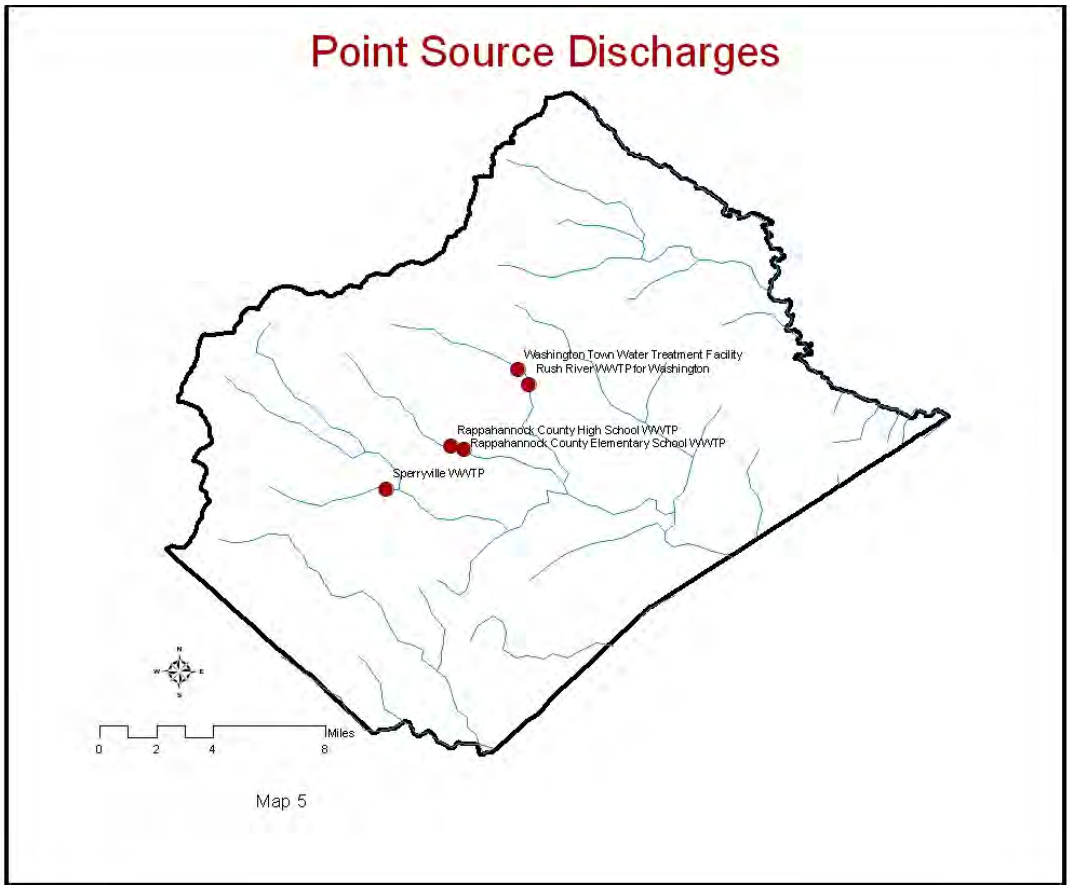


Figure XIII - Map of Point Source Dischargers in Rappahannock County

The total point source discharges range from .0374 MGD to .045 MGD, which is quite low and should have minimal effect on water quality and stream flow.

Concerns for water quantity or quality other than those listed above

As has been described in the Meteorology section, recent conditions and trends are of serious concern for the current and future water supplies for Rappahannock County. What have been historically reliable spring flows are disappearing, droughts are becoming a regular phenomenon with increased temperatures, more thunderstorms (as opposed to long gentle rains), and less snow. Snow is particularly important because it provides a major mechanism for replenishing ground water.

Springs have provided a reliable headwater source for many streams in the County. When they dry up, the streams lose their base flow and transition from perennial to intermittent flow status. This has several serious consequences:

1. The streams are no longer a reliable source of water for agricultural users, which threatens the agricultural base for the County.

2. In addition, farmers will rely more on wells for their water sources. This will have the effect of increasing the GW withdrawals. This could, in turn, affect nearby residential wells, creating a residential water supply problem.
3. Reduced or absent base flows can cause serious ecological damage. Reduced base flows will cause water quality problems, compromising fish habitats, and affecting the entire ecosystem of the streams including causing reduction of macroinvertebrate populations, which then result in reduced adult insect populations. This in turn affects the rest of the ecosystem, reducing, for instance, bird populations that rely on these insects as their food source.
4. Lower base stream flows with increased thunderstorms will increase the impacts of pollution from human, livestock, farms, septic tank, and wildlife sources because it will increase the surface runoff in localized areas.
5. The increased surface runoff can also destabilize the banks of small streams, which will have a detrimental effect on the ecology of these streams. It will also potentially increase the sediment loads in these small streams, which will then travel downstream under flood conditions.
6. The drying up of springs is a potentially alarming situation, because the springs are an indicator of the status of the fractured bedrock aquifer. The springs are located at the "top of the stack", providing ground water supplies downstream.
7. Given the increased human populations downstream of Rappahannock County, which have resulted in increased water demand (both surface and ground water), it is unknown at this time what affects these demands may have on the ground water supplies in the County.

To summarize, while there seem to be sufficient water resources for Rappahannock County's needs at this time, the trends are not encouraging. The County's water supplies are potentially being stressed in three ways:

1. Climate changes that are increasing the frequency and severity of droughts,
2. Loss of reliable water in the headwaters, and
3. Increased demand on the aquifer downstream of the County.

Sections VIII and IX will present some recommendations and measures that should be considered for:

1. Better quantifying the current and future water supply components and trends.
2. Suggesting some measures to ameliorate threats to these water supplies.

It should be noted here that these issues constitute a *regional* problem that affects the entire Rappahannock River Basin. There is every reason to suspect that the same issues are also occurring in adjacent counties. In addition, these conditions create a very real threat of increased pollution, primarily Nitrogen, Phosphorous, bacteria and sediment. Any pollution has the potential to travel downstream to other localities and to the Chesapeake Bay and thus to become a serious concern for downstream residents and for the Bay.

SECTION V: Projected Water Demand: by decade 30 to 50 years into the future (9VAC25-780-100)

As discussed in the following section, existing water use is not informed by overt water conservation practices and the projections quantified here have not considered such programs either. There may be room for improvement in this area.

Increased population:

2010, 2020, 2030, 2040:

The Virginia Employment Commission has population projections for Rappahannock County for 2010, 2020, and 2030. The population estimate for 2040 is estimated by taking the population increase from 2020 to 2030 and applying that increase to 2040. There is no breakout in the population projections between the County and the Town of Washington. The population increases are apportioned between the County and the Town by apportioning the population increases based on the current percentage breakout of the Town's current percentage of the County's population. Given the County's population estimate for 2009 of 7,035 and the 2010 population of Washington, the percent of the Town's population is 1.9% (133/7035 * 100). The projected water demand will use the current value of 85 gallons per person per day, which is 31,025 gallons per year. Note that the population for Washington in 2010 known to be 133, so increased population estimates for Washington for 2010 do not apply.

Table XIII below summarizes the population projections:

Year	Population Projection	Percent Increase from 2009	Washington Population Estimate	County Population Excluding Washington
2010	7,593	7.9 %	133 (Known)	7,460
2020	8,242	17.2 %	156	8,086
2030	9,066	28.9 %	171	8,895
2040 (extrapolated)	9,890	40.6 %	187	9,703

Table XIII. Population Projections for 2010 to 2040

Table XIV below summaries the projected water demand by decade. For Washington, the water demand values use the pumping rates from Table VI in Section II, which will also be able to account for unknown commercial increases. Table XV provides estimated peak daily pumping rates by decade for Washington by applying the percent increases in table XIII.

Year	Washington Pumping Rate (MGY)	County Water Demand Excluding Washington (MGY)
2010	11.186 (known)	231.45
2020	12.07	273.21
2030	14.42	275.97
2040	15.73	301.04

Table XIV. Projected Water Demand for 2010 to 2040

	Year			
Month	2010 (Known)	2020	2030	2040
January	43,200	50,630	55,685	60,739
February	41,300	48,404	53,236	58,068
March	36,700	43,012	47,306	51,600
April	38,200	44,770	49,240	53,709
May	35,700	41,840	46,017	50,194
June	46,400	54,381	59,810	65,238
July	60,900	71,375	78,500	85,625
August	53,600	62,819	69,090	75,362
September	39,800	46,646	51,302	55,959
October	35,500	41,606	45,760	49,913
November	37,800	44,302	48,724	53,147
December	34,800	40,786	44,857	48,929

Table XV. Projected Maximum Pumping Rates by Month for Washington

50 years in the future: Maximum Population Possible

An analysis by Beverly Hunter, who is a resident volunteer, titled "People, Land and Water at the Headwaters of the Upper Rappahannock River Basin" includes an analysis of the maximum population possible if all existing and sub-dividable parcels of land in the County were developed. This "build-out" analysis arrives at a maximum population in the County of 18,000 people. Using 100 GPD per person, this translates to a withdrawal of 1.80 MGD, which is 657 MG per year. If we assume that the groundwater recharge can be kept to about 10.9 inches/yr., the impact will be minimal. A key factor in keeping this impact low is to minimize the "runoff footprint" using LID techniques. Several of these techniques, such as riparian buffers, are already included in the County Stormwater Management Ordinance and in the Comprehensive Plan. In addition, there are numerous local organizations, especially volunteer organizations that are helping to promote minimizing the "runoff footprint" through various means. One governmental organization, the Culpeper Soil and Water Conservation District (CSWCD), has been particularly active in this work. The CSWCD has promoted and leveraged Federal and State funds to successfully promote the use of stream buffers on farmland, as well as holding educational events and selling rain barrels at discount prices. The County has several volunteer organizations which actively promote LID practices while working to

heighten public awareness of water quality and water quantity issues. These organizations include RappFLOW, RLEP, RCCA and PEC.

Increased Agricultural Use

Agricultural withdrawal from streams or from wells is another potential increase in water use. There are no known permitted agricultural withdrawals in the county. However, by law, an agricultural entity is allowed to withdraw up to 1 million gallons per month without a permit. It is unlikely that such water would be withdrawn every month. Suppose 20 agricultural entities each withdraw one million gallons per month during the driest three months. This would translate into 60 million gallons per year withdrawn from streams. At this time, there is no way to determine how much additional water might be withdrawn by agriculture via increased use of GWW.

Figure IX below shows a map of the Washington Service Area

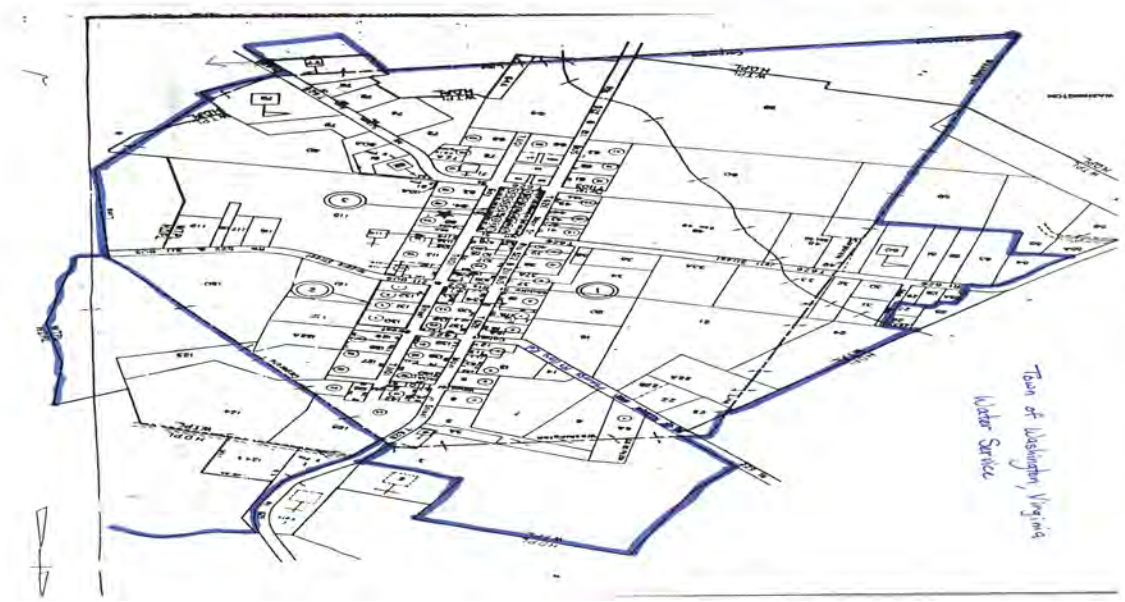


Fig. IX Map of the Washington Service Area

Projection of Water Demand On An Average Annual Basis for Proposed Self-Supplied Nonagricultural Users of More Than 300,000 Gallons Per Month of Surface and Groundwater Located Outside of the Washington CWS:

None

Projection of Water Demand On An Average Annual Basis for Proposed Self-Supplied Nonagricultural Users of More Than 300,000 Gallons Per Month of Surface and Groundwater Located Outside of the Washington CWS:

None

Note: At the time of preparation of this water supply plan, information on cumulative demand, use competition, or in-stream flow information developed pursuant to 9 VAC 25-780-140 G, is not available. The state-wide integrated Water Supply Plan has not been prepared by DEQ, from which analysis will be required to determine the above information.

SECTION VI: Water Demand Management Actions (9VAC25-780 -110)

The Virginia Uniform Statewide Building Code has been used in Rappahannock County since 1992. The version of that code which had been updated to require low flush toilets and low flow plumbing fixtures has been enforced for new and replacement plumbing in Rappahannock County since1992. The level of new construction in the County has been relatively low since these code requirements have been in force. A significant portion, therefore, of the households and businesses in the County and in the Town of Washington have older fixtures with flows or flushes at higher rates.

Low water use landscaping has not been an issue of public record in the County to date. In the Town of Washington community water system, the summer seasonal increase of water use is less than 10%, which suggests that landscape watering is low.

Irrigation of crops is predominantly limited to smaller plots of vegetables and fruits. Because such plots tend to be irrigated by GW, the owners will tend to be conservative about the amounts of irrigation water used and are likely to employ relatively efficient, targeted irrigation methods.

The reported average and peak water use figures and estimates given in Section III are relatively low for reasons that are based on individual practices by residents and businesses, including farmers.

Community awareness and public–spirited action is a hallmark of Rappahannock County residents and businesses, with citizens being personally responsible, but also fiscally conservative and fiercely independent. The historic positive balance between water availability and water demand has not resulted in the need to conserve water, except for short periods during infrastructure difficulties or construction. In part because water use practices tend to be conservative already, there have been no notification or educational mechanisms in Washington designed to minimize demand.

Technical and financial programs have not been warranted to date. The town does not participate in any specific nationally available drinking water conservation program. An effective program for the town or county would need to address rural water uses and concerns of historical properties.

Practices to address water loss in the maintenance of Washington's community water system include an ongoing program to complete loops within the distribution system (Town council meeting fall 2006). The loops minimize the frequency of line flushing required to maintain water quality resulting from dead-end lines. Note that unaccounted water losses in Washington are already less than 10%, so the savings in this regard are likely to be small.

Because of climate change, current conservation practices may not meet the needs of the County and Washington in the future. Recommended Actions to address this issue are provided in Section VIII.

VII: Drought Response and Contingency Plan (9VAC25-780-120)

The Town of Washington is a regional water planning partner with the surrounding Rappahannock County. This is very good practice since the Town and residents of the surrounding county all share the same groundwater resources for their water. The town of Washington community water system has reported water withdrawal or use of 300,000 gallons per month or more in at least one month of some years. Thus, in accordance with 9VAC 25-780-120 a drought response and contingency plan and ordinance needs to be developed for the entire water supply planning region. Because Washington draws its water from groundwater, this plan should be particularly responsive when lower than normal groundwater levels are reported. Implementation and enforcement actions are of course needed in this ordinance.

Rappahannock County does not have a consistent, adequate network of meteorological and groundwater monitoring stations. It does have the currently active, real-time USGS flow gaging stations on Battle Run and the Hazel River.

In the interim, while the ground work is laid for a true locally-based Drought Response and Contingency Plan, Rappahannock County can adopt the regional drought triggers based on the Governor's Drought Advisory Committee for the Northern Piedmont Region. The indices can be found at http://www.deq.virginia.gov/waterresources/drought.

Four drought indicators are used: Groundwater, Precipitation, Reservoir levels, and Streamflow. The reservoir level indicator is not applicable to Rappahannock because there are no reservoirs in the county. The stations that are monitored are:

Groundwater levels in Orange County at Gordonsville Observation Well, USGS Local Number 45P a SOW 030

Reservoir levels at Lake Anna, Spotsylvania Water Supply Reservoir System

Streamflow at the Rapidan River near Culpeper, USGS Station 01667500

Precipitation levels are determined by the Office of the State Climatologist.

In addition, drought forecasts by NOAA can be found at http://www.cpc.ncep.noaa.gov/products/expert_assessment/season_drought.gif .

Of particular interest to Rappahannock are other indicators, especially soil moisture and crop moisture indices. These can be found at http://www.drought.noaa.gov/index.html.

For Rappahannock County residents, the most important and relevant drought indicators are groundwater, streamflows, and precipitation.

Whenever any of the three relevant triggers are at levels that indicate the same, or a more severe drought hazard stage, the Town of Washington should be authorized (by accompanying ordinance) to declare the existing drought stage and measures that are required.

The drought stages are:

1. Normal
2. Drought watch – generally calls for awareness and actions to mitigate impacts that are seen as likely to occur in the foreseeable future. For example, in instances where winter and spring precipitation patterns make it clear that the following summer is likely to be dry, gardeners should refrain from planting annual plants that have high water requirements.
3. Drought warning – generally identifies a situation where drought emergency is likely to occur in the near future. Actions on a voluntary basis are called for, to minimize withdrawals by avoiding non-essential uses of water, and retaining as much water as possible in ground water storage and allowing the minimal stream flows to remain in-stream. Opportunities for cooperative use and re-use of water for special functions may be sought.
4. Drought (emergency) - is considered to apply when water supply is limited, and minimizing immediate water use is critical to ensure sufficient water to meet essential uses.

Because of the possibility of other operational water supply shortage problems within the community water system, and the large number of users who would all potentially be impacted, customers of the town system are also subject to an additional phase: water supply shortage emergency. This additional phase would be administered by the Mayor or by whomever the Town Council designates.

Upon declaration of one of the three relevant drought stages, the actions specified below for the relevant hazard stage would be implemented by all water users, both public and private in the town of Washington.

a. Swimming pools can only be "topped off" sufficiently to support their water treatment systems
b. Car washing is prohibited.
c. Landscape watering is limited to "manual" methods, such as using buckets or hoses for specific plantings. Lawn watering is prohibited.
d. Other actions as determined by the Town.

There should be a regular means for disseminating the drought status and also the drought information from the other drought indicators on the NOAA websites. Suggestions for disseminating the drought status and drought responses could be announced in the Rappahannock News, the regular weekly newspaper widely read by County residents. It could also be included on the newspaper's website (http://www.rappnews.com/) and

could be a prominent part of the County's website (http://www.rappahannockcountyva.gov/). Other avenues for dissemination could include announcements in schools, non-profit websites, and perhaps other means.

Ordinarily drought response actions are targeted to reduce water withdrawals by specific percentages. Observation indicates that non-essential uses of water in Rappahannock County are already quite limited, and thus restricting these uses may not impact water supply and demand very significantly. Future residents and businesses, however, will be advised by these policies that certain activities are subject to restriction and that incorporating them into business operating plans and/or personal lifestyles is required.

A set of recommended water-saving practices, specifically relevant to Rappahannock County and its rural economy needs to be developed and distributed widely. It should be mentioned that CSWCD and non-profit organizations have conducted numerous public events and disseminated literature that suggests ways to save water. This work should be encouraged to continue.

VIII: Statement of Needs and Alternatives Analysis (9VAC25-780-130)

The customary and accepted methods of analysis have indicated that, on a long-term historical basis, the water resources in Rappahannock County should be amply sufficient to meet current and future needs. However, Section IV of this document strongly indicates otherwise. It is entirely possible, even likely, that current and (possible) future conditions will not result in adequate water resources for Rappahannock County's needs.

Despite repeated and apparently deepening drought conditions for more than a decade, several groups with water resources concerns within Rappahannock County and the town of Washington have not been able to identify a comprehensive strategy that could be used to improve the situation. Responses on a private level have been taken and have thus far sufficed.

The lack of a coherent water resource protection strategy is the result of both the low density settlement patterns and the water balance that prevail County-wide. The water that is withdrawn from ground water is very small, representing only 0.1% of total annual rainfall. Reduction in withdrawals would be inconsequential in terms of sustaining water levels locally or across the water supply planning area. Each concerned private water well owner or surface water user has adopted pragmatic measures that meet his/her own needs and perhaps those of their immediate neighbors.

Past efforts to quantify the norms, statistics and extremes for temperature, precipitation, soil moisture-related agronomic indices, groundwater levels, impoundment levels and streamflows, which can to be used for local drought condition indicators and drought response triggers, have repeatedly led us down tortuous paths to dead ends. Therefore, more locally focused monitoring and record keeping and evaluation of needs should be undertaken in order to refine both drought response planning and to assist local users in the county. The data generated here in the headwaters will also provide a regional early warning system to support more measured and better-timed responses in localities in the downstream reaches of the Rappahannock River Basin and in the flatter downgradient portions of the fractured rock aquifers of the Piedmont.

<u>Immediate actions that should be considered:</u>

The rainfall pattern in Rappahannock County in the summer has become mostly localized thunderstorms. Therefore, efforts in all sectors of the County should consider methods to retain stormwater for both groundwater recharge and surface water needs. For example, one inch of rainfall over one acre of land is 27,152 gallons. Retaining this one inch for groundwater recharge instead of allowing it to run off into the streams will provide approximately 319 days of residential water use, assuming 85 gallons of use per day. That one inch of water provides almost one year of water per person!

An excellent resource for homeowners to reduce water use and better retain and use rainwater can be found at http://epa.gov/watersense/water efficiency/when its hot.html.

Agriculture uses should put into place improved drainage methods and the development of stormwater retention ponds. CSWCD and the County Agricultural Extension Agent should be good resources for assisting in these efforts.

An excellent resource for forestry management is the Coweeta Hydrologic Laboratory, which has been performing excellent, scientifically strong research in forestry hydrology for many years. They have many resource materials on their website: http://www.srs.fs.usda.gov/coweeta/. The scientifically sound work on forest hydrology started at this site in 1934, and has been strengthened and continues to this day.

Moving forward, a coordinated effort is needed to:

- Monitor flows from springs and identify their capture zones

- Develop a set of meteorological monitoring stations that will be able to track precipitation on at least an hourly basis to identify rainfall patterns, temperatures, wind speeds, and snowfall.

- Monitor groundwater levels and define and redefine the local seasonal fluctuation of water table levels under the wider range of precipitation conditions. This monitoring can be correlated with the well in Orange County, perhaps allowing us to "backcast" to prior groundwater levels and changes in Rappahannock County.

- Identify critical zones for stream discharge from the ground water system, and zones of groundwater recharge from the streambeds.

- Use the stream flow gages at Battle Run and the Hazel River to update the recharge rate estimates to more current values, and continue to do these analyses on a periodic basis.

The body of new data acquired as a result of the above activities is essential in order to quantify the problems that exist and to then identify and implement alternatives that will be able to sustain the water resources of Rappahannock County.

The USGS flow gaging stations on Battle Run and the Hazel River are critical to monitoring streamflows, estimating groundwater recharge, and as the single long-term record of water resource conditions in Rappahannock County. Under no circumstances should these gaging stations be discontinued.

Groundwater-based residential and commercial heat pumps that are "closed loop" systems should be mandatory. Heat pump systems that draw on groundwater and discharge to surface waters should be banned.

To reiterate, the actions described above should be examined and considered ***as part of a regional approach to water supply planning*** rather than as a Rappahannock County-specific set of actions.

Considerations for Future Needs: Alternatives Analysis

Using the data and analyses developed in the statement of needs, a determination could be made as to whether wiser integrated or conjunctive use of ground water and surface water is possible. In other words, is it possible to work within natural patterns to sustain more water for longer periods in ground water storage by making selective use of flowing (surface) water that will otherwise exit the planning area during high flows.

In addition, there may be measures that water users in Rappahannock County can identify, which, if adopted, may help to reduce water use and minimize the extent to which water demands reach their peak at the very same time that water sources are at a minimum. As just one example, Virginia Tech Cooperative Extension Service Publication 442 – 775 indicates that livestock water requirements during hot weather increase from two to two-and-one-half times the normal requirements. Providing a means to mitigate the heat may prove more effective than providing additional fresh water, when fresh water is in short supply. Such measures can include, for example, providing shaded areas for cattle.

Another action that should be taken is to ensure that commercial forest land, indeed, that all forested land is well-managed. It is possible that other forest management actions could be developed and undertaken after consultation from an experienced forester.

Rappahannock County's population and agricultural base are widely dispersed throughout the County, rendering the development of water supply reservoirs a highly unlikely option. Rather, more localized, strategic efforts, such as improved storm water retention, engineered changes in drainage patterns (such as swales), and buffer strips that can better hold runoff could be considered as smaller-scale but effective alternatives. These strategic measures would be greatly enhanced by having the improved data recommended in Section VIII. GIS techniques using Digital Elevation Data to map terrain and drainage patterns can be very helpful in the targeting of strategic stormwater control measures.

The largest "loss" component in the water balance is evapotranspiration. There are now methods that can estimate ET at fine resolutions and at a daily frequency, using a combination of the improved meteorological data already suggested, combined with remote sensing from satellites such as MODIS and LANDSAT. This is a non-trivial exercise and is more appropriate as a regional approach. It is possible that areas with very high ET can be identified, and measures taken to reduce the ET in those areas. However, given the current highly rural characteristics of Rappahannock County, it is problematic whether ET reduction measures could be effective here. With a more regional ET Center, however, excess ET locations in other areas could be identified.

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